Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley:

BACKGROUND PAPER REPORT

prepared for:

Department of Indian Affairs and Northern Development
Government of the Northwest Territories
Environmental Studies Research Funds

prepared by:

Gartner Lee Limited

in association with:

Highwood Environmental Management Ltd.
Dr. Chris Burn
Joanne Barnaby Consulting
BGC Engineering Inc.
RWDI West Inc.
Klassen and Associates Ltd.

reference: **GLL 22-649**

date: **January 12, 2004**

distribution:

7 Client
3 Gartner Lee Limited

Gartner Lee

Acknowledgements

The project team would like to take this opportunity to thank those individuals who provided comments, input and advice on the various documents prepared for this project. Specifically, we would like to thank the following people:

Alan Kennedy
Alasdair Veitch
Alestine Andre
Alfred Taniton
Alison de Pelham
Allen Firth
Anna May McLeod
Anne Gunn
Barry Greenland
Bas Oosenbrug
Bill Carpenter
Benoit Goudin
Bob Reid
Brett Elkin
Brian Latham
Bruce MacDonald
Celina Stroeder
Colin Beddoes
Craig Machtans
Dan Andre
Doug Halliwell
David Lertzman
Ed Weick
Eddie Kolausok
Eric Gyselman
Eric Tull
Frank T'Seleie
Fred Andrew, Jr.
Gabe Andre
George Low
George McCormick
Giles Morrell
Gordon Mackeinzo
Gordon Yakeleya
Graham Veale
Greg Yeoman
Gunther Abrahamson
Herb Norwegian
Ian Scott
Ingrid Kritsch
James Edwards
Jim Allard
Jim McComiskey
Jimmy Mendo
Jean Marie Beaulieu
Jesse Jasper
Joan Ryan
Jody Snortland
Jozef Carnogurski
Kevin McCormick
Laura Pitkanen
Kim Howland
Kimberly Horrocks
Kirstie Simpson
Kym Hopper-Smith
Larry Dyke
Leslie McCartney
Lorraine Seale
Margo Burgess
Marie-Annick Elie
Martha Johnson
Masaki Hayashi
Mike Power
Mike Robinson
Mike Salomon
Norman Snowshoe
Patrick Clancy
Paul Latour
Peter Boxall
Peter Cizek
Peter Clarkson
Peter Ewins
Peter Ross
Peter Usher
Richard Popko
Richard Wilson
Robert Jenkins
Robert Marshall
Roger Boniface
Roger Odgard
Ron DiLabio
Ross Tallman
Roxanne Chartrand
Sam Stephenson
Sharon Fox
Sheila Mackeinzo
Stan Boutin
Stephanie Sibbetson
Stephen Harbicht
Su Windle
Susan Kutz
Suzanne Carrière
Tim Coleman
Tim Shopik
Tom Andrews
Wilfred Lennie
Woody Elias

The Project Advisory Team were particularly helpful in providing comments and advice on the various documents that were prepared, as well as, providing direction on experts in their respective organizations. The members of the Project Advisory Team are listed in Appendix D.

Finally, we would like to thank Ruth McKechnie and Heidi Heder of Department of Indian Affairs and Northern Development, Ray Case of the Department of Resources, Wildlife and Economic Development (Government of the Northwest Territories), and Fred McFarland, independent consultant, for their support and determination to make this an essential product to understanding what further information is required in order to evaluate, regulate and manage hydrocarbon activities.

Executive Summary

This *Background Paper Report* forms the first of four components of the project entitled *Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley*. The project was undertaken to improve the level of preparedness of the federal and the territorial governments, industry, communities, northern boards and other decision-makers to be able to respond to the environmental assessment and regulatory processes associated with hydrocarbon exploration, development and transmission in the Mackenzie Valley. In the course of completing this project, numerous information and research gaps were identified and confirmed, and priorities for the gaps were established.

The *Background Paper Report* involved the identification of information and research gaps associated with five hydrocarbon development areas (Cameron Hills, Liard Plateau, Norman Wells, Colville Hills and Peel Plateau) and a potential pipeline through the Mackenzie Valley from Inuvik south to the Northwest Territories/Alberta border. Information and research gaps were identified for each of the following biophysical topics: terrain, permafrost, water, air, fish and their habitat, wildlife and their habitat, vegetation, and biodiversity. It also covered a review and brief evaluation of resources and land uses, including harvesting and protected areas; climate change; and, the possible cumulative effects related to ongoing and potential hydrocarbon development. Identification of the gaps was achieved through literature searches, personal communications with principal researchers and others experts in these areas of study, the professional and technical knowledge of the project team members, traditional knowledge, and input from communities in the Mackenzie Valley.

The purpose of this *Background Paper Report* was:

- to consider the environmental impacts that may be expected from hydrocarbon development;
- to identify the research that has already taken place; and
- to determine the gaps in knowledge with respect to baseline information and environmental impacts.

A draft of the *Background Paper Report* provided a basis for three other components of the project: Workshops and Consultation, *Action Plan* and *Final Report*. The workshops and consultation component of the project was done through community visits, a community workshop in Norman Wells, March 3-5, 2003 and a Scientists' Workshop in Yellowknife, April 8-9, 2003. The research gaps and priorities are featured in the *Action Plan*, and an overall summary of the project is featured in the *Final Report*.

Hydrocarbon development has the potential to significantly change the biophysical environment. Similarly, the biophysical environment will dictate the design of a development proposal. This report considered what is known about the biophysical environment in the Mackenzie Valley and the potential impacts that may result from oil and gas development and pipeline construction and operation.

To understand the outcome of this *Background Paper Report*, it is necessary to understand the environmental impact assessment (EIA) process in the Mackenzie Valley. The EIA process requires an understanding of the environmental impacts of a project and a decision be made on the significance of these impacts. The challenge is to gather enough information about impacts to reduce uncertainty so that a determination about the significance of an impact can be made. It is important to have adequate baseline information to support impact predictions, as well as to have a good understanding of the potential impacts on the environment as a result of oil and gas development and pipeline construction in the Mackenzie Valley. This project considered more than 30 years of information about oil and gas activities in the Mackenzie Valley. Although much research and information has been gathered in the Mackenzie Valley, some advances in technology and our understanding of environmental impacts rendered some elements of this previous research and information obsolete, or indicated the need for updating it.

In the completion of this report, both scientific and traditional knowledge (TK) were considered. While scientific literature was accessible, reviewing the original sources for TK was not possible because of the proprietary nature of the information. However, based on references in other reports, it was possible to get an indication of the presence or absence of TK in a particular subject area and interpret how it might inform the understanding of impacts.

Project hydrocarbon development scenarios were also prepared to set the context for the gap research. Scenarios were developed for the Cameron Hills, Liard Plateau, Norman Wells, Colville Hills and Peel Plateau areas, and for a potential Mackenzie Valley pipeline. These scenarios are only estimates, the purpose of which was to assist in the identification of gaps and to provide a sense of the disturbances that may occur and the technological changes that can be expected.

A total of 90 individual biophysical information and research gaps are identified in this report. The following table lists the number of gaps related to baseline information (total 45) and environmental impacts (total 45).

Topic	Baseline Gap	Impact Gap
Terrain and Surficial Geology	6	5
Permafrost	1	4
Hydrogeology	1	1
Surface Water	7	3
Fish and Fish Habitat	8	6
Vegetation and Forests	3	5
Wildlife and Wildlife Habitat	10	7
Biodiversity	2	1
Air	4	2
Climate Change	1	10
Land and Resource Use/Harvesting/Protected Areas	1	0
Cumulative Effects	1	1

Appendix F provides a complete summary of the identified gaps for each of the biophysical topics discussed in this report. The *Action Plan* prioritizes the gaps and indicates the organizations that could be responsible for addressing the gaps.

The adequacy of baseline information was considered for each of the biophysical topics raised in this report. Research indicated that there is a general lack of baseline information for most of the biophysical topics, as is evident in the 45 baseline gaps identified through literature reviews and consultation with scientists and communities. Baseline needs vary between the need to up-date existing information to collecting new data. The kind of baseline information required for cumulative effects assessment and protected areas establishment is of a higher scale than that required for project specific impacts.

A number of gaps were identified with respect to our understanding of impacts from oil and gas development and/or the response to the impacts, i.e., mitigation . If one considers the longer studied impacts identified in Alberta (Cumulative Effects Management Association - CEMA) and Alaska (Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope 2003, National Science Foundation 2000) adequacy of mitigation stands out as an area where research is needed. This includes measures to improve environmental protection, restore impacted habitats, improve understanding of habitat adequacy for species such as caribou, and engineering responses to climate change which are adaptive.

Many of the impacts identified in need of study, also had indicated a need to understand the influence of climate change and the necessary technology adaptations that will be required.

Table of Contents

Acknowledgements
Executive Summary

List of Figures

List of Tables

List of Appendices

List of Abbreviations

CAGPL	Canadian Arctic Gas Pipeline Limited
CASA	Clean Air Strategic Alliance
CCME	Canadian Council of Ministers of the Environment
CEA	Cumulative Effects Analysis
CEAM	Cumulative Effects Assessment Management
CEPA	Canadian Environmental Protection Act
CIMP	Cumulative Impact Monitoring Program
COGOA	Canadian Oil and Gas Operations Act
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPRA	Canada Petroleum Resources Act
CPUE	Catch Per Unit Effort
CRREL	Cold Regions Research and Engineering Lab
CWS	Canadian Wildlife Service
DFO	Department of Fisheries and Oceans
DIAND	Department of Indian Affairs and Northern Development
ELC	Ecological Land Classification
EIA	Environmental Impact Assessment
EL	Exploration Licence
EMAN	Ecological Monitoring Assessment Network
GLUP	Gwich'in Land Use Plan
GNWT	Government of the Northwest Territories
GPS	Global Positioning System
GRRB	Gwich'in Renewable Resources Board
GSC	Geological Survey of Canada
INS	Inertial Navigation System
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
MAGS	Mackenzie Global Energy and Water Cycle Experiment (GEWEX) Study
MVEIRB	Mackenzie Valley Environmental Impact Review Board
MVLUR	Mackenzie Valley Land Use Regulations (under MVRMA)
MVRMA	Mackenzie Valley Resource Management Act
NEB	National Energy Board
NGL	Natural Gas Liquids
NOGAP	Northern Oil and Gas Action Program
NPRI	National Pollutant Release Inventory
NRCan	Natural Resources Canada
NWPA	Navigable Waters Protection Act
NWT	Northwest Territories
OHS	Occupational Health and Safety Regulations (NEB)

PAAG	Pipeline Application Assessment Group
PAH	Polycyclic Aromatic Hydrocarbons
PAS	Protected Areas Strategy
PERD	Panel of Energy Research and Development
PL	Production Licence
PM	Particulate Matter
POS/LS	Position and Orientation System for Land Survey
PWNHC	Prince of Wales Northern Heritage Centre
ROW	Right-of-Way
RWED	Resources, Wildlife and Economic Development (Government of NWT)
SARA	Species At Risk Act
SDL	Significant Discovery Licence
SLUP	Sahtu Land Use Plan
SRRB	Sahtu Renewable Resources Board
TK	Traditional Knowledge
TSP	Total Suspended Particulates

1. Introduction

1.1 Project Overview

North America's increasing dependence on the use of natural gas for heating and electricity and the concurrent increase in world hydrocarbon prices, has revived a long-standing interest in the development of hydrocarbon reserves, particularly natural gas, in the Canadian western Arctic and Alaska. In recent years, several proposals have been researched to consider the feasibility of transporting northern gas via pipeline(s) to southern Canadian and U.S. markets. With the settlement of land claims in the Mackenzie Valley well under way, an application to construct and operate a natural gas pipeline in this area began with the recent release of the Mackenzie Gas Project Preliminary Information Package (April 2003). The Preliminary Information Package describes the Mackenzie Gas Project components and activities, and identifies potential environmental and socio-economic issues requiring consideration While the possibility of a pipeline has captured the attention of the public, oil and gas exploration and development has also been proceeding most notably in Colville Hills, Norman Wells, the Liard Valley and Cameron Hills.

This *Background Paper Report* forms the first of four components of the project entitled Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley. The project was undertaken to improve the level of preparedness of the federal and the territorial governments, industry, communities, and other decision-makers to be able to respond to the environmental assessment and regulatory processes associated with hydrocarbon exploration, development and transmission in the Mackenzie Valley. This project required an identification of the current gaps in biophysical information, confirmation of the gaps by communities and scientific experts and finally a plan of action to address those gaps. The project will also assist Aboriginal organizations, communities, and the non-government sector in evaluating future hydrocarbon exploration, development, and transmission projects in the Mackenzie Valley.

Information and research gaps for this project were identified for the following topics:

- terrain and surficial geology;
- permafrost;
- hydrogeology;
- surface water;
- fish and fish habitat;
- vegetation and forests;
- wildlife – mammals and forest birds;
- wildlife – migratory birds / raptors;
- biodiversity;
- air;
- climate change;
- land and resource use/harvesting/protected areas; and,
- cumulative effects.

The project was consisted of four main components:

Component 1, Background Paper Report: The first component involved the identification of gaps for each of the biophysical components listed above. This was achieved through literature searches, personal communications with principal researchers and others expert in these areas of study, the professional and technical knowledge of the project team members, traditional knowledge (TK), and input from communities in the Mackenzie Valley. The compilation of this gap identification process is contained in the *Background Paper Report*.

Component 2, Workshops and Consultation: The second component involved presenting the identified gaps to communities, scientists, aboriginal groups and other stakeholders in the Mackenzie Valley for discussion and confirmation. through a series of workshops and community visits. The gaps were confirmed, refined or dismissed by participants according to their validity. Additional gaps were also identified. The *Gwich'in and Sahtu (Norman Wells) Community Workshop Results, May 3-5, 2003* and *Scientists' Workshop Results, April 8-9, 2003* were prepared to summarize the results of this work.

Component 3, Action Plan: The *Action Plan* was prepared as the third component of this project. The *Action Plan* summarizes the gaps finalized through Component 2 and includes a listing of gaps requiring immediate action. The *Action Plan* was prepared to guide information gathering and research activities related to the Mackenzie Valley hydrocarbon developments to be used by government, industry and communities and others.

Component 4, Final Report: The *Final Report* provides an overview of the *Background Paper Report, Norman Wells Workshop* and *Scientists' Workshop* reports, and the *Action Plan*.

This project focussed on the biophysical environment and did not consider socio-economic issues except where a socio-economic issue was linked to land and resource use directly associated with hydrocarbon development and gas pipeline construction and operation. The socio-economic issues such as jobs, benefits and training and social issues such as health and family violence were not considered in this project. That evaluation is being undertaken through a different exercise.

1.2 Purpose of Background Paper Report

The purpose of this *Background Paper Report* is to present the results of the biophysical information and research gaps (gap analysis) associated with oil and gas exploration and development and a potential pipeline in the Mackenzie Valley. This includes gaps related to environmental assessment, regulation and management of oil and gas development. In undertaking the work, past, and current scientific information and research, TK and input from communities and experts and specialists was considered.

This particular gap analysis report concentrated on a potential chilled gas pipeline and the ongoing and potential hydrocarbon exploration and developments in the Mackenzie Valley excluding the Mackenzie Delta and near-shore Beaufort Sea. This report concentrates on such biophysical attributes as terrain, permafrost; water; air, fish and their habitat, wildlife and their habitat, vegetation, and biodiversity. It also covers a review and brief evaluation of resources and land uses, including harvesting and protected areas; climate change; and, the possible cumulative effects related to ongoing and potential hydrocarbon development. With respect to the latter attributes:

- Land and resource use information was documented, including information and research on harvesting, and proposed and existing protected areas in the Valley. The potential effects of hydrocarbon development on the representativeness of the protected areas with respect to the goals of the Northwest Territories (NWT) Protected Areas Strategy (PAS) were considered, including information required to support the goals.
- Climate change and climate change effects were documented in order to provide a context for the review of the information on the biophysical attributes in the Mackenzie Valley.

The purpose of this *Background Paper Report* was to :

- consider the environmental impacts that may be expected from hydrocarbon development;
- identify the research that has already taken place; and
- determine the gaps in knowledge with respect to baseline information and environmental impacts

To establish the context for the research, a description of possible transmission pipeline route scenario(s) was prepared as were descriptions of the hydrocarbon activities that may take place within the next in 5-15 years[1] in key areas in the Mackenzie Valley. The Mackenzie Valley's geographic scope is the NWT exclusive of Inuvialuit Settlement Region (i.e., exclusive of Mackenzie Delta and Beaufort Sea). In particular, research concentrated on hydrocarbon development areas known as the Liard Plateau, Cameron Hills, Norman Wells, Colville Hills, and Peel Plateau, as well as, a potential pipeline corridor from Inuvik to the Alberta border.

1.3 Background Paper Report Structure

Including this introduction section (Section 1), the report is divided into five main sections. Section 2 outlines the methods used for integrating TK and western science, preparing development scenarios, conducting the research, and finally identifying the information and research gaps. Section 3 describes the scenarios for the hydrocarbon development areas and the potential pipeline. Section 4 provides background information on the various discipline topics and identifies information and research gaps related to baseline information and impact assessment. Section 5 lists the references cited throughout this report.

[1] Timeframe sourced from Request-for-Proposal, Contract No. 20-02-0255: Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley (September 19, 2002)

2. Methodology

The research for this project focused on a potential pipeline extending from the Alberta/NWT border to Inuvik, and on five hydrocarbon development areas, including Peel Plateau, Colville Hills, Norman Wells, Liard Plateau and Cameron Hills (Figure 1).

The biophysical information and research gaps identification work relates to understanding the environment in which oil and gas activities are taking place or could take place, and those research gaps related to the environmental assessment, regulation and monitoring of oil and gas activities. Therefore, the research was split into two streams: (1) research gaps for environmental impacts and, (2) research gaps in understanding the environment (baseline information).

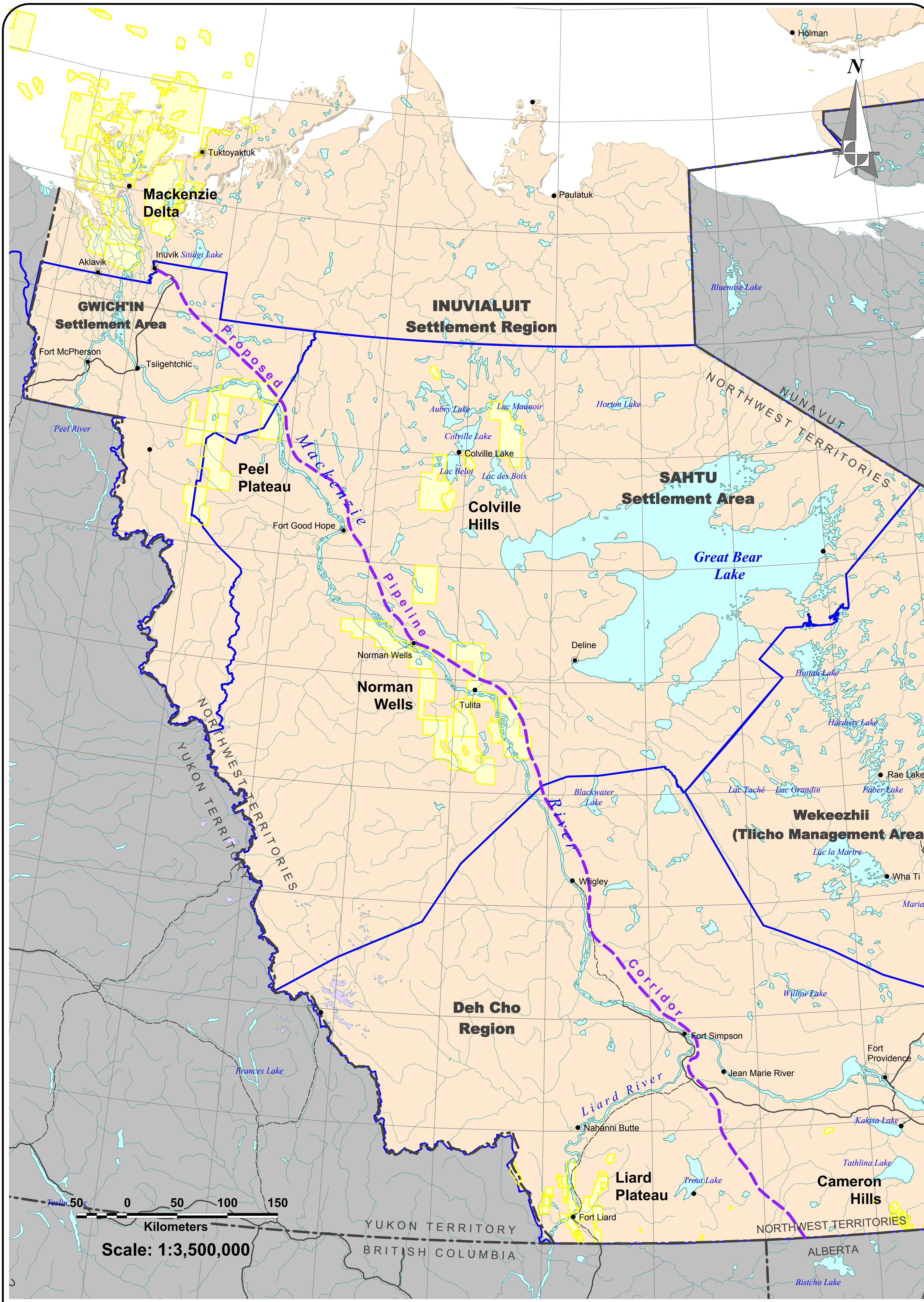
An essential part of the gap work was to consider both scientific and TK information, and the information from communities in the Mackenzie Valley

2.1 Integrating Traditional and Scientific Knowledge

Two kinds of knowledge were used in preparing this report: TK and mainstream scientific knowledge.

Given that many concepts of TK exist (Appendix A), it was necessary to establish a consistent approach to the consideration of TK. The definition and concept of TK in this report is the definition that was developed during a TK workshop called by the Mackenzie Valley Environmental Impact Review Board (MVEIRB).

> "*Traditional Knowledge is knowledge that has been acquired through observation, experiences and interaction of aboriginal peoples with the natural environment over a period of thousands of years. The experience and observations of individuals is shared with members of a "community" and is integrated into collective understandings and interpretations. These interpretations shape behaviours, relationships, beliefs, and socio-economic decisions. This shared experience and understanding is passed on from generation to generation orally, through traditions and ceremonies designed to enlighten community members, and through encouraging members to share their own insights, experiences and observations. The knowledge of individuals about specific geographic areas or as people with specific expertise about certain elements is a normal part of the traditional system. This specialized knowledge, however, is shared openly with the community as a whole, and forms part of the basis for collective understandings. Knowledge is therefore continuously evolving and provides the aboriginal community with the ability to adapt to changes and to predict future outcomes based on past experience. The relationship between people and the natural environment has been informed by this knowledge and has enabled Aboriginal people to use natural resources in a sustainable manner. Aboriginal peoples are best equipped to access, interpret, represent and apply the distinct knowledge of their peoples."*
> (Barnaby and Emery 2002).



Legend

Approximate Location of Proposed Pipeline Corridor

Oil & Gas Dispositions (Sept. 2002)

Source of Basemap:
Natural Resources Canada, 1999
Atlas of Canada Basemaps, 1:2,000,000 scale
UTM Zone 10, NAD83 Projection

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2004

Project Number: 22-649

File Name: 22649-F1d-R3.WOR

Revision: 3

Study Area Map

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No.

1

TK was not directly collected for the purposes of this gap analysis report because of the proprietary nature of TK information and the challenges of accessing TK. TK gathered and held by communities, as holders of the knowledge, are responsible for its interpretation, distribution and use. The TK-related information in this report primarily drew on secondary sources of information. Interviews with community representatives formed the primary source of TK information. The representatives confirmed whether TK information was available and its general nature. Where available, publicly accessible TK information was also reviewed and summarized in this report.

The following types of information were considered in preparing this report:

- data and information: e.g., baseline information, census information;
- interpretative knowledge: e.g., effects analysis;
- ecosystem management: e.g., planning and management; and
- values-based decision-making: e.g., regional planning.

Data and Information

Data and information includes knowledge related to burial sites, berry picking areas, location of fish, for example. It is the study of a traditional way of life, land use and occupancy, travel routes, traplines, and hunting and fishing areas. It may also be sites and areas of cultural, spiritual and historical significance including harvesting sites.

Interpretative Knowledge

Little TK has been used in effects analysis, or in the prediction of project effects. Some retrospective studies have been done, such as the Sahtúgot'ine (the Dene of Great Bear Lake) study on the impacts of 1930s-1960s radium and uranium mining in the Sahtu. TK as interpretative knowledge, is knowledge that is used to predict or understand impact effects such as land use and occupancy information may indicate or provide information on pipeline route selection or the significance of spills or leaks in certain locations.

Ecosystem Management

TK has been used in the planning and management of projects through land use planning and the establishment of protected areas by identifying environmentally and culturally sensitive regions or areas.

Values-based Decision-Making

The unique values that underlie TK have been included in the planning and management of development.

Scientific knowledge, largely in the form of refereed scientific papers, government reports, and personal communication with scientific experts, was obtained through such sources as: government and university libraries, research databases (e.g., ASTIS), government departments, and internet.

TK-related information and scientific knowledge were used together to identify information and research gaps in the available biophysical information for the Mackenzie Valley.

2.2 Roles, Input and Participation

2.2.1 Community Input and Participation

Community input and participation formed a crucial element of the information gaps research. To achieve adequate input, community visits, engagement of Regional Liaison Staff[2] and workshops were all employed. To facilitate communications about this project, posters were prepared and posted in communities. On the posters, four questions were posed to spark discussion:

- how would oil and gas development affect the land, water, wildlife and air?
- are there any regulations, guidelines or management plans in place to address these issues?
- do you know if there has been any research done about these issues?
- what other kinds of science and TK studies need to be done to address these issues?

The responses to these questions were used to verify the development scenarios (Section 3), the identified environmental effects, the related scientific and TK information, and information and research gaps.

The Regional Liaison Staff provided direct contact with appropriate aboriginal organizations in each community and region that could provide information relevant to this project. These staff also provided advice and help in organizing the *Norman Wells Workshop* and in identifying individuals to attend the workshop.

2.2.2 Role of Researchers, Team Leads, Senior Peer Reviewers And Scientific Experts

The Gartner Lee Project Team was comprised of individuals with specific expertise in the biophysical attributes found in the Mackenzie Valley. Team Leads were appointed to guide researchers in the following discipline areas, which correspond to the identified biophysical attributes considered in this gap analysis:

- terrain and surficial geology;
- permafrost;
- hydrogeology;
- surface water;
- fish and fish habitat;
- vegetation and forests;
- wildlife – mammals and forest birds;
- wildlife – migratory birds / raptors;

[2] The Gwich'in Tribal Council and the Sahtu Renewable Resources Board specifically, for the purpose of this project, engaged Regional Liaison Staff. The funding for the position was through contribution agreement from DIAND.

- biodiversity;
- air;
- climate change;
- land and resource use/harvesting/protected areas; and,
- cumulative effects.

The Team Leads provided the researchers with expert advice and direction for researching information and identifying gaps in each of these areas of interest. The researchers completed a detailed review and brief evaluation of past and current information and research relevant to the Mackenzie Valley, in each of these areas. The Team Leads, based on their particular area of expertise and professional knowledge, then reviewed the gap analysis prepared by the researchers. The Team Leads essentially acted as “gate-keepers” of the information prepared by the researchers, ensuring its consistency, accuracy and quality.

A team of three Senior Peer Reviewers reviewed the draft *Background Paper Report* and the draft *Final Report* to provide an objective evaluation of the research. Each of the Senior Peer Reviewers brought extensive northern and/or industry experience, and in-depth knowledge to this task. The Senior Peer Reviewers also were involved in an advisory capacity during critical points of the project to provide key discipline contexts and direction to the Project Team.

External scientific experts that were contacted during this project were principal researchers undertaking research in the areas of the identified biophysical attributes considered in this project. Expertise from communities was also obtained. Through personal communication with these experts, the Project Team was able to confirm the research and gap analysis results, and identify additional relevant information.

Scientific experts also provided input at the *Scientists’ Workshop,* April 8-9, 2003.

2.3 Preparation of Development Scenarios

To set the context for the information gap research, it was necessary to develop an understanding of the current trends and forecasts for hydrocarbon development (development scenarios) for the next 5 - 15 years in the Mackenzie Valley. These “development scenarios” (as they are collectively referred to) are only estimates to assist in the identification and analysis of information gaps and to provide a sense of what disturbances may happen or what technological changes can be expected. They were not perceived to indicate what actions may take place in the Mackenzie Valley.

The Project Advisory Team and the Gartner Lee Project Team reviewed these development scenarios and provided comments and additional information used to complete them. The members of the Project Advisory Team and the Gartner Lee Project Team are listed in Appendices D and E, respectively.

The following subsections generally describe how the development scenarios were prepared, and Section 3 provides a detailed description of the development scenarios. The various documents used, and the experts and industry representatives consulted to complete these development scenarios are referred to throughout Section 3.

2.3.1 Mackenzie Valley Oil and Gas Development Area Scenarios

There are five identified oil and gas development areas, including Peel Plateau, Colville Hills, Norman Wells, Liard Plateau, and Cameron Hills. in the Mackenzie Valley (Figure 1). Each has a unique history and resource potential for development. To provide consistency of information and results obtained for these oil and gas development areas, a potential development scenario was prepared for each area that included a review and summary of the following information:

- **Background:** An overview of location and historical oil and gas activities.
- **Existing Resources:** A description of existing oil and gas resources/reserves.
- **Exploration Potential:** A description of possible exploration activities.
- **Development Potential:** A description of oil and gas development activities based on existing significant discovery and Production Licence issuance, and currently known reservoir potential. The projections about the number of production wells is also based on expert opinion, and although this information is considered reliable, it is only for planning purposes for this exercise and may not be precise.

Each development-potential description also included the following information:

- **Type:** Oil, gas.
- **Development timeframe:** 5 to 15 years; this timeframe is not intended to suggest that wells brought to production would be completed, decommissioned and abandoned within 15 years, it is only an arbitrary period used for planning purposes.
- **Reserves:** The projected number of production wells.
- **Infrastructure:** General description of infrastructure requirements for construction, operation, and tie-in to existing infrastructure or proposed gas transmission pipelines.
- **Staging Requirements:** Identifying where and what staging and supply points may be required and located for construction, operation and decommissioning.
- **Resource Requirements:** General indication of what resources may be required (e.g., new or existing winter road access, construction camp facilities).

2.3.2 Mackenzie Valley Oil and Gas Seismic Exploration Scenario

The seismic exploration scenario describes some of the common methods used in seismic exploration in the Mackenzie Valley today. It includes the following information:

- **Type:** Seismic survey, exploration type and description of activities
- **Exploration Activities:** The estimated amount of seismic and exploration drilling to be undertaken within the exploration timeframe
- **Exploration Timeframe:** 5 to 15 years

- **Infrastructure:** General description of the infrastructure requirements for seismic exploration
- **Staging Requirements:** Identifying the staging requirements for seismic exploration
- **Resource Requirements:** General indication of what resources may be required (i.e., camps, personnel, equipment)

2.3.3 Generic Mackenzie Valley Gas Pipeline Development Scenario

Several natural gas pipeline feasibility projects (e.g., Arctic Gas) were researched for information useful in compiling this development scenario. Information from all of the proposals reviewed was combined to create a generic Mackenzie Valley natural gas pipeline development scenario. Various experts and industry representatives were also consulted and provided additional information that assisted in compiling this scenario. Since the preparation of the pipeline development scenario for the purposes of this report, the Preliminary Information Package has been filed by the Mackenzie Gas Producers group.

2.4 Identifying Information and Research Gaps: Scoping the Issues

2.4.1 Environmental Impact Matrices

As noted above, development scenarios were created to illustrate the various stages of oil and gas exploration, development and transmission in the Mackenzie Valley. The development scenarios were prepared strictly to establish some boundaries for the research in this report. The information from the development scenarios was summarized into impact matrices which examined potential impacts associated with:

- potential seismic exploration activities in the specific oil and gas development regions of the Mackenzie Valley;
- potential hydrocarbon development activities in the specific oil and gas development regions of the Mackenzie Valley; and,
- a potential natural gas transmission pipeline through the Mackenzie Valley.

These development scenarios included description of typical activities that could be associated with these types of projects (Section 3) and an identification of the possible level of these activities over a 5 to 15 year timeframe (Appendix B).

Matrices were developed to identify the environmental impacts that may happen as a result of the activities described in the development scenarios. A matrix is a tool that identifies where activities associated with a project might have an effect on the environment. For the purpose of this work, two types of matrices were developed. One matrix included project activities for a "typical" natural gas pipeline. The second matrix included project activities associated with exploring and developing oil and natural gas resources. Both matrices used the same biophysical components of the environment, land and resource use, and harvesting. These matrices can be found in Appendix C of this report.

2.4.1.1 Creating the Matrices

The matrices for this project were modelled after a Level 2 matrix previously developed for a multi-product pipeline (Federal Environmental Assessment Review Office 1978). The environmental components were listed on the horizontal axis (x-axis) and identified potential environmental effects including those biophysical attributes and traditional resources and land uses of the Mackenzie Valley. The vertical axis (y-axis) features typical activities associated with various stages of hydrocarbon development, or natural gas pipeline development. Both the x-axis components and the y-axis activities were reviewed, revised and confirmed with the Project Advisory Team and by the Gartner Lee Project Team.

2.4.1.2 Filling in the Matrices

The Gartner Lee Project Team completed the matrices. Whenever an effect was identified, an “x” was put in the box corresponding to the project activity causing the potential effect. The Project Advisory Team reviewed the results and provided comments.

2.4.1.3 Identifying Research Priorities

Once the matrices were completed, each identified effect (denoted by ‘x’) was analyzed to determine if the effect fell into one of the following categories:

- legislation or guideline prescribes mitigation for the effect (R);
- legislation or guideline prescribes mitigation for the effect but environmental issues remain (RR);
- standard mitigation available, but not linked to a legislation or guideline (NR);
- effect is poorly understood or poorly mitigated (P); or
- mitigation available through project engineering or other design (EG).

This exercise was completed in order to identify the priority areas on which to focus the information gap research. Research priority was placed on those areas where issues remain or environmental issues are poorly understood. Table 1 illustrates the categorization of the environmental effects, and identifies those priority areas for researching gaps.

Table 1. Classification of Environmental Effects and Identification of Priority Research Areas Resulting From a Potential Natural Gas Pipeline Through the Mackenzie Valley, or Development of Oil And Gas Areas in the Mackenzie Valley.

Classification Codes:

R = legislation or guideline prescribes mitigation for the effect

RR = legislation or guideline prescribes mitigation for the effect but environmental issues remain

NR = standard mitigation available, but not linked to legislation or guideline

P = effect is poorly understood or poorly mitigated

EG = mitigation available through engineering design or other design

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
Surface Water	Flow	R	NWT Waters Act/ Fisheries Act/ Gwich'in and Sahtu Land Claims/ NWPA/NEB Act (for pipelines)
	Drainage/flood characteristics	R, EG	NWT Waters Act/ Fisheries Act/ Gwich'in and Sahtu Land Claims/ Dominion Water Power Act
	Quality changes	R, EG	NWT Waters Act/ Fisheries Act/ Gwich'in and Sahtu Land Claims/ CEPA/ Canada Water Act/NEB-COGOA
	Quantity changes	R, EG	NWT Waters Act/ Fisheries Act/ Gwich'in and Sahtu Land Claims
	Ice regime changes	P, EG	
Ground Water	Water table alteration	P, NR	NRCan/NEB Act
	Quantity changes	P	NRCan/NEB Act
	Quality changes	R	NWT Waters Act/ Fisheries Act/ Gwich'in and Sahtu Land Claims/ CEPA/NEB
Lake and river shorelines /bottoms	Alteration	R	NWPA/ Fisheries Act
Wetlands	Alteration	NR	Environment Canada – Federal Policy for Wetland Conservation/NEB
Noise	Intensity changes	RR	NEB – OHS Regulations
	Duration changes	RR	NEB – OHS Regulations
	Repetition changes	RR	NEB – OHS Regulations
Land	Soil erosion	R	MVLUR/ NEB - COGOA
	Soil stability changes	R	MVLUR/ NEB - COGOA

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
	Soil horizon alteration	R	MVLUR /NEB - COGOA
	Soil compaction/settling	R	MVLUR/ NEB - COGOA
	Flood plain alteration/usage	P	
Geotechnical	Slides/slumps	R, EG	MVLUR/ NEB – COGOA, NEB Act/ NRCan
	Earthquakes	NR, EG	NRCan
	Frost susceptibility	R, EG	MVLUR/ NEB – COGOA; NRCan
	Permafrost alteration	R, EG	MVLUR/ NEB – COGOA; NRCan
	Active layer disturbance	R, EG	MVLUR/ NEB – COGOA; NRCan
Atmosphere	Air quality changes	NR/P	GNWT Air Quality Code of Practice Upstream Oil and Gas Industry NR/P indicated due to limited enforceable air quality standards for NWT, while other jurisdictions have higher standards that are generally adopted by industry in the NWT.
	Particulate increases	NR/P	GNWT Air Quality Code of Practice Upstream Oil and Gas Industry (draft) NR/P indicated due to limited enforceable air quality standards for NWT, while other jurisdictions have higher standards that are generally adopted by industry in the NWT.
	Greenhouse gas emissions	NR/P	NEB – COGOA/CEPA Canada's Climate Change Voluntary Challenge and Registry Inc. program the NPRI program NR/P indicated due to global scale of effect
	Wind regime alteration	NR/P	
	Inversion susceptibility increase	P	
	Fog/Ice fog susceptibility increase	NR/P	Environment Canada - Weather forecast and severe weather warnings
Terrestrial populations (species)	Vegetation/forest cover removal	P	GNWT Forest Management Act and associated regulations MVLUR A Wildlife Policy for Canada Migratory Birds Convention Act

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
	Wildlife (vertebrates) loss	NR/P	GNWT Wildlife Act A Wildlife Policy for Canada Migratory Birds Convention Act
	Invertebrates loss	NR/P	A Wildlife Policy for Canada
	Rare/endangered species impacts	NR/P	SARA COSEWIC Territorial listed species A Wildlife Policy for Canada
	Introduction of invasive species	P	A Wildlife Policy for Canada
Aquatic populations (species)	Flora loss	R	Fisheries Act, NWT Waters Act, MVRMA A Wildlife Policy for Canada
	Fish (vertebrates) loss	R	Fisheries Act, NWT Waters Act, MVRMA A Wildlife Policy for Canada
	Invertebrates loss	R	Fisheries Act, NWT Waters Act, MVRMA A Wildlife Policy for Canada
	Rare/endangered species impacts	NR/P	SARA COSEWIC Territorial listed species A Wildlife Policy for Canada
	Introduction of invasive species	P	A Wildlife Policy for Canada
Terrestrial communities	Habitat fragmentation	P	A Wildlife Policy for Canada Migratory Birds Convention Act NWT Protected Areas Strategy NEB Act (for pipelines)
	Ecological relationship alteration	P	A Wildlife Policy for Canada NWT Protected Areas Strategy

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
	Community structure alteration	NR/P	A Wildlife Policy for Canada NWT Protected Areas Strategy NEB Act
Aquatic communities	Habitat fragmentation	NR/P	DFO - No net loss of fish habitat A Wildlife Policy for Canada Migratory Birds Convention Act
	Ecological relationship alteration	NR/P	DFO - No net loss of fish habitat A Wildlife Policy for Canada
	Community structure alteration	NR/P	DFO - No net loss of fish habitat A Wildlife Policy for Canada
Terrestrial lifecycle	Reproduction rate decrease	P	GNWT Wildlife Act
	Nest/den disturbance	P	GNWT Wildlife Act Migratory Birds Convention Act
	Gestation/incubation/ life stage impacts	P	GNWT Wildlife Act
	Rearing impacts	P	GNWT Wildlife Act
	Juvenile dispersal alteration	P	GNWT Wildlife Act
	Migration route alteration	P	GNWT Wildlife Act
	Critical habitat losses	P, R	GNWT Wildlife Act Migratory Birds Convention Act
	Forage removal	P	GNWT Wildlife Act
Aquatic lifecycle	Reproduction rate decrease	R	Fisheries Act
	Nursery/life stage impacts	R	Fisheries Act Migratory Birds Convention Act

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
	Juvenile dispersal /Rearing impacts	R	Fisheries Act
	Migration route alteration	R	Fisheries Act
	Over wintering habitat loss	R	Fisheries Act
	Forage removal	R	Fisheries Act Migratory Birds Convention Act
Biodiversity	Species loss, loss of genetic diversity, change to ecosystems	NR/P	United Nations Convention on Biodiversity; Canadian Biodiversity Strategy GNWT is implementing the Convention on Biodiversity through its NWT Biodiversity Action Plan SARA contributes to maintaining biodiversity
Heritage resources	Archaeological site disturbance/loss	R	NWT PWNHC Heritage Resources Act
	Cultural/spiritual site disturbance/loss	NR/P	
Traditional land use and harvesting	Country food quality decrease – fish	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Country food quality decrease – caribou	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Country food quality decrease – moose	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Country food quality decrease – ducks	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Country food quality decrease – geese	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Country food quality decrease – small furbearers	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA

Environmental Component	Environmental Effects	R / RR NR / P / EG	Mitigation Approach/ Notes
	Hunting loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Fishing loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Trapping loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Gathering loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Cultural land use loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Cultural land use loss of quality	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Spiritual land use loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Spiritual land use loss of quality	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
	Water loss of access	NR/P	Gwich'in and Sahtu Land Claims Agreements, MVRMA
Land use	Land use conflicts	NR/P	Gwich'in and Sahtu Land Claims Agreements/Surface Rights Board
	Unique physical features loss	NR/P	NWT Protected Areas Strategy
Effects of the environmental on the project			
Climate change[3]	Permafrost changes	P/EG	NRCan / Project induced and effects of changes on the project.
	Forest fire susceptibility	P	Project induced and effects of increased fire risk on the project.
	Flooding susceptibility	P	Snow cover, precipitation changes; flooding effects on river crossings, lakes
	Ice conditions – changes to ice conditions caused by climate change	P	NWTWA, Fisheries Act, River crossings, pipeline crossings; access and winter road crossings, winter road season length will all be affected by changed ice conditions
	Temperature changes	P	Warming/cooling changes
Geotechnical	Earthquakes	P, EG	NRCan
	Permafrost	P, EG	MVLUR/NEB – COGOA; NRCan (Project induced)
	Hazard zones/changes	P	NRCan

[3] Kyoto Protocol is applicable

CEPA = Canadian Environmental Protection Act
COGOA = Canadian Oil and Gas Operations Act
COSEWIC = Committee on the Status of Endangered Wildlife in Canada
DFO = Department of Fisheries and Oceans
GNWT = Government of the Northwest Territories
MVLUR = Mackenzie Valley Land Use Regulations (under MVRMA)
MVRMA = Mackenzie Valley Resource Management Act
NEB = National Energy Board
NPRI – National Pollutant Release Inventory
NRCan = Natural Resources Canada
NWPA = Navigable Waters Protection Act
NWT = Northwest Territories
OHS = Occupational Health and Safety Regulations (NEB)
PWNHC = Prince of Wales Northern Heritage Centre
SARA = Species At Risk Act

2.4.2 Gap Identification and Research

Once the environmental effects were categorized, and priority areas identified, possible information gaps were researched. Both scientific and TK information sources were consulted to identify gaps associated with baseline and environmental impact information. Gaps were identified:

- where baseline information was lacking, considered poor quality or dated; and,
- where information related to environmental impacts was lacking, where environmental impacts or associated mitigation measures are poorly understood or unknown.

There exists over 30 years of information about oil and gas activities and the environment in the Mackenzie Valley that may still have some relevancy to today's regulators and environmental assessment practitioners. For example, the applications and supporting research for the Canadian Arctic Gas Pipeline Limited (CAGPL) and Foothills Pipeline Company pipeline proposals to construct a pipeline in the Mackenzie Valley, and the subsequent review by Thomas Berger ("Northern Homeland, Northern Frontier" – the report of Justice Berger's inquiry) are just two examples of information from the 1970s. There was also the research conducted under the Northern Oil and Gas Action Program (NOGAP), the Panel of Energy Research and Development (PERD), and the Environmental Studies Research Funds (ESRF) in the 1980s and 1990s. Each of these undertakings contributed to the understanding of impacts related to oil and gas development and worked towards educating regulators and the public.

While much research has been conducted and information gathered with the passage of time, developments in other hydrocarbon areas have resulted in technological advances and changes in the engineering design of exploration, development, and transmission of hydrocarbons. Similarly, there is a better understanding of the environmental impacts of hydrocarbon activities. Some of these advances may render elements of the previous research and information obsolete, or indicate the need for updating it. While the industrial (project) scenarios have changed over the years, so have some of the environmental issues. For example, climate change, the conservation of biodiversity, and the consideration of cumulative effects have taken a more prominent place in the planning, environmental assessment and management of projects.

For this project, searches of literature and databases (e.g., the reports listed in the Request For Proposal plus others) were conducted using various methods. With the assistance of information managers, the research team reviewed the available data and literature, beginning with the most recent records and working backwards through older records to gather information and characterize the gaps. The research team also contacted scientific experts (see Section 2.2.2) active in undertaking studies in the Mackenzie Valley, and asked for relevant documents and for their advice on potential gaps. Expertise was also provided by people in communities either through the *Norman Wells Workshop* or community visits. Once the initial evaluation and characterization of the gaps was completed, the results were presented to the team leads for refinement and confirmation. Peer review of the draft report was then completed, prior to finalization and distribution to the client.

The research focussed on the NWT. Information outside the NWT is generally not applicable to the study area in the context of research requirements for environmental assessment. However, where it was considered useful, information from areas outside of the NWT (e.g., Alaska, Alberta) was reviewed and referenced in this report.

Complimentary to the work summarized in this report, the Government of the Northwest Territories (GNWT) identified the need for adequate baseline information for land use and development decision-making and long-term monitoring. *Common Ground: NWT Economic Strategy 2000* (Economic Strategy Panel 2000) makes two recommendations concerning baseline data for the collection of baseline data necessary for cumulative impact monitoring and for the expansion of baseline data on ecosystems, wildlife and sustainable harvest levels. *Towards a Better Tomorrow: A Non-renewable Resource Development Strategy for the Northwest Territories* (GNWT 2000) identifies the need to establish a monitoring and mitigation regime for both biophysical and socio-economic environments. Adequate baseline data is recognized as the foundation of this regime.

3. Development Scenarios: Areas of Oil and Gas Potential in the Mackenzie Valley

The NWT has a long history of hydrocarbon utilization, exploration and development (Table 2). However, its reserves are far from the major population centres of southern Canada, and extracting the resources and shipping them south involves numerous challenges e.g., environmental conditions, large capital costs, limited infrastructure development. For these and other reasons, it has been the more accessible locations in Canada that have tended to be explored and developed first.

As part of this project, hydrocarbon exploration, development and pipeline transmission scenarios were prepared. The key oil and gas development areas of the Mackenzie Valley for which specific scenarios were developed are: Cameron Hills, Liard Plateau, Norman Wells, Colville Hills, and Peel Plateau. As well, scenarios have also been prepared for seismic exploration, and a potential Mackenzie Valley pipeline project. Figure 1 identifies these development areas, and a possible routing of a natural gas pipeline.

The primary sources of information used in developing the scenarios were:

- Our Petroleum Challenge: Exploring Canada's Oil and Gas Industry (Bott 1999);
- Deck presentations on the Mackenzie Gas Project (Mackenzie Gas Pipeline Producers 2002a,b);
- ArctiGas Preliminary Information Package for the *Northern Gas Pipeline Project* (ArctiGas, undated); and
- Personal communication with staff from DIAND, CAPP and Imperial Oil.

For information on approvals, permits and licenses required for activities associated with the development scenarios outlined below, the reader is referred to the following website: http://www.oilandgasguides.com/. The website refers to the Regulatory Roadmaps Project, which is a jointly sponsored initiative of CAPP and Government Regulatory Agencies. The project prepares comprehensive guides to regulatory approval processes for oil and natural gas exploration and production in selected jurisdictions. An example of one of the guides is: *Oil and Gas Approvals in the Northwest Territories, Southern Mackenzie Valley: a guide to regulatory approval processes for oil and natural gas exploration and production on public lands in the Southern Mackenzie Valley*.

Table 2. Historical Highlights of Oil and Gas Exploration in Northern Canada (adapted from Morrell 1995)

HISTORICAL HIGHLIGHTS	
Before 1789	Indians make use of petroleum seeps along the Mackenzie River at Bosworth Creek.
1789	Alexander Mackenzie logs "petroleum" seeps from the lower Ramparts during his exploration of the Deh Cho (Great River).
1800s	Dene Indians and Hudson's Bay Co. traders use Fort Good Hope tar springs as their principal source of pitch. In 1860, the Canadian oil industry began with the discovery of oil at Petrolia in southern Ontario.
1887	Emile Petitot notes "Asphalt in great quantities".
Early 1911	A Dene named Karkasse directs the attention of J.K. Cornwall (of the Northwest Trading Co.) to "flotsam oil" along the banks of the Mackenzie River, leading to the identification of oil seeps at Norman Wells.
1913 – 1914	Area of seepage's at Norman Wells staked by Bosworth – at the same time as the Turner Valley discovery in Alberta.
1919	Imperial Oil buys Norman Wells prospect from J.K. Cornwall.
1920	Northwest Discovery No. 1 flows oil from fractures in the Canol Formation. "Oil comes to surface [in] black globules…trenches fill with oil".
1942	Canol Project. Limited development of the Norman Wells field to fuel the war effort in the Pacific. In the following year, oil began flowing through the Canol pipeline to Whitehorse, Yukon at rates of 3,000 barrels per day.
1944	Production reaches 4,400 barrels per day but ceases after the war. The pipeline was dismantled in the late 1940s.
Late 1960s	Permitting of frontier lands for exploration results in extensive geophysical exploration and drilling in the Mackenzie Valley and Delta.
1971 – 1972	Discovery of Taglu, Parson Lake and Niglintagak natural gas reserves in Mackenzie Delta, onshore.
1972	Pointed Mountain gas field in southwest Mackenzie Valley begins producing; natural gas piped south into British Columbia.
1974	The "oil shock" intensifies concern about domestic supply, resulting in the development of incentive programs for frontier exploration and a surge in exploration.
1977	After extensive public consultation with regard to environment and social sensitivities, the Berger Commission recommends that no pipeline be built along the Yukon north shore to Alaska and that a ten year moratorium be placed on pipeline

HISTORICAL HIGHLIGHTS	
Before 1789	Indians make use of petroleum seeps along the Mackenzie River at Bosworth Creek.
	construction in the Mackenzie Valley. Government ceases land disposition until Native land claims are settled.
1975 – 1985	Exploration drilling intensifies throughout the Canadian frontier and especially in the Mackenzie Delta and Beaufort Sea.
1984	Settlement of Inuvialuit land claim (Western Arctic region).
1986	Discovery of Ikhil natural gas reserve in Mackenzie Delta (onshore).
1986	Norman Wells facilities expanded and a pipeline is built to southern markets. Field put on full development for the first time. Fall in oil prices curbs new investment in frontier exploration.
1989	Exploration rights made available in the Mackenzie Delta/Beaufort Sea region for the first time in 20 years.
1992	Settlement of Gwich'in land claim (southern Mackenzie Delta, northern Mackenzie Valley region of the NWT).
1993	Settlement of Sahtu land claims (central Mackenzie Valley, Colville Hills, Greta Bear Lake region of the NWT). Signing of land claims with Inuit of Nunavut (eastern Arctic). Signing of Umbrella Final Agreement with Council of Yukon Indians.
1994	Lands again available for exploration following settlement of Native land claims in the NWT.
1999	The Inuvik Gas Project is officially opened: the Ikhil natural gas pipeline was built to supply natural gas from the Ikhil reservoir in the Mackenzie Delta to Inuvik
2000	Chevron Canada Limited and partners receive permission to develop a gas field near Fort Liard and pipe natural gas into the Pointed Mountain pipeline system.
Late 1990s - 2001	Interest is again seen in developing a natural gas pipeline down the Mackenzie Valley, to deliver Mackenzie Delta (Taglu, Parson Lake and Niglintagak) and/or Prudhoe Bay natural gas to market. Several companies begin investigating various routes and options.
2003	The Honourable Robert D. Nault, Minister of Indian Affairs and Northern Development and Deh Cho First Nations Grand Chief Michael Nadli signed the Deh Cho Process Interim Resource Development Agreement.

3.1 Hydrocarbon Exploration, Development, Production, and Management Overview

3.1.1 Oil and Gas Resource Management Overview

Managing the development of oil and gas resources for Canada's Frontier Lands in the NWT is a federal responsibility, fulfilled by the Department of Indian Affairs and Northern Development (DIAND). DIAND has the mandate to ensure that northern oil and gas resources are managed wisely, and in a manner that balances the northern and national interests in the context of Aboriginal land claims, promotes investment in the sustainable development of northern resources, and provides related information and advice.

Petroleum resource management on Canada's federal lands north of 60 degrees latitude is exercised under two federal statutes: the *Canada Petroleum Resources Act* (CPRA) and the *Canada Oil and Gas Operations Act* (COGOA). The CPRA[4] governs the issuance of rights of Crown lands to the private sector, tenure to the allocated rights, and the setting and collection of royalties. The COGOA regulates petroleum operations in the interest of the production and conservation of resources, protection of the environment and safety of workers. Operational regulation under COGOA and certain technical determinations under CPRA are the responsibility of the National Energy Board (NEB). Other legislation concerning land and water use, and environmental protection are fundamental to the sustainable development of oil and gas resources in the North (e.g., the *Mackenzie Valley Resource Management Act* - MVRMA). Independent boards set up pursuant to land claim agreements in the Mackenzie Valley manage these aspects. The following highlights are from a DIAND publication on the oil and gas regime in the NWT as of 1999 (Bott 1999). Finally, the *NWT Environmental Protection Act* also provides for the management and disposal of wastes, as well as being the regulatory backdrop for the NWT Air Quality Standards, an air quality guideline[5], under the *NWT Environmental Protection Act*, sets air quality standards.

3.1.1.1 Highlights of the Oil and Gas Management Regime

Industry Driven

Prior to offering Crown lands for bids, industry is invited to select or nominate parcels of interest to them through a Call for Nominations. Maximum parcel size is set deliberately large in poorly explored areas to encourage integrated exploration programs. Nominations of lands are subsequently tendered through a competitive Call for Bids (although the Crown reserves the right not to proceed with a Call for Bids).

---

[4] Note: The CPRA does not provide carte blanche for exploration/ development rights in protected areas.
[5] Guideline for Ambient Air Quality Standards in the Northwest Territories: Sulphur Dioxide (SO_2), Ground Level Ozone (O_3), Total Suspended Particulate (TSP), Fine Particulate Matter ($PM_{2.5}$)

Community Consultation

After parcels of land are nominated, the Crown consults with the potentially affected communities on the acceptability of opening up parcels of land and what size those parcels should be.

Fair and Simple Rights Issuance

The rights issuance process is fair: it gives all parties an equal opportunity to bid on the posted parcels by prescribing a minimum period of 120 days for a Call for Bids to remain open. All terms and conditions associated with the offering are known in advance. The process is simple: a single bidding criterion is used in the selection of the winner from bids received by the closure of the Call and which conform to the requirements for bid submission.

Minimum Financial Exposure

The standard bidding criterion for recent rights issuance in the North has been the total amount of money that the bidder proposes to spend doing exploratory work on the parcel within a specified time period. The criterion is referred to as a "work proposal".

Refundable Work Deposit

When "work proposal" is selected as the bidding criterion, the winning bidder receives an Exploration Licence for up to nine years, divided into two periods. Work proposal bids relate only to Period 1 of the term, and the winning bidder's commitment is secured by a deposit, in the form of a financial instrument acceptable to the Minister (Letter of credit preferred), equivalent to 25 % of the bid posted. The deposit is refundable as expenditures are made at the rate of one dollar for every four dollars spent. Expenditures are currently allowed at representative rates for seismic exploration and drilling, which are periodically reviewed in consultation with industry. These rates are appended to each Exploration Licence.

Discovered Hydrocarbons Held on Known Reservoir

Successful explorers apply to the NEB for technical review and declaration of the extent of their discovery. Upon declaration of a significant discovery, the explorer can apply for and shall be granted a Significant Discovery Licence (SDL) to cover that part of their Exploration Licence underlain by the discovery. The whole of the discovered reserves (to the extent that it is known upon application) is covered by the Significant Discovery Licence, rather than the horizon type ownership licences issued in Alberta.

Explorer Controls Timing of Development

The Significant Discovery Licence has an indefinite term in recognition of the fact that some discoveries may not be immediately economic to produce. In fact, the market driven climate that prevails in today's exploration industry ensures that companies are unlikely to explore for discoveries that they cannot expect to develop and produce in the short term.

Renewable Production Licence

Once the developer determines that the discovery is of commercial value (e.g., enough reserve of known certain value to warrant the expense of developing the discovery) and wishes to begin producing oil or gas, the company applies to the NEB for a declaration of commercial discovery area in relation to that discovery. On the basis of this declaration, and the approval of a development plan by the NEB (subject to Governor-in-Council consent) a Production Licence may be issued for a term of 25 years. The licence is renewable as long as production continues.

3.1.1.2 The Rights Issuance Process

The regime under the CPRA is simple, straightforward, competitive and profit-sensitive. The geographic focus of oil and gas exploration in the North consists of a two-step approach:

- a call for nominations, followed by
- a call for bids.

Canada does not currently have an "open-door" approach to issuing oil and gas rights. Instead, the Minister invites Industry to nominate blocks within a larger region following consultation with northern Aboriginal organizations and other stakeholders. Nominations within this region are accepted within the limited period that the Call for Nominations is open. Government recognizes that Issuance of Calls on a regular and consistent basis would increase the certainty for companies working in the North and reduce one source of fluctuation in the levels of exploratory activity.

Call for Nominations

Calls for nominations, although not required by law, are generally issued for periods ranging from one to three months. This gives industry the opportunity to identify blocks of land it would like to see posted for bidding. All nominations received through this process are given full consideration for inclusion in a succeeding call for bids. There is a maximum size limit for blocks tailored to the exploration maturity (i.e., how much exploration and development activity is already occurring in the area) of the region of the Call. Block size, and the term of the Exploration Licence, are designed to allow for the mounting of a comprehensive exploration program (i.e., seismic exploration) with the potential to identify a choice of drilling targets with the Exploration Licence. Overlapping nominations are dealt with on a first come-first served basis.

Call for Bids

A call for bids on exploration rights to specific blocks is required by legislation before Crown acreage may be released for oil and gas exploration. The outcome of a successful call for bids is the issuance of

Exploration Licences to the successful bidders on each block. Legislation requires that a call for bids remains open for a minimum of 120 days.

Each call states the requirements to be met for acceptance of a bid, the terms and conditions to be contained in the licence, a sample Bid Submission Form and attachments related to benefits requirements and relevant land claim provisions. Upon closing of the call for bids, all bids received are assessed against the single bidding criterion required by legislation. This is typically the value of the work proposal but may be cash, or some other criterion as stated in the Call. The highest bid wins. In the case of a work proposal bid, an Exploration Licence is awarded once the winning bidder has posted a work deposit equivalent to 25% of the bid amount submitted and provided the issuance fee of $250 per grid.

3.1.1.3 The Regulatory Instruments

The CPRA provides three forms of licences:

- the Exploration Licence - term of nine years maximum;
- the Significant Discovery Licence - indefinite term; and
- the Production Licence - renewable term of 25 years.

In order to operate on lands covered under these licences, Land Use Permits, and possibly Water Licences and other regulatory approvals, would be required.

a) Exploration Licence

An Exploration Licence confers certain rights relating to oil and gas exploration on the lands to which the licence applies over the term of the licence. An Exploration Licence allows for:

- the right to exploration for and the exclusive right to drill and test for petroleum;
- an exclusive right to develop the lands for petroleum production; and
- the exclusive right to obtain a Production Licence.

It is worth noting that surface exploration for oil and gas, (i.e., by seismic methods, geological investigation or remote sensing) are not exclusive rights. These activities may be pursued without an Exploration Licence subject to operators obtaining the appropriate approvals (i.e., requiring a Land Use Permit).

An Exploration Licence may be issued for a maximum term of nine years. The term of the Exploration Licence is usually divided into two periods, which may vary in length depending upon their location. For example, the term of nine years divided into two periods of six and three years may be appropriate in the remote north or deep offshore. A term of seven years divided into two periods of four and three years may be applicable in the southern territories. The length of the first period recognizes the time necessary to undertake an exploration program culminating in the drilling of a well. In regions where operating seasons are curtailed by ice movement, access across sensitive terrain, or other environmental factors, the first period of the licence will be longer.

Period 1 of the Term

The drilling of a well in Period 1 qualifies the licence holder to retain the licence for Period 2 of the term. Any work or activity undertaken during Period 1 is credited against the work deposit and refunded in accordance with the schedule of allowable expenditures, which forms part of the licence. Since the work deposit is only 25% of the work proposal bid, approved expenditures are credited at the rate of $1 for every $4 spent.

Period 2 of the Term

Escalating rentals on a per hectare basis are applicable during Period 2 of the term. Rentals are required in full at the beginning of each year in Period 2 and are fully refundable as allowable expenditures are incurred.

b) Significant Discovery Licence

When exploration results in a petroleum discovery, the legislation provides that an application may be made for a Declaration of Significant Discovery. The significant discovery declaration by the NEB defines the area extent of the discovery and is required prior to application for a Significant Discovery Licence (or Licences) covering the extent of the discovery.

The declaration process, administered by the NEB, confirms a hydrocarbon discovery that satisfies specific technical criteria and describes the area over which the discovered resources extend. Current practice provides that Declarations of Significant Discovery are not restricted to substance or geological formation and include all oil and gas accumulations within the lands described from surface to basement (or bottom extent of the reservoir).

The rights conferred by the Significant Discovery Licence are identical to those provided by the Exploration Licence:

- the right to explore for and the exclusive right to drill and test for petroleum;
- the exclusive right to developing the lands for petroleum production; and
- the exclusive right to obtain a Production Licence.

The Significant Discovery Licence is a unique feature of the regime under the CPRA. It rewards successful exploration by providing indefinite tenure to the petroleum discovery as it relates to the Exploration Licence. No rentals are currently applied to Significant Discovery Licences.

The absence of a time limit reflects the common reality that a discovery may be of a size and in a location that makes it uneconomic to develop for the time being. This in turn allows the developer to decide when to initiate development and apply for a Production Licence, possibly as other discoveries are made in the region or new infrastructure is developed.

The Significant Discovery Licence replaces the Exploration Licence in relation to the significant discovery area.

c) Production Licence

Once the developer has determined the discovery can be commercially produced, the legislation provides that an application may be made for a Declaration of Commercial Discovery. The commercial discovery declaration defines the area extent of what is to be developed and is required prior to application for a Production Licence. The determination of a commercial discovery area is undertaken by NEB, and defines those lands which contain petroleum reserves in relation to a discovery that justify the investment of capital and effort to produce.

The rights conferred by the Production Licence in relation to the commercial discovery area are:

- the right to explore for and the exclusive right to drill and test for petroleum;
- the exclusive right to develop the lands for petroleum production;
- the exclusive right to produce petroleum from those lands; and
- title to the petroleum produced.

A Production Licence is issued for a term of 25 years. Extensions are automatic if commercial production is underway at the end of the term. If production has ceased, but it is possible that production might recommence at some time in the future, the licence qualifies for extension. The Production Licence replaces the Significant Discovery Licence in relation to the commercial discovery area.

3.1.1.4 Hydrocarbon Activity Overviews

From the proponents or developers perspective, certain activities are implicit and required to fulfil the terms and conditions of the above mentioned licences. These activities can be broadly described as exploration, development/production and transmission. The Development Scenarios prepared for this project reflect these stages. The following reviews are modelled after Petroleum Communication Foundation (1999).

Exploration Overview

The first step in defining hydrocarbon potential is the exploration phase. This can range from a geologist looking at the landscape, analyzing rock samples and drill cuttings, analyzing down hole geophysical well logs (along with geophysical contractors), and looking for clues to determine where likely hydrocarbon reserves may be found, to undertaking seismic programs and exploration drilling. Historical geological and seismic data collected from an area is also reanalyzed to determine where likely targets could be found.

Today in the Mackenzie Valley, the regions having a high likelihood of hydrocarbon potential, or that have historically demonstrated existing reserves continue to attract exploration activities. Seismic programs in an area can be conducted by seismic exploration companies on a speculative basis, in the hopes of finding potential reserves. If results are positive, this data may then be marketed or sold to exploration companies with the capabilities and resources to secure the necessary licences and permits, and to undertake an exploration drilling program. Companies that may already have known reserves in an area in order to identify additional reserves also conduct seismic programs.

Once hydrocarbon potentials have been identified, exploration drilling is the next step. This involves transporting a drill rig into the area, establishing drill locations, setting up the rig and completing the drilling. In the Mackenzie Valley, these activities are generally carried out during the winter when overland access is easier and can be completed with little environmental impact. An exploration drilling program in one winter season may involve drilling more than one well in an area, in order to make the best use of the drill rig and crew.

Throughout drilling, various information logs are kept that record such data as the type and thickness of the rock layers, and speed of penetration. Other down hole geophysical testing is also done once drilling is complete. If hydrocarbons are found, tests to determine the rate of flow, quality and potential quantity of the reservoir are conducted. If tests indicate the well is a dry hole, the hole is plugged, cemented and abandoned.

Development/Production Overview

This step involves preparing a well for production, then actually producing a reservoir. Preparing a well for production involves inserting and securing a production casing to line the total length of the well bore (essentially a steel pipe inserted and secured down hole and into the reservoir or production formation). At this stage, other infrastructure is required, such as pipeline gathering systems, storage facilities, safety equipment, etc. The transmission pipeline system to take the product to market is also being planned, constructed or tied-in at this stage. Once the appropriate licences and permits are in place and the supporting infrastructure has been built, the well can begin producing.

In order to conserve Canada’s hydrocarbon resources, government regulators generally require that a hydrocarbon reservoir be produced as fully and efficiently as possible. There are various techniques that have been developed over the years to accomplish this, including stimulating the formation by physical or chemical means, and drilling development wells in or adjacent to a proven reservoir to optimize recovery. It may take more than one well to recover the majority of hydrocarbons from a reservoir. With advanced technology, one drilling pad can facilitate the drilling of many wells by a technique known as directional drilling – which essentially sends many wellbores out into the reservoir at different angles (slanted or curved). Horizontal drilling techniques also allows for more of the reservoir to be contacted by the wellbore for extraction. These and other specialized techniques allow for more efficient recovery with reduced environmental impacts, as fewer drill pads are required.

Transmission Overview

To transport large quantities of hydrocarbons produced from a reservoir in an efficient manner, pipelines are the method of choice. Hydrocarbons extracted from geological formations are usually not a pure product, but contain byproducts that are either of no use to the petroleum industry or require refining to extract useful products. For example, natural gas containing hydrogen sulphide is known as sour gas. It tends to be acidic in nature and causes corrosion in the extraction and transmission equipment, and it is a poisonous gas to living organisms, requiring special handling techniques. Natural gas may also contain natural gas liquids, which need to be removed before shipping the gas to market.

These hydrocarbons and byproducts are usually sent to a refinery for processing to extract the many useful byproducts for consumption, and remove any waste. Some byproducts, such as natural gas liquids, can be removed in the field at or near the production site. In the case of natural gas liquids, they are sometimes re-injected into geological formations as a way of disposing of them.

3.2 Mackenzie Valley Oil and Gas Seismic Exploration Scenario

This exploration scenario is only an illustration of typical activities to assist in the identification and analysis of information gaps. To assist in achieving the goals and objectives of this project, a “What if” planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.2.1 Background

Seismic exploration in the oil and gas industry is one of the most common geophysical tools used to identify underground geological formations with potential oil and gas reserves. Seismic cross sections of the underground formations being investigated are generated from data collected using a series of sensors (geophones) laid out on the surface to capture reflected energy waves, generated from energy producing sources near or on the ground surface, from subsurface geological boundaries or interfaces. These geological boundaries or interfaces tend to be where density changes in the substrate occur (i.e., due to porosity, different rock layers, faults, the presence of oil or gas or other materials), and an energy wave is reflected back to the surface sensors. Information collected by these sensors is then compiled and analysed using a computer. A 2-dimensional (2-D; obtained by analysing data from a single line of surface sensors) or a 3-dimensional (3-D; obtained by analysing data collected from multiple intersecting lines of surface sensors) “seismic picture” of the underground geological formations is produced.

3.2.2 Seismic Exploration Methods

There are several standard methods for collecting seismic survey information that are used by industry today. The location of the seismic program and the ease of access to the area will generally determine the type of seismic survey equipment used. For the Mackenzie Valley, most geographic areas where seismic exploration is undertaken are located in remote wilderness areas, accessible generally only by helicopter or fixed wing aircraft. Conducting winter seismic surveys when fixed wing or helicopter access is not possible, ground access is used. Cut-lines of 4 to 6 metre widths are cleared and tracked vehicles are used for transporting drill rigs and crews. Many of the areas have had some seismic exploration work carried out in the past, usually employing access methods not acceptable by today's standards (i.e., 8 to 12 metre wide clear cut seismic lines). In order to maximize the use of the seismic information collected, most seismic exploration undertaken today use the 2-D or 3-D survey methods. The only technical difference between 2-D and 3-D seismic exploration methods is that multiple receiver lines are used for 3-D seismic, while only one receiver line is used for 2-D seismic.

Low impact seismic techniques are also possible, and have been used in the Mackenzie Valley successfully. However, this approach does require helicopter access to transport drill rigs between drill sites.

3.2.2.1 Low Impact 2-D and 3-D Seismic Exploration

Activities associated with 2-D and 3-D seismic exploration include (after MVEIRB 2000):

- hand clearing and selectively cutting 1.5 metres wide cut lines spaced several metres apart along a certain geographic heading in an area;
- bucking wood debris to small lengths and laying flat;
- removing any leaners (trees overhanging the cut line and those that may pose a hazard of falling);
- drilling seismic source points every 100 metres along a cut line;
- loading a set amount of dynamite charge in each seismic point hole (i.e., 20 to 25 kg), back filling each hole with drill cuttings, inserting a plastic hole plug to 1 metre depth, and top filling the hole with remaining drill cuttings;
- set-up geophones along the seismic cut-lines for the acquisition of the seismic data; and
- once the seismic charges are shot, the geophones would be removed, all dynamite cap wires would be removed or cut flush with ground level, and larger disturbed areas would generally be reclaimed.

3.2.2.2 Vibroseis

Vibroseis is a method that sends energy waves from a heavy, vibrating vehicle into the earth. These vehicles are equipped with a large pad that imparts a controlled vibration into the ground. Geophones collect the "vibrational" information that is reflected back off underlying geologic structures. The information is translated into electronic energy and processed into a 3D-graphic. Vibroseis is considered to be generally low impact.

3.2.2.3 Airguns

Airguns are used for seismic surveys in marine or freshwater conditions. Airguns, towed in an array behind a boat or in shallow waters may be laid out on the surface, produce seismic waves by rapidly expelling a bubble of compressed air into the water. Like vibroseis, the underlying geologic structures reflect back information that is collected and translated into electronic energy. This information is translated into a 3D-graphic.

3.2.3 Seismic Technology

The key component in acquiring accurate seismic data is to be able to correlate surface source point (seismic source points where dynamite charges are set) and receiver point (where geophones are set up) positions with subsurface structures identified in the seismic picture. Traditionally, seismic lines were clear-cut to enable the seismic survey crew to use theodolites and line-of-sight survey techniques to accurately establish these points. Once the seismic survey was completed, elaborate geometric calculations were done in order to obtain position co-ordinates, elevation profiles and generate maps of every seismic source and receiver point. Using a global positioning system (GPS) to keep track of surface source and receiver point positions has reduced the reliance on line-of-site seismic survey techniques; however, GPS performance is reduced (or even unusable) in mountainous terrain where satellite signals are blocked.

An inertial navigation system (INS - such as the Schlumberger-Geco Navpac), and a second generation position and orientation system for land survey (POS/LS – such as the Applanix system that combines inertial and GPS positioning) have been developed (Gillet *et al*. 2000; Pathfinder 2002). The Navpac and POS/LS systems have been used successfully for seismic surveys in the Mackenzie Valley and elsewhere. By using an INS or POS/LS for establishing seismic survey source and receiver point positions, and gathering all of the elevation and other data required for mapping, the need to clear-cut line-of-sight seismic survey lines is reduced. Instead, a walking trail is all that is required to establish the source and receiver point positions along a seismic line. A 4m x 4m clearing is still required for a heli-portable drill to be used to drill the source holes, and the helicopter landing pads every 2 km are also required. Equipment, such as the Navpac and POS/LS navigation and positioning systems make low impact seismic surveying possible and the resulting seismic picture more accurate. This technology can still be used very effectively with conventional line-of-sight clear-cut seismic programs.

3.2.4 Exploration Activities

The number of potential seismic exploration programs to be undertaken in each of the oil and gas development areas in the Mackenzie Valley over the next 5 to 15 years have been estimated, and range from one 1 to five 5 programs per year. These estimates were derived from information about the number of seismic programs that have been undertaken in each area in the past. Knowing what hydrocarbon reserves there are in each area and knowing how much seismic data coverage there is for each area, it was reasonable to suggest that there is a potential for a similar level of seismic exploration activity to continue. There may be circumstances that could arise that would affect the number of potential seismic programs undertaken in each area, such as whether or not regulatory approvals were obtained soon enough to undertake the programs, and the costs and benefits to companies to undertake seismic programs (influenced by hydrocarbon prices and demand).

In the Cameron Hills and Liard Plateau oil and gas development areas, the number of seismic exploration programs undertaken while the Deh Cho Process(an on-going land claims type negotiations between the federal/territorial governments and the First Nations of the region) is underway would be minimal with interim land withdrawal in place. Any seismic programs undertaken in these areas would not occur on withdrawn land.

3.2.5 Exploration Timeframe

Seismic exploration is an activity that is carried out in the very early stages of exploring for oil and gas. Typically a very large geographic area, in a region where known petroleum bearing geological formations are located and accessible, needs to be surveyed, using seismic exploration techniques, in order to find any potential oil and gas deposits. Once potential oil and gas bearing strata are identified, further data analysis and perhaps exploratory drilling takes place to prove reservoirs, delineate the field, and determine the commercial viability of the deposit. Many factors are considered, and many organizations (i.e., industry, regulators, land owners, communities) may be involved in the decision making process, before a determination to proceed with oil and gas production is ever taken. Put another way, a lot of seismic exploration activities may be undertaken in an area that may lead to only a few potential petroleum bearing geological formations being identified, which in turn may result in only a very few, or no commercially viable reserves being identified, or produced.

Once oil or gas production is started, in order to offset the high costs of conducting all of the necessary exploration and development activities to get to production (particularly in the remote Frontier Lands of the Mackenzie Valley), wherever possible additional viable oil and natural gas reserves are searched for in the area. Therefore, it is expected that on going seismic exploration activities would potentially be undertaken over the entire timeframe of 5 to 15 years in the identified oil and gas areas of the Mackenzie Valley. Some of the seismic exploration work undertaken may be going back and shooting 3-D seismic in areas where older and outdated seismic exploration work has been done in the past.

A seismic exploration program is typically the amount of seismic exploration work that can be accomplished in one winter season, under a Land Use Permit. A Land Use Permit will be valid for more than one year, and may support more than one seismic program. In most cases for seismic exploration, a Water Licence would not be required. These procedures and guidelines are generally terms and conditions attached to the required Land Use Permit.

3.2.6 Infrastructure

Infrastructure requirements for seismic exploration in the five identified development areas of the Mackenzie Valley may be low, as there is pre-existing infrastructure available for use. Where it is not available, infrastructure requirements would normally be minimal and may include:

- temporary camp facilities;
- helicopter landing pads;
- winter hanger facilities (portable/temporary); and
- equipment storage and maintenance.

The majority of seismic exploration would likely take place in the winter season to reduce environmental impacts and for improved access.

3.2.7 Staging Requirements

Seismic exploration staging requirements are generally minimal compared to other stages of oil and gas exploration and development. Camp and other infrastructure requirements would likely be transported (i.e., by truck, barge, winter road) to a near by community or other industrial staging area. Once the winter seismic exploration season begins, the infrastructure would be transported to a centralized staging area for the planned seismic program.

Other major staging requirements may include:

- camp accommodation;
- water use and disposal;
- helicopter pads, and possibly fixed wing landing strips;
- helicopter/fixed wing hanger/wintering facilities;
- equipment storage;
- equipment maintenance areas;
- regular supply delivery; and
- temporary supply storage.

Low impact seismic exploration undertaken with heli-portable drilling equipment would require the following staging requirements, for each seismic line:

- new heli-portable drill points would require a 4 metre x 4 metre pad every 100 metres along the seismic line, natural clearings would be used wherever possible;
- heli-pads every 2 kilometres (for safety reasons) require a 20 metre diameter pad, natural clearings would be used wherever possible; and
- transportation of drill rig, equipment, supplies and personnel by helicopter to and within seismic exploration program area.

Conventional ground based seismic exploration would require the following staging requirements for each seismic line:

- staging area access to seismic exploration area, generally by winter road;
- tracked vehicle to clear seismic line and transport drill rig; and
- survey equipment, supplies and personnel.

These conventional seismic survey programs may also have helicopter support for personnel transport and emergency response.

3.2.8 Resource Requirements

The resource requirements for a seismic exploration program would include:

- temporary camp facilities;
- personnel hired from local communities, northern communities and the south;
- logistical requirements arranged internally or through local/northern suppliers;
- equipment supplied by seismic exploration company (internally); and

Waste generation and disposal regulated through Land Use Permit.

3.3 Cameron Hills Oil and Gas Development Scenario

This development scenario is only a potential estimate of typical activities to assist in the identification and analysis of information gaps. To assist in achieving the goals and objectives of this project, a "What if" planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.3.1 Background

This development area extends roughly from the Hay River west to approximately 119° 30' W longitude (to the eastside of the Trout Lake oil and gas development area). The majority of oil and gas activity is centred between 117° 00' W and 118° 00' W longitude and 60° 00' N and 60° 20' N latitude.

This area is contained in the greater geological formation known as the Western Canada Sedimentary Basin, where it extends from the Mackenzie Mountains and Rocky Mountain foothills in the west (where the average depth to target is around 4,500 metres) and shallows out to the east (where the average depth to target is around 700 metres), ending east of the Cameron Hills area where the Canadian Shield begins. Activity in this area is an extension of the more intense activity occurring in adjacent areas in northern Alberta. Although oil and gas exploration occurred as early as the 1920s, it was not until the mid-1940s that exploration activity increased, and the mid-1960s that drilling activity increased. However, exploration has only continued at a relatively low to moderate level since then, with renewed interest in the area in the late 1990s and into the 2000s with the discovery and production of oil and gas reserves.

3.3.2 Existing Resources

There are 11 Significant Discovery Licences (10 gas, 1 oil/gas) and nine Production Licences (2 oil, 7 gas)held in the area (DIAND 2002a). There are currently nine wells in production, of which five are producing natural gas (sour 1.7% H_2S) and four have been completed for oil. Oil or gas is gathered and is or will be piped to facilities in northern Alberta.

3.3.3 Exploration Potential/Land Access

On-going oil and gas exploration may occur to augment existing resources in the Cameron Hills area. Seismic exploration may be a combination of 2-D and 3-D programs to support on-going drilling exploration programs. It is important to note that this area is part of the Deh Cho region of the NWT, which is subject to the Deh Cho Process. Much of the Deh Cho Region has now been subject to interim land withdrawal (April 2003, http://www.ainc-inac.gc.ca/nt/dehcho/images/map-withdrawal_e.jpg) until the Deh Cho Process is completed. The issuance of exploration rights is prohibited through the *Interim Measures Agreement* for the next 5 years. Withdrawals are, however, unlikely to affect a strip of land adjacent to the 60th parallel. This land extends up to about 60°15’ N, an area which includes the existing rights issuance at Cameron Hills, and much of the land in the vicinity of Fort Liard and certain other areas to be defined within the traditional lands of other Deh Cho communities. Any exploration that does occur here would be based on the premise that an exploration cycle, consisting of lands being offered for nomination, etc., would happen.

Based on the past level of seismic exploration activity in this area, there could potentially be up to five seismic programs applied for each year. With interim land withdrawals in place while the Deh Cho Process is underway there would potentially be fewer seismic programs applied for each year than previously. Exploration drilling that might potentially occur in this area as a result of these seismic programs could be up to four wells per year, and potentially one to two with interim land withdrawal.

3.3.4 Development Potential

3.3.4.1 Type

The area contains natural gas (sweet and sour) and some oil reserves that tend to be contained in relatively small, shallow pools at around 1,200 to 1,800 metres below surface.

3.3.4.2 Development Timeframe

Within 5 to 15 years, it is expected that the producing field may be decommissioned and abandoned.

3.3.4.3 Reserves

It is expected that approximately 17 natural gas production and delineation wells will be drilled on known existing licences. New oil production is not anticipated based on current understanding of the field; however, oil resources in the field are currently being developed and will be produced and piped into Alberta. New exploration under any new Exploration Licences that may be issued in the future could lead to further oil or natural gas discoveries and additional production wells.

Based on the results of the potential exploration activities noted above, and on interim land withdrawals occurring, the number of potential production and delineation wells could range from 3 to 6 wells primarily natural gas production) over the next 5 to 15 years.

3.3.4.4 Project Development Requirements

This area already has infrastructure and access in place to support the existing production wells.

New wells may require separate site access to the existing infrastructure only, including:

- production pads;
- processing facilities;
- access roads;
- gathering pipeline systems;
- tie-in to existing processing systems and transmission pipeline; and
- temporary construction facilities.

A general description of these possible requirements is found in Table 3 and is based on the potential for 20 to 23 production and delineation wells being drilled over the 5 to 15 year timeframe. The information in this table was prepared from analyzing similar information from various sources related to gas development wells and associated infrastructure. These sources were primarily: various Deck presentations of the Mackenzie Gas Producers; Our Petroleum Challenge, 6th edition; and personal communication with representatives from Imperial Oil and DIAND.

Table 3. Cameron Hills Project Development Requirements

Requirement	Description	Note
Production Pads	• 1 to 3 pads per field[6] • typically covering 2 to 6 ha • 1 to 2.5 metres thick gravel pad • on-site or remote sumps • 20 to 69[7] production pads in total	The size of the reservoir will generally dictate how many production pads are required. Typically, the field is produced from as few locations as possible, using directional drilling techniques where feasible.
Facilities (possible facilities depending on reserves developed)	Gas wells (sour and sweet): • flare stack; • solution gas gathering for processing/use off-site, or on-site; • re-injection on, or off site (if required to maintain reservoir pressure);	Additional processing of gas may occur at existing facilities located in the area or off-site in Alberta.

[6] Field – the geographical area encompassing a group of one or more underground petroleum pools sharing the same or related infrastructure. (Source: Petroleum Communication Foundation, 1999. Our Petroleum Challenge, 6th Edition. Produced by the Petroleum Communication Foundation, Calgary, AB.)

[7] Based on 1 to 3 pads per field and 20 to 23 production and directional wells being drilled, the minimum and maximum number of wells estimated would be: minimum 1 x 20 = 20, maximum 3 x 23 = 69.

Requirement	Description	Note
	• NGLs separation and collection, or ship with gas to processing facility • Compression facility to maintain pipeline pressure and reservoir pressure if required Oil wells: • Gathering system • Pumping station • Separate oil pipeline	
Access Roads	Access roads to each new well location from existing road infrastructure in area. Requirements: • Gravel/borrow material • Water crossings/culverts • 20 to 69 (see footnote 7) access roads required	Access roads already exist in the area to service existing facilities. New wells would require access for the rig components and for on-going access during production. Only winter access is available into the area. Permanent access not required to maintain sites.
Gathering Pipeline Systems	In-field gathering system: • Buried pipelines from each of 20 to 69 production sites • Typically small to medium diameter pipe (4 to 8 inches) • For each gathering pipeline, a permanent right-of-way (ROW) of up to 20 metres width • For each gathering pipeline, a temporary construction workspace is required	Anticipate winter construction of pipeline gathering systems.
Tie-in to Existing Facilities	Each pipeline gathering system to tie-in to existing transmission pipeline or to processing facilities in the area. Pipeline tie-in to occur at a compressor facility, or to have a pressure equalization system to equalize the pressure between the field gathering system and the	Gathering systems to be single pipeline systems that transport both gas and NGLs, or separate systems for gas and NGLs..

Requirement	Description	Note
	transmission pipeline.	
Temporary Construction Facilities	• Staging area for each well site, or use central existing staging area • Temporary construction workspace for gathering pipeline systems • Temporary construction infrastructure for stream crossings by gathering system and/or pipeline • New or existing borrow pits • Construction crew temporary accommodation, on or off site • Water source for hydrostatic testing of pipelines	Facilities may be used during decommissioning and abandonment of existing production wells

3.3.4.5 Staging Requirements

Construction materials, equipment and supplies would likely be transported from southern manufacturing points on pre-existing road networks. Construction would likely be undertaken during the winter season, with materials and supplies delivered prior to construction start-up.
Personnel transport may be staged from Hay River, or flown in to the construction site from a southern location.

Other major staging requirements may include:

- camp accommodation;
- water use and disposal;
- helicopter pads, and possibly fixed wing landing strips (one required and constructed);
- equipment storage (located at processing site);
- equipment maintenance areas (located at processing site);
- regular supply delivery; and
- temporary supply storage.

3.3.4.6 Resource Requirements

The resource requirements for the Cameron Hills development scenario may include:

- gravel resources for construction and on-going maintenance would be acquired from (assumed) existing or new gravel quarries;
- personnel hired from local communities, northern communities and the south;

- logistical requirements arranged internally or through local suppliers;
- equipment supplied through sub-contractors and delivered to site;
- supplies and materials are provided by third party sources, and transported to site;
- water use and disposal (above a certain amount) is arranged through regulatory requirements; and
- waste generation and disposal is regulated.

3.4 Liard Plateau Oil and Gas Development Scenario

This development scenario is only a potential estimate of typical activities to assist in the identification and analysis of information and research gaps. To assist in achieving the goals and objectives of this project, a “What if” planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.4.1 Background

This development area extends from the Trout Lake development area west to the Yukon/NWT border. The majority of oil and gas activities are occurring between approximately 122° 30’ W longitude and the Yukon/NWT border, and 60° 00’ N and 60° 45’ N latitude.

This area is contained in the greater geological formation known as the Western Canada Sedimentary Basin. It extends from the Mackenzie Mountains and Rocky Mountain foothills in the west (where the average depth to target is around 4,500 metres) and shallows out to the east (where the average depth to target is around 700 metres) ending east of the Cameron Hills area where the Canadian Shield begins. Activity in the Liard Plateau area is an extension of the more intense activity occurring in adjacent areas in northeastern British Columbia. Increased drilling activities in the mid-1960s lead to the discovery and eventual development of the Pointed Mountain natural gas field in the southwest corner of the Mackenzie Valley. This field was first produced in 1972, and is now in the last stages of production achieving a cumulative production total, to the end of 1993, of 8.6 x E9 m^3 (303 billion cubic feet (bcf)) of an estimated pool reserve of 10.2 x E9 m^3 (360 bcf) (Morrell 1995).

3.4.2 Existing Resources

On the west side of the Liard Plateau, the Pointed Mountain natural gas field has been producing natural gas (mildly sour and acid: ~0.44% H_2S; ~10% CO_2) since the 1970s. A gas pipeline is used to ship product south to processing facilities in northern British Columbia. In the early 2000s to the west of the Liard River and north of the community of Fort Liard, four sour natural gas (Devonian) wells and a re-injection well were developed, with a common natural gas transmission pipeline connecting to the Pointed Mountain natural gas transmission line. South of the community of Fort Liard two natural gas fields have begun producing, with a product transmission line running to the Maxhamish Gas Plant in northern British Columbia.

There are currently 10 Significant Discovery Licences (9 gas, 1 unknown) and six Production Licences (all gas) in the area (DIAND 2002b). Five fields have been produced, and three of these are currently still producing. Five existing discoveries remain undeveloped, and exploration continues. The Pointed Mountain production field is largely depleted and currently shut-in.

3.4.3 Exploration Potential/Land Access

On-going oil and gas exploration will occur to augment existing resources in the Liard Plateau area. Seismic exploration would be a combination of 2-D and 3-D programs to support on-going drilling exploration programs. It is important to note that this area is part of the Deh Cho region of the NWT, which is subject to the Deh Cho Process – an on-going land claims type negotiations between the federal/territorial governments and the First Nations of the region. Much of the Deh Cho region may be subject to interim land withdrawal until the Deh Cho Process is completed. The issuance of exploration rights would be prohibited on withdrawn lands until the Deh Cho Process is completed. Any exploration that does occur here would be based on the premise that an exploration cycle, consisting of lands being offered for nomination, etc., would happen.

Based on the past level of seismic exploration activity in this area, there could potentially be up to five seismic programs applied for each year. With interim land withdrawals in place while the Deh Cho Process is underway there would potentially be fewer (e.g., 1 to 2) seismic programs applied for each year. Exploration drilling that might potentially occur in this area as a result of these seismic programs could be up to four wells per year, and potentially one to two with interim land withdrawal.

3.4.4 Development Potential

3.4.4.1 Type

The area contains both sweet and sour natural gas (sweet from shallow plain reservoirs and sour from deeper Devonian (i.e., geological reservoirs) reserves.

3.4.4.2 Development Timeframe

Within 5 to 15 years it is expected that several of the currently producing wells would be decommissioned and abandoned.

3.4.4.3 Reserves

It is expected that approximately two new natural gas production and delineation wells will be drilled based on known existing reserves.

Based on the results of the potential exploration activities noted above, and whether or not interim land withdrawals occur, the number of potential production and delineation wells could range from three to six wells (primarily natural gas production) over the next 5 to 15 years.

3.4.4.4 Project Development Requirements

The development area is spread out and quite large, and while some locations already have infrastructure and access in place to support the existing production wells, other areas would likely need new infrastructure.

New wells may require:

- production pads;
- processing facilities;
- access roads;
- gathering pipeline systems;
- tie-in to existing processing systems and transmission pipeline; and
- temporary construction facilities.

The general description of these requirements is found in Table 4. The information in this table was prepared from analyzing similar information from various sources related to gas development wells and associated infrastructure. These sources were primarily: various Deck presentations of the Mackenzie Gas Producers; Our Petroleum Challenge, 6th edition; and personal communication with representatives from Imperial Oil and DIAND.

Table 4. Liard Plateau Project Development Requirements

Requirement	Description	Note
Production Pads	• 1 to 3 pads per field • typically covering 2 to 6 ha • 1 to 2.5 metres thick gravel pad • on-site or remote sumps • 3 to 18[8] production pads in total	The size of the reservoir will generally dictate how many production pads are required. Typically, the field is produced from as few locations as possible, using directional drilling techniques where feasible.
Facilities (possible facilities)	Gas wells (sour and sweet): • flare stack • solution gas gathering for processing off-site, or on-site • re-injection on, or off site (if required, and to maintain reservoir pressure where required) • NGLs separation and collection, or ship with gas to processing facility	Additional processing of gas may occur at existing facilities located in the area or off-site in British Columbia.

[8] Based on predicted 3 to 6 wells over timeframe, and 1 to 3 production pads per field. The minimum and maximum number of wells estimated would be: minimum 3 x 1 = 3; maximum 6 x 3 = 18.

Requirement	Description	Note
	• Compression facility to maintain pipeline and reservoir pressure if required pressure	
Access Roads	Access roads to each new well location from existing road infrastructure in area. Requirements: • Gravel/borrow material • Water crossings/culverts • 3 to 18 access roads required	Access roads already exist in parts of the area to service existing facilities. New wells would require access for the rig components and for on-going access during production, and in some cases completely new access.
Gathering Pipeline Systems	In-field gathering system: • Buried pipelines from each of 3 to 18 production sites • Typically small to medium diameter pipe (4 to 8 inches) • For each gathering pipeline, a permanent ROW of around 20 metres width • For each gathering pipeline, a temporary 20 to 50 metre width construction ROW	Anticipate winter construction of pipeline gathering systems.
Tie-in to Existing Facilities	Each pipeline gathering system to tie-in to a new transmission pipeline that will tie-in to an existing transmission pipeline (if existing, or a new line). Pipeline tie-in to occur at a compressor facility, or to have a pressure equalization system to equalize the pressure between the field gathering system and the transmission pipeline.	Gathering systems to be single pipeline systems that transport both gas and NGLs, or separate systems for gas and NGLs..
Temporary Construction Facilities	• Staging area for each well site, or use central existing staging area • Temporary construction workspace for gathering pipeline systems • Temporary construction infrastructure for stream crossings by gathering system and/or pipeline • New or existing borrow pits • Construction crew temporary accommodation, on or off site • Water source for hydrostatic testing of pipelines	Facilities may be used during decommissioning and abandonment of existing production wells

3.4.4.5 Staging Requirements:

Construction materials, equipment and supplies would likely be transported from southern manufacturing points on existing road networks. Construction would likely be undertaken during the winter season, with materials and supplies delivered prior to construction start-up.

Personnel transport may be staged from Fort Liard, or flown in to the construction site from other northern or from southern locations.

Other major staging requirements may include:
- camp accommodation;
- water use and disposal;
- helicopter pads, and possibly fixed wing landing strips;
- equipment storage;
- equipment maintenance areas;
- regular supply delivery; and
- temporary supply storage.

3.4.4.6 Resource Requirements:

The resource requirements for the Liard Plateau development scenario may include:
- gravel resources for construction and on-going maintenance would be acquired from (assumed) existing or new gravel quarries;
- personnel hired from local communities, northern communities and the south;
- logistical requirements arranged internally or through local suppliers;
- equipment supplied through sub-contractors and delivered to site;
- supplies and materials are provided by third party sources, and transported to site;
- water use and disposal is arranged through regulatory requirements; and
- waste generation and disposal is regulated.

3.5 Norman Wells (Central Mackenzie Valley) Oil and Gas Development Scenario

This development scenario is only a potential estimate of typical activities to assist in the identification and analysis of information and research gaps. To assist in achieving the goals and objectives of this project, a “What if” planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.5.1 Background

The Norman Wells development area is located in the central Mackenzie Valley region, and includes oil and gas activities occurring in the approximate area from the confluence of the Mountain and Mackenzie Rivers south and east along the Mackenzie River to 64° N latitude by 124° W longitude. Activities are occurring on lands east and west of the Mackenzie River in this area.

Oil seeps have been known to exist in this area of the Mackenzie River since the mid-1700s. Little of this material was utilized, and interest in the area did not increase until the early 1900s when the search for oil really began in Canada. This area was originally developed as a producing field in the 1940s with small volumes of oil exported by the Canol pipeline to Whitehorse. Subsequent production was very limited until the mid-1980s with the construction of the Norman Wells to Zama (Alberta) 12 inch (305 mm) oil pipeline and a major expansion of the field occurred. Today, there is a central processing facility located within the townsite of Norman Wells, with over 165 production wells, and 156 water injection wells maintaining reservoir pressure. Production for Norman Wells was 1.79 x E6 m^3 (11.3 million barrels) in 1993, with cumulative production of approximately 16 x E6 m^3 (100 million barrels). About 43% of the estimated total reserves of oil are expected to be recovered; however, the operator is continuing to look for new ways to maximize the recovery of oil before production stops (Morrell 1995).

3.5.2 Existing Resources

The Norman Wells oil field development has been operating since the mid-1980s when the oil fields were expanded and oil was shipped south through the newly constructed Norman Wells to Zama pipeline. Infrastructure includes an 860 km long, 305 mm diameter oil pipeline to northern Alberta, three pumping stations, six artificial island production wells in the Mackenzie River (Deh Cho Island, Ekwe Island, Itel-ke Island, Little Bear Island, Rayuka Island, Rampart Island), use of two natural island (Goose and Bear Islands) for production activities, several land based production wells, and associated equipment, offices and personnel. Approximately 4,800 m^3 (30,000 barrels) of oil are piped through the pipeline each day. Spare capacity does currently exist in the line, which will increase over the next decade as production from the field declines (Morrell 1995).

3.5.3 Exploration Potential/Land Access

The Norman Wells oil field has been extensively defined through many years of seismic, exploration and production drilling. As oil field production begins to decline, new exploration drilling will likely occur to try and maximize the amount of oil recovered from the field. There remain opportunities to discover oil pools along the up-dip edges of the field geological structure and within the complex structure of the geological formation (Morrell 1995), and north and south of the field within the central Mackenzie Valley region.

Other exploration activity is occurring within the area (not directly associated with the Norman Wells oil field), searching for viable hydrocarbon deposits. There are approximately 10 ELs in the area (DIAND

2002c). The exploration potential for the central Mackenzie Valley area is estimated at potentially up to three seismic programs per year, and potentially two exploration wells per year (until 2010). Seismic exploration programs would likely be predominately 2-D.

3.5.4 Development Potential

3.5.4.1 Type

The area contains primarily crude oil reserves at Norman Wells. There is significant potential for further discoveries of oil and possibly natural gas in the greater region.

3.5.4.2 Development Timeframe

Within 5 to 15 years, it is expected that several of the currently producing well's will be brought to completion, decommissioned and abandoned.

The Norman Wells production field is likely to be depleted by approximately 2020 at which time decommissioning and abandonment of field facilities will commence. Additional finds of oil and natural gas reserves, and/or natural gas related processing facilities may serve to keep certain facilities in operation.

3.5.4.3 Reserves

It is expected that approximately four production and delineation oil wells will be drilled based on known existing reserves associated with the Norman Wells field. Natural gas production wells are not anticipated in this area.

Based on the results of the potential exploration activities noted above, approximately two production and delineation oil wells are anticipated over the next 5 to 15 years. With the development of a potential natural gas pipeline down the Mackenzie Valley, exploration activities would likely increase, which may result in the discovery of additional natural gas reserves, and potentially more natural gas production wells. This could potentially result in two additional development wells being drilled in the area.

3.5.4.4 Project Development Requirements

Exploration and development activities in this area are concentrated around the Norman Wells oil field, then spreading north and south along both sides of the Mackenzie River. In the Norman Wells area, there is existing infrastructure and access in place to support existing and any new production wells. Areas north and south of Norman Wells may require new infrastructure.

New wells may require:

- production pads;
- processing facilities;

- access roads;
- gathering pipeline systems;
- tie-in to existing processing systems and transmission pipeline; and
- temporary construction facilities.

The general description of these requirements is found in Table 5. The information in this table was prepared from analyzing similar information from various sources related to gas development wells and associated infrastructure. These sources were primarily: various Deck presentations of the Mackenzie Gas Producers; Our Petroleum Challenge, 6th edition; and personal communication with representatives from Imperial Oil and DIAND.

Table 5. Norman Wells Project Development Requirements

Requirement	Description	Note
Production Pads	• 1 to 3 pads per field • typically covering 2 to 6 ha • 1 to 2.5 metres thick gravel pad • on-site or remote sumps • 6 to 18[9] production pads in total	The size of the reservoir will generally dictate how many production pads are required. Typically, the field is produced from as few locations as possible, using directional drilling techniques where feasible.
Facilities	Gas wells if discovered: • flare stack • solution gas gathering for processing off-site, or on-site • re-injection on, or off site (if required and to maintain reservoir pressure if required) • NGLs separation and collection, or ship with gas to processing facility • Compression facility to maintain pipeline pressure and reservoir pressure if required Oil • Oil wells may link into existing capacity and facilities.	Anticipate oil to be the primary product being produced.
Access Roads	Access roads to each new well location from existing road infrastructure in area. Requirements:	Access roads already exist in parts of the area to service existing facilities. New wells would

[9] Based on 1 to 3 pads per field and 6 production and delineation wells being drilled, the minimum and maximum number of wells would be: minimum 6 x 1 = 6; maximum 6 x 3 = 18.

Requirement	Description	Note
	• Gravel/borrow material • Water crossings/culverts • 6 to 18 access roads required	require access for the rig components and for on-going access during production, and in some cases completely new access.
Gathering Pipeline Systems	In-field gathering system: • Buried pipelines from each from each of 6 to 18 production sites • Typically small to medium diameter pipe (4 to 8 inches) • For each gathering pipeline, a permanent ROW of up to 20 metres width • For each gathering pipeline, a temporary construction ROW	Anticipate winter construction of pipeline gathering systems.
Tie-in to Existing Facilities	Each pipeline gathering system to tie-in to a new transmission pipeline that would tie-in to an existing transmission pipeline, if available. Pipeline tie-in to occur at a compressor facility, or to have a pressure equalization system to equalize the pressure between field gathering systems and the transmission pipeline.	Gathering systems to be single pipeline systems that transport both gas and NGLs, or separate systems for gas and NGLs. Separate oil gathering systems as required.
Temporary Construction Facilities	• Staging area for each well site, or use central staging area • Temporary construction workspace for gathering pipeline systems • Temporary construction infrastructure for stream crossings by gathering system and/or pipeline. • New or existing borrow pits • Construction crew temporary accommodation, on or off site • Water source for hydrostatic testing of pipelines	Facilities may be used during decommissioning and abandonment of existing production wells

3.5.4.5 Staging Requirements

Construction materials, equipment and supplies may be transported from southern manufacturing points on existing road networks. Construction would likely be undertaken during the winter season, with materials and supplies delivered prior to construction start-up.

Personnel transport may be staged from Norman Wells, or flown in to construction site from other northern or from southern locations.

Other major staging requirements include:

- camp accommodation;
- water use and disposal;
- helicopter pads, and possibly fixed wing landing strips;
- equipment storage;
- equipment maintenance areas;
- regular supply delivery; and
- temporary supply storage.

3.5.4.6 Resource Requirements

The resource requirements for the Norman Wells development scenario may include:

- gravel resources for on-going maintenance would be acquired from existing or new gravel quarries;
- personnel hired from local communities, northern communities and the south;
- logistical requirements arranged internally or through local suppliers;
- equipment supplied through sub-contractors and delivered to site;
- supplies and materials are provided by third party sources, and transported to site;
- water use and disposal is arranged through regulatory requirements; and
- waste generation and disposal is regulated.

3.6 Colville Hills Oil and Gas Development Scenario

This development scenario is only a potential estimate of typical activities to assist in the identification and analysis of information and research gaps. To assist in achieving the goals and objectives of this project, a “What if” planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.6.1 Background

Activities in the Colville Hills development area are located approximately between 125° W and 127° W longitude and from the community of Colville Lake south to approximately 66° N latitude. There is also exploration activity occurring in a large area east of Colville Lake.

This is a large and sparsely explored area. Some exploration activities have been underway since at least the early 1970s when the first natural gas discovery was made at Tedji Lake. Following the resumption of issuance of Exploration Licences in the early 1980s, exploration activities have increased in the area resulting in several more natural gas discoveries. Oil seeps are common in the area, though no oil reserves have been discovered.

3.6.2 Existing Resources

There are no production wells located in this area; however, exploration activities have been on-going for sometime. Five exploration wells were drilled in 2001 in the area. There are currently four Significant Discovery Licences (all gas) and two Exploration Licences in the area (DIAND 2002c). There is potential for further discoveries to be made on Sahtu private lands.

3.6.3 Exploration Potential/Land Access

Of the three Significant Discovery Licences, Tweed Lake contains sweet dry gas, Tedji Lake and Bele contain substantial condensate reserves in addition to natural gas. Oil source rocks are present and may contribute light oil or condensate to the largely natural gas accumulations. The potential for small to medium sized oil pools in undrilled structures appears high (Morrell 1995). It should be noted that the natural gas and oil potential in this area has not been proven.

The exploration potential for this area could see up to three seismic exploration programs per year, up to two exploration wells per year (until 2010). Seismic exploration programs would likely be predominately 2-D.

The likelihood of a Mackenzie Valley natural gas pipeline in the near future would likely increase the amount of exploration activity. The three Significant Discovery Licences in the area would be prime candidate locations for wells that could provide additional gas reserves to the pipeline.

3.6.4 Development Potential

3.6.4.1 Type

The area contains sweet gas reserves, and some light oil showings; however, no oil reserves have yet been found.

3.6.4.2 Development Timeframe

5 to 15 year timeframe

3.6.4.3 Reserves

It is expected that approximately three production and delineation sweet natural gas wells will be drilled based on known existing reserves. Oil production wells are not anticipated in this area at this time.

Based on the results of the potential exploration activities noted above, approximately seven production and delineation natural gas wells are anticipated over the next 5 to 15 years to properly produce the fields. With the development of the potential natural gas pipeline down the Mackenzie Valley, exploration activity will likely increase, resulting in potentially higher natural gas production wells.

3.6.4.4 Project Development Requirements

The areas for production well development are located immediately south of Colville Lake (two Significant Discovery Licences) and one south of Lac Belot, located south and west of Colville Lake. There does exist winter access into these areas. These access routes would likely be used for production access.

New production wells may require:

- production pads;
- processing facilities;
- access roads;
- gathering pipeline systems;
- tie-in to existing transmission pipeline; and
- temporary construction facilities.

The general description of these requirements is found in Table 6. The information in this table was prepared from analyzing similar information from various sources related to gas development wells and associated infrastructure. These sources were primarily: various Deck presentations of the Mackenzie Gas Producers; Our Petroleum Challenge, 6th edition; and personal communication with representatives from Imperial Oil and DIAND.

Table 6. Colville Hills Project Development Requirements

Requirement	Description	Note
Production Pads	• 1 to 3 pads per field • typically covering 2 to 6 ha • 1 to 2.5 metres thick gravel pad • on-site or remote sumps • 10 to 30[10] production pads in total	The size of the reservoir will generally dictate how many production pads are required. Typically, the field is produced from as few locations as possible, using directional drilling techniques where feasible.

[10] Based on 3 wells form known reserves and 7 anticipated from new reserves 7 + 3 = 10. Based on 1 to 3 wells per field the minimum and maximum number of wells would be minimum 10 x 1 = 10, maximum 10 x 3 = 30.

Requirement	Description	Note
Facilities	Gas wells (sweet): • flare stack • solution gas gathering for processing off-site, or on-site • re-injection on, or off site and to maintain reservoir pressure (if required) • NGLs separation and collection, or ship with gas to processing facility • Compression facility to maintain pipeline pressure and reservoir pressure if required	Anticipated that the three gas wells will be produced in the next 5 to 15-year timeframe, with an additional 7 based on known potential.
Access Roads	Access roads to each new well location would likely be required. Requirements: • Gravel/borrow material • Water crossings/culverts • Up to 30 access roads required	Winter access roads already exist in the area to access the exploration activities. New wells would require access for the rig components and for on-going access during production.
Gathering Pipeline Systems	In-field gathering system: • Buried pipelines from each 10 to 30 production sites • Typically small to medium diameter pipe (4 to 8 inches) • For each gathering pipeline, a permanent ROW of around 20 metres width For each gathering pipeline, a temporary 20 to 50 metre width construction ROW	Anticipate winter construction of pipeline gathering systems.
Tie-in to Existing Facilities	Each pipeline gathering system to tie-in to a new transmission pipeline which will tie-in to a potential Mackenzie Valley gas transmission pipeline. Pipeline tie-in to occur at a compressor facility, or to have a pressure equalization system to equalize the pressure between the gathering system and the transmission pipeline.	Gathering systems to be single pipeline systems that transport both gas and NGLs or separate systems for gas and NGLs.

Requirement	Description	Note
Temporary Construction Facilities	• Staging area for each well site • Temporary construction workspace for gathering pipeline systems • Temporary construction infrastructure for stream crossings by gathering system and/or pipeline • New or existing borrow pits • Construction crew temporary accommodation, on or off site • Water source for hydrostatic testing of pipelines.	Combined staging area may be feasible for the two SDLs immediately south of Colville Lake.

3.6.4.5 Staging Requirements

Construction materials, equipment and supplies would be transported from southern manufacturing points on existing transportation networks to Hay River. Materials would then be barged to a staging area on the Mackenzie River for likely winter transport to the sites. Construction would likely be undertaken during the winter season, with materials and supplies delivered prior to construction start-up.
Personnel transport would likely be staged from Colville Lake, or flown in to construction site from other northern or from southern locations.

Other major staging requirements include:
- camp accommodation;
- water use and disposal;
- helicopter pads, and possibly fixed wing landing strips;
- equipment storage;
- equipment maintenance areas;
- regular supply delivery; and
- temporary supply storage.

3.6.4.6 Resource Requirements

The resource requirements for the Colville Hills development scenario may include:
- gravel resources for construction and on-going maintenance would be acquired from (assumed) existing or new gravel quarries;
- personnel hired from local communities, northern communities and the south;
- logistical requirements arranged internally or through local suppliers;
- equipment supplied through sub-contractors and delivered to site;
- supplies and materials are provided by third party sources, and transported to site;
- water use and disposal is arranged through regulatory requirements; and
- waste generation and disposal is regulated.

3.7 Peel Plateau Oil and Gas Development Scenario

This development scenario is only a potential estimate of typical activities to assist in the identification and analysis of information and research gaps. To assist in achieving the goals and objectives of this project, a "What if" planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between these development scenarios and what actually happens is purely coincidental.

3.7.1 Background

The Peel Plateau/Plain development area is approximately located from the Mackenzie River south to 66° N latitude, and between 131° W longitude and the Yukon/NWT border.

Hydrocarbon exploration has been on-going in this area since the mid-1950s, with 52 wells having been drilled (including Peel Plateau).

3.7.2 Existing Resources

There are no production wells located in this area; however, exploration activities have been on-going, at a low level of activity, for sometime. There have been very few significant showings and no significant discoveries. Minor gas showings in old wells, but not associated with large pools (Morrell 1995). There are currently five ELs in the area (http://www.ainc-inac.gc.ca/oil/index_e.html).

3.7.3 Exploration Potential/Land Access

This area is remote and expensive to get equipment and crews into and out of. Exploration would potentially continue, though at a low level of around one seismic exploration program per year and up to one exploration well per year, usually bunched to maximize rig use.

3.7.4 Development Potential

3.7.4.1 Type

The area contains sweet gas.

3.7.4.2 Development Timeframe

5 to 15 year timeframe

3.7.4.3 Reserves

There are no developable reserves identified in this area. It is unlikely that there will be any potential reserves found within the next 5 to 15 years.

3.7.4.4 Project Development Requirements

There does exist winter access into the area. These access routes would likely be used for production access as required. As there is a very low potential for developing production wells in this area, no further scenario development for this area is required.

3.8 Generic Mackenzie Valley Gas Pipeline Development Scenario

This development scenario is only a potential estimate for illustrative purposes of a typical natural gas transmission pipeline and potential associated activities to assist in the identification and analysis of information and research gaps. To assist in achieving the goals and objectives of this project, a “What if” planning approach was followed to help ascertain the important research and biophysical information gaps. This scenario is not a complete project lifecycle description, and is not intended to reflect what might actually happen. Any similarity between this development scenario and what could potentially happen is purely coincidental.

3.8.1 Project

Generic Mackenzie Valley gas pipeline proposal. The scope of this development scenario is limited to the Mackenzie Valley, from Inuvik south to the NWT/Alberta border.

3.8.2 Objective

The transportation of Mackenzie Delta and possibly Prudhoe Bay, Alaska natural gas to southern markets. There is also built in capacity to allow other producers connection access.

3.8.3 Project Proposal Highlights

The generic Mackenzie Valley gas pipeline proposal is a concept project proposal[11]. There have been preliminary investigations into possible routing options, regulatory requirements, environmental considerations, and overall feasibility of such a project. Based on this information and that provided by experts (see References, Section 5), this concept project development scenario has been prepared.

The main project highlights are presented in Table 7.

---

[11] The development scenarios are not based on the Preliminary Information Package filed by proponents of the Mackenzie Gas Project with the NEB in June 2002 (the scenarios were developed prior to the filing of the Preliminary Information Package)

Table 7. Generic Mackenzie Valley Gas Pipeline Proposal Highlights (Mackenzie Gas Pipeline Producers 2002 a, b; and ArctiGas undated, 2001)

Highlight	Description	Note
Gas pipeline (buried) size and length.	Inuvik to Norman Wells (buried pipeline)	28 to 36 inch (711 to 914 mm) diameter ~300 miles (~480 km) length
	Norman Wells to border (Zama, Alberta) Buried pipeline	28 to 36 inch (711 to 914 mm) diameter ~500 mile (~800 km) length
Pipeline Capacities	Design base natural gas capacity (the capacity initially available to justify the project).	800 – 1,200 MCFD (23 – 30 million M3/day) One source indicated a preliminary design capacity of over 5 billion cubic feet/day based on a twin 36 inch (914 mm) pipeline system
Natural Gas Liquids (NGL) volume	The approximate volume of NGLs contained in the design base gas capacity. NGLs are co-mingled with natural gas from produced fields. Combined product is piped to Norman Wells/Inuvik where NGLs are stripped out then piped south in the existing Norman Wells to Zama pipeline, while the natural gas is piped through a new pipeline.	1,600 – 2,400 M3/day (10,000 – 15,000 barrels/day)
Block valves	Remote and emergency shut-off block valves will be required with a spread of 25 to 50 kilometres.	24 to 48 block valves
ROW	Pipeline ROW (approximate) width, including 25 yard (30 metre) buffer zones each side.	60 yard (~ 75 metres)
Compressor stations	Pipeline compressor stations required to maintain pressure of gas in pipeline, based on design base capacity.	4 (up to 16 additional locations planned if twin pipelines)
Liquid recovery station.	Processing facility for NGLs recovery at Norman Wells/Inuvik.	1 to 2
Water crossings	Many creeks, streams and rivers, as well as wetlands, are anticipated along the proposed route of a pipeline. Specialized engineering and construction techniques would be used for construction, depending on the nature of each crossing.	

3.8.4 Project Development Phases and Associated Timeframes

The following are the anticipated major project stages of a generic Mackenzie Valley gas pipeline proposal, with timeframe estimates and a list of some relevant activities associated with each stage.

Project Definition Stage: 3 to 5 years

- environmental field work;
- consultations;
- regulatory applications;
- binding open invitation to other gas developers to help determine final pipeline size/capacity; and
- final route selection.

Construction Stage: 3 to 7 years

- drill additional wells (Mackenzie delta);
- construct pipeline and field facilities over three winter seasons (anticipated);
- pipeline construction could begin at four different locations along route at same time;
- materials and supplies to be barged to staging areas, which will move as construction proceeds in each section; and
- trans-shipment point Hay River (anticipated).

Operation and Maintenance Stage: No Timeframe Provided

- environmental monitoring;
- regular/emergency maintenance;
- potential expansion (additional gas resources connecting into pipeline, with pressure adjustment equipment as required);
- gas processing at Norman Wells/Inuvik to remove natural gas liquids;
- NGLs to be transported south through existing pipeline owned by Enbridge Pipelines Inc. (Norman Wells to Zama) pipeline; and
- compressor station operation and maintenance.

Abandonment and Restoration (estimate) Stage: No Timeframe Provided

- facilities decommissioning and abandonment;
- pipeline to be abandoned in place (except at river/stream crossings); and
- environmental monitoring/follow-up monitoring.

3.8.5 Project Development Requirements

The construction stage of a generic Mackenzie Valley gas pipeline proposal would likely be undertaken in a phased approach:

- surveying the route location of the pipeline corridor;

- staging areas prepared and, materials and supplies transported to sites the summer before construction begins, then every summer until completion;
- develop sites for granular resources;
- clearing and levelling/preparation of the pipeline right-of-way (ROW) beginning at four locations;
- trenching;
- welding, hydro-testing and laying pipe;
- back-filling trench;
- installation of block valves and compressor stations where required;
- dry and wet crossings which may include directional drilling or open-cut methods for stream crossings; and
- reclamation/stabilization of the ROW.

The portion of the pipeline route from Norman Wells to the NWT/Alberta border would parallel the existing Norman Wells to Zama pipeline corridor. The remaining portion of the pipeline corridor from Norman Wells to Inuvik would be through new, undeveloped territory. As noted above, the NGLs stripped from the natural gas at Norman Wells/Inuvik would be piped south in the existing pipeline - a new pipeline to ship NGLs may not required

3.8.6 Staging Requirements

Pipeline construction materials may be transported from southern manufacturing points to the Hay River trans-shipment point, and then barged to staging areas in each section. Construction would be undertaken during the winter season, with materials and supplies delivered during the summer season.

Personnel transport may be staged from several central population centres with airport facilities and scheduled flights to other communities/southern locations as the project development proceeds down the Valley (such as Hay River, Yellowknife, Norman Wells and Inuvik).

Other major staging requirements may include:

- camp accommodation;
- water use and disposal;
- helicopter pads, fixed wing landing strips;
- equipment storage;
- equipment maintenance areas;
- regular supply delivery; and
- temporary supply storage.

3.8.7 Resource Requirements

The resource requirements for a generic Mackenzie Valley gas pipeline proposal may include:

- gravel resources for construction would be acquired from (assumed) adjacent gravel quarries;

- personnel hired from local communities, northern communities and the south;
- logistical requirements arranged internally or through local suppliers;
- equipment supplied through sub-contractors and delivered to site;
- supplies and materials are provided by third party sources, and shipped to site;
- water use and disposal is approved through regulatory requirements; and
- waste generation and disposal is regulated.

From information prepared for a potential Mackenzie Valley natural gas pipeline (single 914 mm (36 inch) pipeline scenario), for the portion of the pipeline from Inuvik to the Alberta border, some of the potential construction phase infrastructure requirements have been identified (Table 8).

Table 8. Construction Phase Infrastructure Requirements, Mackenzie Valley Natural Gas Pipeline (Colt Engineering 2001)

Infrastructure Requirement	Estimated Amount
Equipment Stock Pile Sites	14
Gravel Borrow Sites	85
River Landing Sites	19
Temporary Access Roads	35
Camps	13

Some of the borrow sites that have been identified may remain active during the life of the project.

4. Information and Research Gaps

This section describes the available background information for the biophysical environment contained within the study area (Figure 1) for this project, and outlines information and research gaps related to available baseline information and impact assessment. Section 3 describes development scenarios for five hydrocarbon development areas and potential pipeline extending north-south through the Mackenzie Valley. The scenarios were largely used in determining the wide range of potential impacts identified through the matrix exercise described in Section 2.4.1. This exercise along with Table 1 focused the efforts of the research team in determining information and research gaps related to impact predictions.

The requirement for cumulative effects assessments at the project-specific level was considered in developing the research and information gaps outlined in this section. The gaps outlined in Section 4.12 (Cumulative Effects Analysis), are focussed on the regional aspect of cumulative effects.

Appendix F provides a summary of the gaps identified in this section, and also provides a cross-reference to the *Action Plan* report.

4.1 Terrain/Surficial Geology

As presented in Section 2 the impacts of hydrocarbon development were summarized in a series of matrices (Appendix C). Project components and activities related to oil and gas field development and potential pipelines may affect or result in changes to:

- landform physical characteristics;
- landform delineation;
- permafrost distribution;
- drainage conditions;
- soil erosion and slope stability;
- soil compaction and settling;
- changes in soil depth and moisture content;
- groundwater flow;
- vegetation cover;
- animal migration; and
- frost susceptibility.

Terrain and surficial geology may also have an effect on the design of any project. Seismic activity, slope stability and drainage must all be accounted for in project design. The integrity of any facilities could be compromised by a failure to take into account the local physical conditions. This is where terrestrial and surficial geology baseline information is particularly important.

4.1.1 Baseline

Surficial or "surface" geology is the look and the make of the land through the description of the type, distribution and composition of land features. Presently, in the NWT land features or landforms such as mountains, valleys and plains and their physical composition (e.g., rock, till, sand and gravel, clay) are primarily the result of glacial erosion, transport and deposition during the last glaciation. These landforms and their physical characteristics (e.g., material types, grain size, drainage characteristics, relief etc.) in combination with isostatic rebound, tectonics, soil development and climate form the basis of present day ecology of NWT. The interdependence of these factors and the interrelationship between the disciples of geology and biology, form an important concept in understanding the impact of hydrocarbon development activities in NWT.

Information about the terrain and surficial geology of the Mackenzie Valley is available from a variety of sources. General field studies by the Geological Survey of Canada (GSC) and project-specific geotechnical assessments are the most common types of information. For example, the GSC has undertaken surficial geology mapping for a Mackenzie Valley transportation corridor (1971, 1979, 1995, 2000, 2002). These maps identify and include terrain evaluation for engineering purposes, sources of sand and/or gravel, geomorphic processes, natural hazards, thickness of drift, and ground ice (Duk-Rodkin 1993a). Much of the terrain and surficial geology information is held by DIAND, Natural

Resources Canada (NRCan), and GNWT through the Department of Resources, Wildlife and Economic Development (RWED).

An index of selected map-based references, including references to published reports related to various proposed Mackenzie Valley pipeline corridors has been compiled and indexed according to specific categories of interest, including information held by industry, geology and geological features and granular resource inventories (Schwarz 2002). For example, mapping of Quaternary geology is complete at a scale of 1:250,000 for most of the Mackenzie Valley or is being upgraded for areas with only reconnaissance coverage. The GNWT and DIAND have combined efforts to consolidate northern geological related information and government expertise at the C.S. Lord Northern Geoscience Centre, located in Yellowknife. This facility delivers geoscience programs in the NWT, and holds extensive archives and databases of related maps and information. Information about this facility and its holdings can be found at http://www.ainc-inac.gc.ca/nt/gdv_e.html.

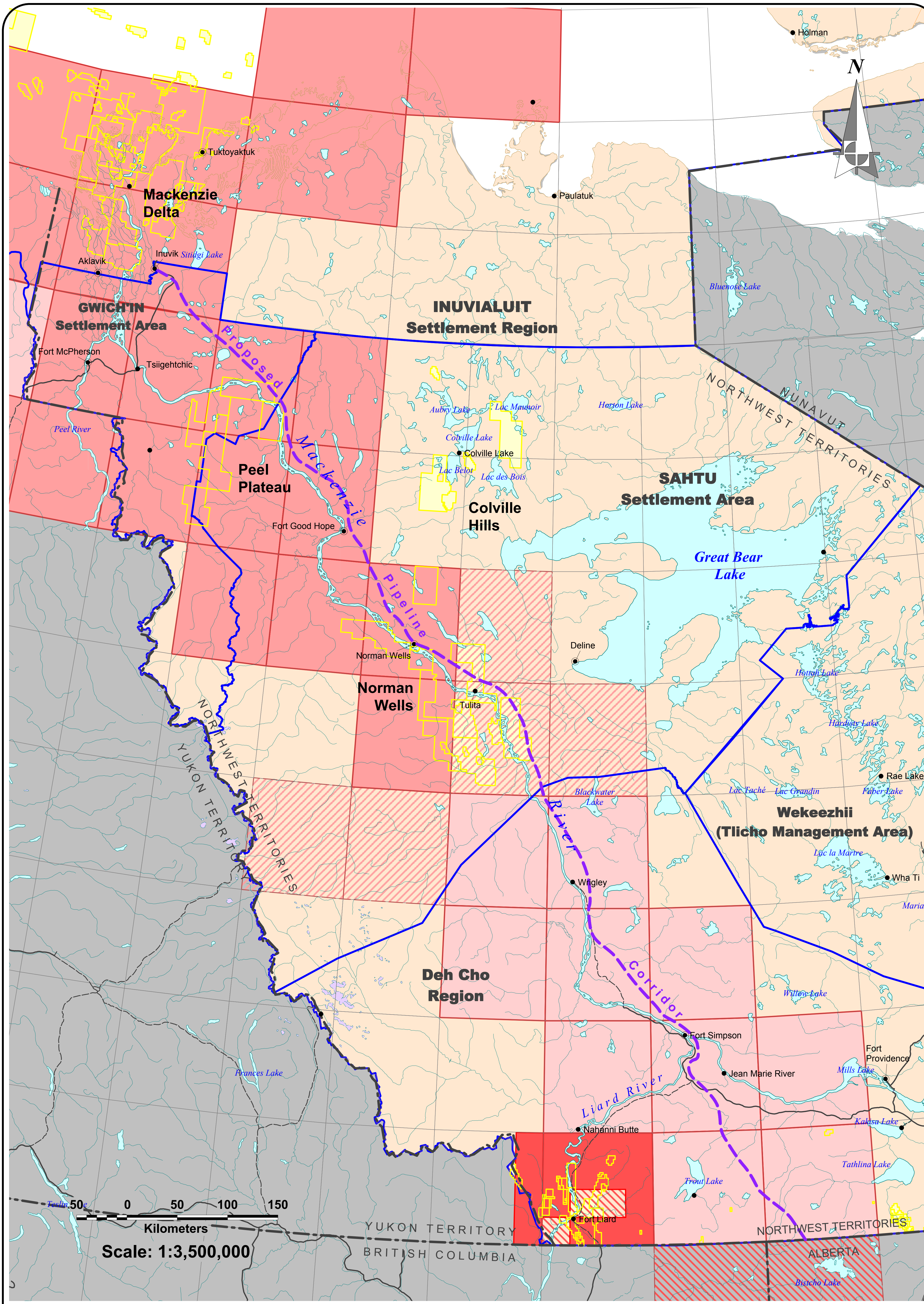
Several surficial geology maps have been produced at various scales in the Mackenzie valley, including the following:

Reference	Approximate Area of Mapping
Aylsworth *et al*. (2000)	Entire Mackenzie Valley, adjacent mountains, Mackenzie Delta, adjacent Beaufort coast
Rampton (1981a,b)	a -Aklavik, District of Mackenzie, b - Mackenzie Delta, District of Mackenzie
Duk-Rodkin and Hughes (1992a-h)	a - Arctic Red River, District of Mackenzie, b - Canot Lake, District of Mackenzie, c - Fort Good Hope, District of Mackenzie, d - Fort McPherson, District of Mackenzie, e - Martin House, District of Mackenzie, f - Ontaratue River, District of Mackenzie, g - Trail River, District of Mackenzie, h - Travaillant Lake, District of Mackenzie
Duk-Rodkin and Hughes (1993a,b)	a - Sans Sault Rapids, District of Mackenzie, b - Upper Ramparts River, District of Mackenzie
Duk-Rodkin and Hughes (2002a,b)	a - Carcajou Canyon, District of Mackenzie, b - Norman Wells, District of Mackenzie
Fulton (1970)	Mackenzie Valley
Hughes (1970)	Mackenzie Valley
Hanley (1973)	Fort Norman, Carcajou Canyon, Norman Wells and Sans Sault Rapids
Hanley *et al*. (1975)	Norman Wells, Mahoney, Lake, Canot Lake, District of Mackenzie
Rutter *et al*. (1993)	Southern Mackenzie River valley, District of Mackenzie

Reference	Approximate Area of Mapping
Rutter and Boydell (1979)	Kakisa River, District of Mackenzie
Rutter and Boydell (1980a-c)	a - Bulmer Lake, District of Mackenzie, b - Root Lake, District of Mackenzie, c - Wrigley Lake, District of Mackenzie
Rutter and Boydell (1981)	Sibbetson Lake, District of Mackenzie
Rutter *et al*. (1980a-f)	a - Camsell Bend, District of Mackenzie, b - Dahadinni River, District of Mackenzie, c - Fort Simpson, District of Mackenzie, d - Mills Lake, District of Mackenzie, e - Trout Lake, District of Mackenzie, f - Fort Liard, District of Mackenzie

Figure 2 shows a map index indicating the locations for which surficial geology mapping has been prepared. It also gives an indication of the scale of the mapping: preliminary, final reconnaissance scale or final detailed scale. NRCan considers the detailed scale to be very useful for environmental assessment work associated with the potential pipeline, while the reconnaissance scale is considered less useful and the preliminary maps are considered to be inadequate. Figure 2 shows that existing mapping south from Great Bear River is particularly poor for the purposes of environmental assessment. For the development areas in particular, mapping (at a scale of at least 1:100,000) is required for Colville Hills, Peel Plateau, Liard Plateau and Cameron Hills (R. DiLabio pers. comm. 2003). This mapping will also allow for the identification of surficial deposit thickness, terrain hazards, slope stability conditions, and general locations of terrain and soils that are susceptible to instability due to thaw. The identification of such features will provide a basis for understanding potential hazards that can be used for project design and location planning, as well as avoiding potential environmental impacts.

Field development and pipeline construction require the use of granular resources for pads, supports, and access roads. The development of these granular resources has its own impacts (e.g., access road construction, stream crossings). Granular resource requirements for hydrocarbon development, such as a pipeline, may place pressure on the limited known supplies of granular materials of the region and may also create negative impacts on associated wildlife habitat such as eskers. For this reason, up-to-date baseline granular resource information is required such that the resource can be effectively managed. Granular resources have been studied along the potential pipeline route since the first pipeline proposal in the 1970s (Mackenzie Highway Granular Materials Working Group 1975; Mahnic and Fujino 1993; Schwarz 2002). However, it was identified and confirmed at the *Scientists' Workshop* that this information requires verification and updating in terms of location, quantity and quality parameters.



Legend

Approximate Location of Proposed Pipeline Corridor

Oil & Gas Dispositions (Sept. 2002)

Surficial Geology Mapping

- Preliminary
- Reconnaissance scale
- Reconnaissance scale (in prep.)
- Detailed scale
- Detailed scale (in prep.)

Source of Data:
Natural Resources Canada, 2003

Reviewed By:	HK/GS
Drawn By:	WJ/FKP
Date Issued:	Jan. 2004
Project Number:	22-649
File Name:	22649-F2-R3.WOR
Revision:	3

Surficial Geology Mapping

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No.

2

Recently, DIAND compiled, on CD-ROM, a listing of granular resource deposits in the NWT that are associated with the oil and gas industry (Mackenzie 2000). Mackenzie River bed materials have been identified as a potential source for granular resources though considerable research is required before the potential value of the riverbed material as a granular source can be established. There is concern about the ecological effects of dredging on fish and fish habitat in the Mackenzie River (EBA Engineering Consultants Ltd. 1987).

Explicit documentation of TK in terms of approach, scope and community information relating to terrain and surficial geology is generally not available. There are, however, writings by Father Emile Petitot and Alexander Mackenzie which make reference to place names in the Gwich'in and Sahtu Settlement Areas and Deh Cho Region that provides information on the terrain or surficial geology, e.g., Thunder River near Fort Good Hope means place of flint (Pilon 1990). More recently, place name research in the Mackenzie Valley (Dogrib Treaty 11 Council 2002) concluded that name meanings tended to relate to geography, group history and resources. Further, terrain with unique physical or surficial geological features often has cultural or spiritual significance (Dene/Metis Negotiations Secretariat 1986; GRRB and Raygorodetsky 1997; Quon 1999). In addition, the Gwich'in Social and Cultural Institute has also conducted place name research.

TK has been captured in the Gwich'in and Sahtu land use planning processes and protected areas initiatives. In reports such as Places We Take Care Of by the Sahtu Land Use Planning Board and the Edehzhie Candidate Protected Area Proposal (Deh Cho) considerable information has been collected with respect to terrain through the documentation of trails, areas of cultural and historic significance. This information provides surrogate information on terrain and surficial geology.

A recent survey entitled *Northern Pipelines Survey of Expert Opinion on Permafrost and Geotechnical Issues and the use of GSC Products and Services* was conducted by Lawrence (2003a). The primary goal of the survey was to identify knowledge gaps in research activities related to geotechnical and permafrost issues associated with potential hydrocarbon activities in northern Canada. It is believed that such knowledge gaps have the potential to impede future resource development in the areas of assessment, approval, development and transportation of oil and gas in this region. A secondary goal of the survey was to evaluate usefulness of the activities and products produced by the GSC to their clients, and to suggest methods to improve on their products and delivery. The survey was distributed to 51 people, from communities ranging from university, government, regulatory agencies, engineering consultants, to pipeline companies. There was general agreement amongst the 50% of respondents that progress on issues and concerns raised during the early 1970s and 1980s relating to geotechnical and permafrost in the north had been addressed; however, the issues remain the same. The primary gaps in knowledge put forth included a deficiency of data related to:

- permafrost soil behaviour (frost heave, thaw settlement, contaminant transport, interaction of sumps and permafrost);
- soil thermal regimes (permafrost thickness, depth, temporal changes, delineation of ice rich permafrost and massive ice);
- route selection;

- stream crossings (stability of river channels, design, construction and operation of large diameter, chilled pipelines);
- resource development;
- design input and prediction of terrain response to human and natural influences (slope stability, mass movement, hydrogeology, creep, erosion of permafrost); and
- environmental concerns (construction of temporary and permanent access of right-of-ways, winter and ice road design and operation, remediation of contaminated soils, permafrost restoration, monitoring of old drill sites).

Climatic warming was the primary “new” concern given by respondents of the Lawrence (2003a) survey as requiring extensive investigation, as it was not comprehensively debated in the 1970s and 1980s. The significant reduction in oil and gas development, in addition to research and data collection in northern Canada since the 1970s and 1980s was stated as a major obstacle to future development. Respondents stated that such research and data collection activities must now be drastically increased in order to accurately and meaningfully address new hydrocarbon development proposals and this data must be both electronically available and accessible in industry standard data formats.

It is estimated that more than 1000 earthquakes occur each year in Canada. Most are too small to be felt by humans (less than 3 on the Richter scale). Earthquakes occur across much of Canada. Most earthquakes in Canada occur along the active plate boundaries off of the British Columbia coast, and along the northern Cordillera (southwestern corner of the Yukon Territory and in the Richardson Mountains and Mackenzie Valley) and arctic margins (including Nunuvat and northern Quebec). Earthquakes also occur frequently in the Ottawa and St. Lawrence Valleys, in New Brunswick, and the offshore region to the south of Newfoundland. http://www.pgc.nrcan.gc.ca/seismo/eqinfo/q-a.htm#can

The Canadian Cordillera typically shows intense seismicity north of 60 degrees in a broad zone through the Mackenzie and Richardson Mountains. The largest earthquake recorded here, with magnitude of 6.9, occurred in the Mackenzie Mountains in December, 1985. http://www.pgc.nrcan.gc.ca/seismo/eqinfo/q-a.htm#can**.**

Earthquakes have the potential to damage to buildings, infrastructure and the environment. Studies on the impact of earthquakes on pipelines were completed at the time of the original Mackenzie pipeline proposal. Some of these studies investigated the effects of landslides, overstressing the pipe, and liquefaction (Hasegawa 1974; LeBlanc and Hasegawa 1974; LeBlanc and Wetmiller 1974; Stevens and Milne 1974). The 1985 earthquakes in the Nahanni area are an example of the potential earthquake hazard for pipeline integrity and the hydrocarbon development areas (e.g., Weichert and Honer 1987; Wetmiller *et al.* 1987). Earthquakes recorded in the area have caused rock slides and slumping river banks in nearby valleys (Evans *et al.* 1987).

Many studies on earthquake hazards in western Canada are conducted through the Pacific Geoscience Centre of the Geological Survey of. The GSC operates a network of seismograph stations to continuously monitor earthquake activity, and provides seismic hazard maps for the national Building Code of Canada so that buildings and critical structures can be designed to withstand earthquakes. (http://www.pgc.nrcan.gc.ca/seismo/eqinfo/q-a.htm#can)

Studies have been conducted on fluid injection induced earthquakes (e.g., Cypser and Davis 1994; Milne and Berry 1976). It is generally thought that this is due to increased pore pressure in the basement rock, facilitating slippage along pre-existing faults. Earthquakes may also be caused by fluid extraction (e.g., Grasso and Wittlinger 1990; McKenzie 1989; Wetmiller 1986; Segal 1985; Kovach 1974). Fluid extraction can sometimes reduce pore pressure of an area enough to locally alter the state of stress, thus inducing an earthquake.

Engineering guidelines are used to influence the design and construction of project related infrastructure to ensure a minimum level of built-in resilience to protection from earthquakes. In order for these guidelines to be effective, an accurate indication of the true earthquake potential in the oil and gas development areas in the Mackenzie Valley and for the potential pipeline route is required.

4.1.1.1 Baseline Knowledge Gaps

1. Need to gather TK and/or interpret TK as it may relate to terrain and surficial geology.

2. Surficial Geology Mapping:
   a) Need surficial geology mapping at a scale of 1:100,000 or more detailed for the development areas especially Colville Hills, Peel Plateau, Liard Plateau and Cameron Hills and along the potential pipeline route south from Great Bear River.
   b) Need to map the surficial deposit thickness, terrain hazards and slope stability conditions in the Mackenzie Valley.

3. Update and verify granular resources information in terms of location, quantity and quality parameters.

4. Need to assess the earthquake potential in the oil and gas development areas in the Mackenzie Valley, particularly in the Liard Plateau area.

5. Need to document the general locations of terrain and soils that are susceptible to instability due to thaw[12].

4.1.2 Impact Assessment and Regulatory Processes

There are no known documented sources of TK about the impact of hydrocarbon development activities on terrain and surficial geology in the study regions. However, there is some evidence that TK may be impacted by development activities. For example, community-based workshops in the Gwich'in and

[12] A general determination can be obtained through interpretation of surficial geology mapping and aerial photographs. Detailed information on terrain instability can only be obtained through specific sampling (boreholes) of soil and ground ice conditions

Sahtu Settlement Areas and Deh Cho Region, brought out concerns about development effects on local resource and land use issues such as impacts on traditional trails. Likewise, at the *Norman Wells Workshop*, a component of this project, community participants expressed the view that it was sometimes difficult to obtain specific information about projects because of the proprietary nature of the information. For example, seismic line locations information has not always been available to aboriginal communities (as reported in the *Norman Wells Workshop*) making it difficult to evaluate the impact of the project on traditional use areas.

Many of the terrain issues (e.g., disruption of permafrost areas, soil compaction, loss of surface organic layers, change in surface water flow patterns) identified in the 1970s and 1980s remain unresolved, and require further research by government agencies (GSC), university researchers and consulting firms as addressed in the Lawrence (2003a) survey. While there is now experience in Canadian western arctic pipeline design construction and operation in permafrost terrain, this is limited to smaller diameter oil lines, and not entirely transferable or applicable to the different diameter pipes, routes, and thermal modes of operation of proposed gas lines.

Ground ice content is an important factor controlling slope stability in permafrost terrain. Long-term creep deformation of ice-rich permafrost has been documented from a slope adjacent to the Great Bear River (Savigny and Morgenstern 1986) and the Tuktoyaktuk Peninsula (Dallimore and Collett undated). In each case, seasonal and annual ground displacements in permafrost have been measured. Currently, the GSC has installed additional monitoring stations for slope creep near Wrigley. This creep is distinct from the movement of the active layer above permafrost, commonly known as solifluction or gelifluction (Washburn 1979).

Soil creep is defined as “the slow, steady downhill movement of soil and loose rock on a slope” (Parker 1997). Soil creep characteristics of ice and frozen soil are dependent on grain size, moisture content and thermal regime, the temperature of the ground increases (especially in fine grained soil) and the ground thaws, ice-bonding between soil particles decreases, because of the increase in unfrozen water content. The result is a soil that loses all its strength and begins to creep as a load is applied to surface (Smith *et al*. 2001). Permafrost temperatures very close to 0°C throughout much of the Mackenzie Valley may promote gradual but ongoing movements (creep) at depths well below the active layer on slopes (L. Dyke pers. comm. 2003). It is also possible that creep within an excessively deep thawed zone may contribute to pipeline deformations (L. Dyke pers. comm. 2003), as such additional research and assessment of this process is required. Creep of ice-bonded soils has been blamed for distress along the Norman Wells pipeline (M. Burgess pers. comm. 2003; L. Dyke pers. comm. 2003). Considerable efforts are underway to document this process in the Mackenzie Valley. There are creep measurements available for massive ground ice bodies in the Mackenzie Delta area, extending back to 1990, and sites have recently been established to document creep of warm but still frozen materials near Wrigley, NWT. (L. Dyke pers. comm. 2003). These measurements must be maintained for an additional time interval sufficient to yield results that allow characterize, along with an appropriate theoretical formulation, the ground motions likely to be caused by soil creep (L. Dyke pers. comm. 2003).

Studies have been undertaken into the construction of pipelines in northern climates in areas of discontinuous permafrost (e.g., Rutter *et al*. 1973; U.S. Army Cold Regions Research and Engineering Lab (CRREL) 1981; Godfrey and Eaton 1986; Williams 1986; Interprovincial Pipe Line (NW) Ltd. 1982; Hanna and McRoberts 1988; Canada-France Pipeline Ground Freezing Experiment 1988ab, 1991, 1992, 1993, 1994; MacInnes *et al*. 1989, 1990; Pilon *et al*. 1989; Nixon *et al.* 1990; Williams 1992, 1993; Burgess *et al*. 1993; Burgess and Tarnocai 1997; Agra Earth and Environmental Ltd. and Nixon Geotech Ltd. 1999; Burgess and Lawrence 2000). Beginning in 1982, Canada and France partnered together to initiate the Canada-France Pipeline Ground Freezing Project (GSL Network - http://www. freezingground.org/GSLNetwork/) in an effort to research the problems associated with pipeline construction in cold climates, which has produced numerous scientific reports throughout the years (Williams 1986; GSL Network - http://www.freezingground.org/GSLNetwork/).

The NWT portion of the CANOL crude oil pipeline has provided a unique opportunity to study the impacts of earlier construction and operation activities. Abandoned in 1945, recent studies of the corridor show that the removal, compaction, and burial of the often peaty soil surface layers has resulted in less organic matter at the soil surface when compared to undisturbed areas (e.g., Harper and Kershaw 1996; Harper and Kershaw 1997). Also noted were warmer subsurface temperatures and diminished subsurface moisture in disturbed areas as compared to undisturbed areas. (Kavik-Axys and LGL 2001). After forty years post-construction biological and geomorphological processes have not yet stabilized and recovery of the site continues (Kershaw 1983). This information has been useful in shaping contemporary pipeline development (Kavik-Axys and LGL 2001).

Since 1982, Enbridge Pipelines Inc. (formerly Interprovincial Pipe Line) have been monitoring construction and operation of the Norman Wells to Zama oil pipeline. Of note are studies considering terrain impacts such as slope stability and scour holes created over the pipeline at stream crossings. These studies were correlated with pipe movement, bending strain, and detection of pipe wall deformations as a result of changes in the terrain (Hanna and McRoberts 1988; MacInnes *et al*. 1989, 1990; Burgess *et al*. 1993; Burgess and Tarnocai 1997; Burgess *et al*. 1998; Agra Earth and Environmental Ltd. and Nixon Geotech Ltd. 1999; Nixon and Burgess 1999; Burgess and Lawrence 2000). The results of this monitoring have contributed greatly to the understanding of constructing pipelines in permafrost conditions.

Recent geological mapping by the GSC has delineated approximately 3,400 landslides, both in bedrock and unconsolidated Quaternary sediments along the Mackenzie valley (Aylsworth 1992; Duk-Rodkin 1993b; Aylsworth *et al*. 2000; Aylsworth and Traynor 2001; Duk-Rodkin and Robertson 2001; Aylsworth *et al*. 2001). For example, along the Liard River in the vicinity of Ft. Liard, current landslides show evidence of gradual, ongoing motion and to date have been troublesome to the maintenance of oil and gas installations and infrastructure. Examples included Chevron well K-29, and Anderson's well K-34, both situated on active landslides and annual causing disruption of well casings (L. Dyke pers. comm. 2003). There is little known of the mechanism by which these slides have formed, the extent to which they are still moving, or the means by which dormant slides may be re-activated. The extent to which permafrost may be a factor in the activity or location of these slides is unknown (L. Dyke pers. comm. 2003).

The Cretaceous shales bordering the Peel Plateau are also subject to landslides wherever river erosion is actively undercutting slopes. These shales may be particularly susceptible to failure because of the saline nature of the shale porewater and consequently the freezing point depression (Williams and Smith 1989; Heginbottom 2000; L. Dyke pers. comm. 2003). That is, materials that would normally be frozen and resistant to landslides may in fact lack ice-bonding and have greatly reduced shear strength. Several factors including groundwater seepage and insulation by the snowpack at the base of steep slopes may potentially control the thermal state and extent of ice-bonding within these slopes. These factors control the extent of ice-bonding and hence the stability of slopes (Williams and Smith 1989; Smith *et al*. 2001; L. Dyke pers. comm. 2003).

Large rotational landslides in glacial deposits along the Mackenzie River and major tributaries are probably the most spectacular slope failures, but may not merit extensive continued investigation (L. Dyke pers. comm. 2003). These slides are localized along river shorelines with high banks in areas of active river scouring and toe erosion[13]. Furthermore, failure rates and retreat of head-scarps are directly controlled by riverbank dynamics, one of the better documented geomorphic processes (Aylsworth *et al*. 2000; Dyke 2000). There is a major research question concerning the dependence of mechanical behaviour and shear strength of ice-bonded sediments on the rate of load application. At present there is very little information on conventional strength parameters for use in design of slopes in frozen natural materials. Preliminary indications that these strength parameters are highly dependent on loading rate suggest that further research is necessary for considerations at specific sites (Dyke 2000; L. Dyke pers. comm. 2003).

Active layer detachment is one of the most common types of slope failures in permafrost terrain (Dyke 2000). There are standard engineering approaches for predicting the stability of slopes susceptible to this style of failure, but the accuracy of such prediction is likely limited by the lack of an adequate understanding of the role of ground ice fabric in the stability calculation. Forest fires most commonly trigger this slope failure. It is not the immediate heat of the fire but rather the affect on the ground surface vegetation (i.e., burning of vegetation/organic mat) that is the triggering factor. Depending on the degree to which the insulating capacity of ground surface vegetation is destroyed, summer thaw will increase and promote the destabilizing effect of ground ice melt (Aylsworth *et al*. 2000; Dyke 2000; Smith *et al*. 2001). Snowpack characteristics following forest fires may also have an effect on active layer thickening and surface subsidence (Kershaw 2001). Following the large forest fires of 1994 and 1995 in the vicinity of Fort Norman, numerous flows developed along the banks of the Mackenzie River and its tributaries (GSC website - http://sts.gsc.nrcan.gc.ca/permafrost/landslides.html). Little is known about the interaction between ground ice content and severity of burning that controls stability. Furthermore, there is a lack of understanding of the possible interaction between ROW thawing and excessive thawing adjacent to a ROW caused by a forest fire (L. Dyke pers. comm. 2003). It is predicted by some climate change experts that the frequency of forest fires may increase which may in turn increase the number or extent of slope failures.

---

[13] Toe erosion means erosion that takes place at the base of a slope such as a cliff. Toe erosion from flowing water at the base of the slope can over-steepen the natural angle, and the slope may respond by cutting further back to regain a natural angle. Falling trees on a slope may be evidence of this back cutting as are the exposed soils at the place where the toe erosion is occurring.

The removal of granular resources from a region has the potential to cause the development of thermokarst collapse features[14], most notably in fine grained sediments, due to the removal of overlying insulating layers. Fine grained frozen soils are susceptible to significant settling during thawing, and are termed "thaw unstable", because as thawing progresses, pore water pressures build up in the soil and soil strength decreases as excess water is unable to drain away. Thaw unstable soils are composed of sediments such as silt, clay and organic materials like peat (Smith *et al*. 2001). Granular soils composed of sand and gravel generally have large pore spaces enabling excess water to drain, thus greatly reducing their susceptibility to settling, and are therefore termed "thaw stable".

The potential degradation of permafrost by human activities or developments is a primary concern, including pipeline ROWs. Disturbance and loss of permafrost can lead to thawing, excess soil pore pressure, and generally more sensitive soils. This, in turn, can lead to slope instability, potentially causing slumping and slides (Williams 1986; Williams and Smith 1989; Smith *et al*. 2001). This change has to be reflected in engineering design which can only be verified through comprehensive and long term data base compilation of ground temperatures and surficial geological mapping that shows permafrost distribution and regional trends such as active layer depths and ice content across NWT. In addition, surface and sub-surface water flow regimes are affected by changes in permafrost (Smith *et al*. 2001). Resulting ecological impacts from these changes could include changes in surface vegetation communities and related wildlife habitat. Although slope destabilization caused by ROW thawing was only a minor occurrence for the Norman Wells pipeline, wider ROWs such as the proposed Mackenzie Valley pipeline are more susceptible to slope failures. An assessment of the susceptibility of slope destabilization caused by ROW thawing is therefore warranted (L. Dyke pers. comm. 2003)

While much has been studied regarding the impacts of pipelines on terrain, more research is required to fully understand the short- and long-term impacts of operating vehicles over permafrost terrain, including partially thawed soils and soils susceptible to compaction. These impacts most notably include soil compaction and rutting, which have the potential to cause degradation of permafrost, erosion and drainage issues. Soil compaction and rutting impacts have been well studied in more southern areas such as Alberta, but are not well understood in northern regions. An understanding of these impacts is required to ensure that environmental assessment predictions are valid and the environmental risk is managed in an appropriate manner. An understanding of these impacts would also assist with the development of appropriate specific operating criteria and regulatory terms and conditions.

[14] Thermokarst is characterized as irregular, hummocky terrain produced by the melting of ground ice (French 1976). Thermokarst development is primarily a result of the disruption of the thermal equilibrium of the permafrost, which results in an increase in the depth of the active layer, causing the ground surface to subside Thermokarst processes are particularly troublesome to pipeline construction in the north, where they can create major geotechnical problems. A selection of the numerous research projects that have been conducted on the development of thermokarst and its associated effects include: Mackay (1970), Kerfoot (1973), Rampton (1973), Burn (1982), Burn and Smith (1988, 1990), Osterkamp et al. (2000), Robinson (2000), Smith *et al.* (2001).

4.1.2.1 Impact Knowledge Gaps

1. Slope Movement Mechanics:
   a) Need to assess forest fire as a landslide trigger along the potential pipeline route.
   b) Need to assess susceptibility of slope destabilization caused by ROW thawing.
   c) Need to assess creep of frozen ground as a cause of pipeline deformation.
   d) Need to assess slope failures in the Liard Plateau and Peel Plateau.

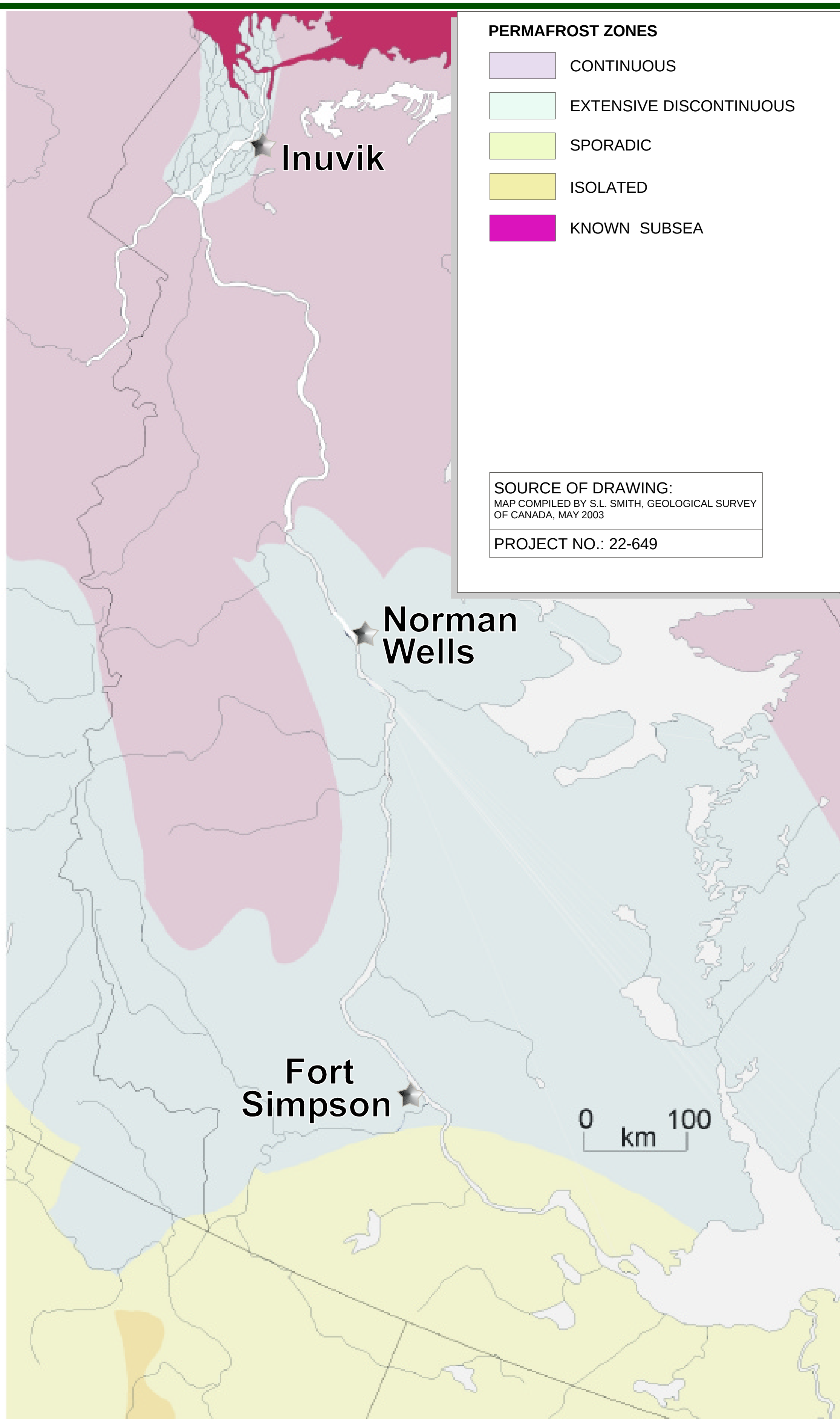
2. Identify environmental impacts and appropriate mitigation measures related to soil compaction and rutting.

4.2 Permafrost

Permafrost is most commonly defined on the basis of temperature, as “soil or rock that remains below 0°C continuously for more than two years” (Muller 1947). At present, permafrost covers approximately half of the land surface in Canada most notably in northern regions and within the western mountains; however, it can also be found in undersea areas, such as the Beaufort Sea (Smith and Burgess 2000, 2002; Heginbottom 2000; GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html).

Permafrost can be divided into two types: continuous and discontinuous. Continuous permafrost is perennially frozen ground, generally thick, uniform and spatially extensive, as compared to discontinuous permafrost, which is shallower in nature and contains unfrozen sections or large gaps of unfrozen ground. Zones of sporadic discontinuous permafrost and isolated patches of permafrost are also possible. Figure 3 shows the continuous, discontinuous and sporadic permafrost zones for the western NWT. Figure 4 shows a typical schematic section of the permafrost zones, as well as relative active layer and permafrost thicknesses.

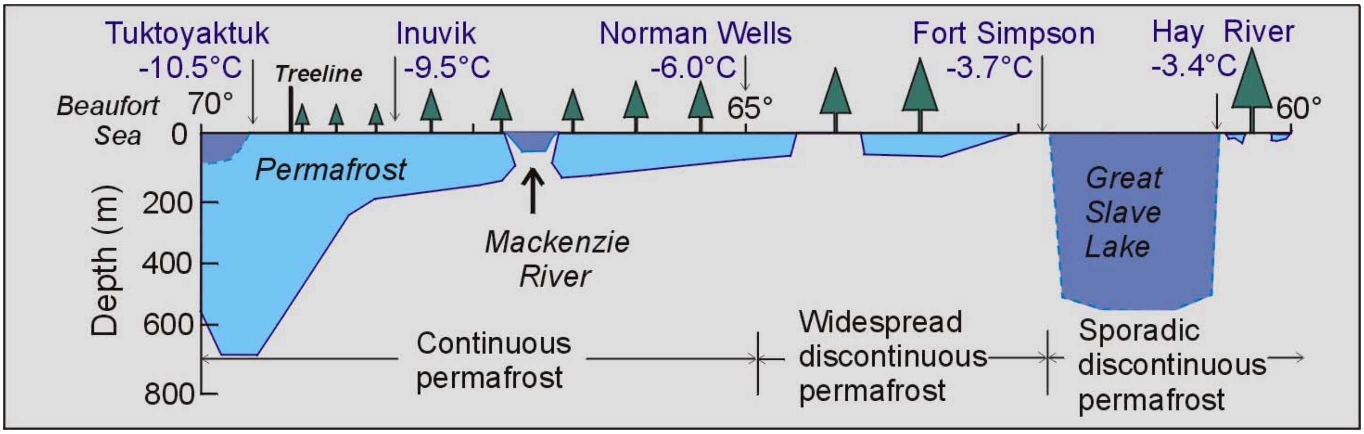
Permafrost terrain has a distinct, thin (15 centimetres to 5 metres thick) unfrozen layer of material that is termed the active layer. The thickness of the active layer varies according to seasonal freeze and thaw cycles and associated with the melting of the permafrost table each year (Ritter 1986). The existence of permafrost is primarily controlled by long term climate trends; however, its thickness, spatial distribution and ground temperatures are dependent upon the thermal condition of the ground surface – including natural ground cover such as snow, vegetation type and density, soil type and drainage characteristics are also important factors determining ground surface temperature (Wolfe 1998; Burgess and Smith 2000; Heginbottom 2000).



Gartner Lee Limited

PERMAFROST ZONES OF WESTERN NWT

Figure 3



	Tuktoyaktuk	Inuvik	Norman Wells	Fort Simpson	Hay River
Active layer thickness	35 cm - >1.0 m	50 cm - >1.5 m	60 cm - >1.5 m	1.25 m - >2.0 m	?
Permafrost thickness	200 - >700 m	100 - ~200 m	0-60 m	0-10 m	0-5 ? m

Figure 4. **Schematic of permafrost zones, and relative active layer and permafrost thicknesses**

A result of ground temperatures continuously at or below 0°C , is that most of the moisture in the ground is frozen, forming ground ice. Ground ice can occur in two major forms (Heginbottom 2000):

1. structure forming ice (bonds enclosing sediments) (Photo 1); or
2. massive ice (large bodies of pure ice) (Photo 2).

Photo 1. Reticulate Ice, an example of the structuring forming ice form (U.S. Army Corps of Engineers website http://www.crrel.usace.army.mil/permafrosttunnel/1g2_ Permafrost.htm)

Photo 2. An ice cored pingo, an example of the massive ice form (GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html**)**

Hydrocarbon projects can impact permafrost through disruption of the ground thermal regime by the loss of surface vegetation cover, by salt content from migrating sump fluids and by impacts from the temperature of buried chilled pipelines. Shallow groundwater flow can also be impacted through changes in the thermal conditions of frozen terrain in the Mackenzie Valley.

4.2.1 Baseline

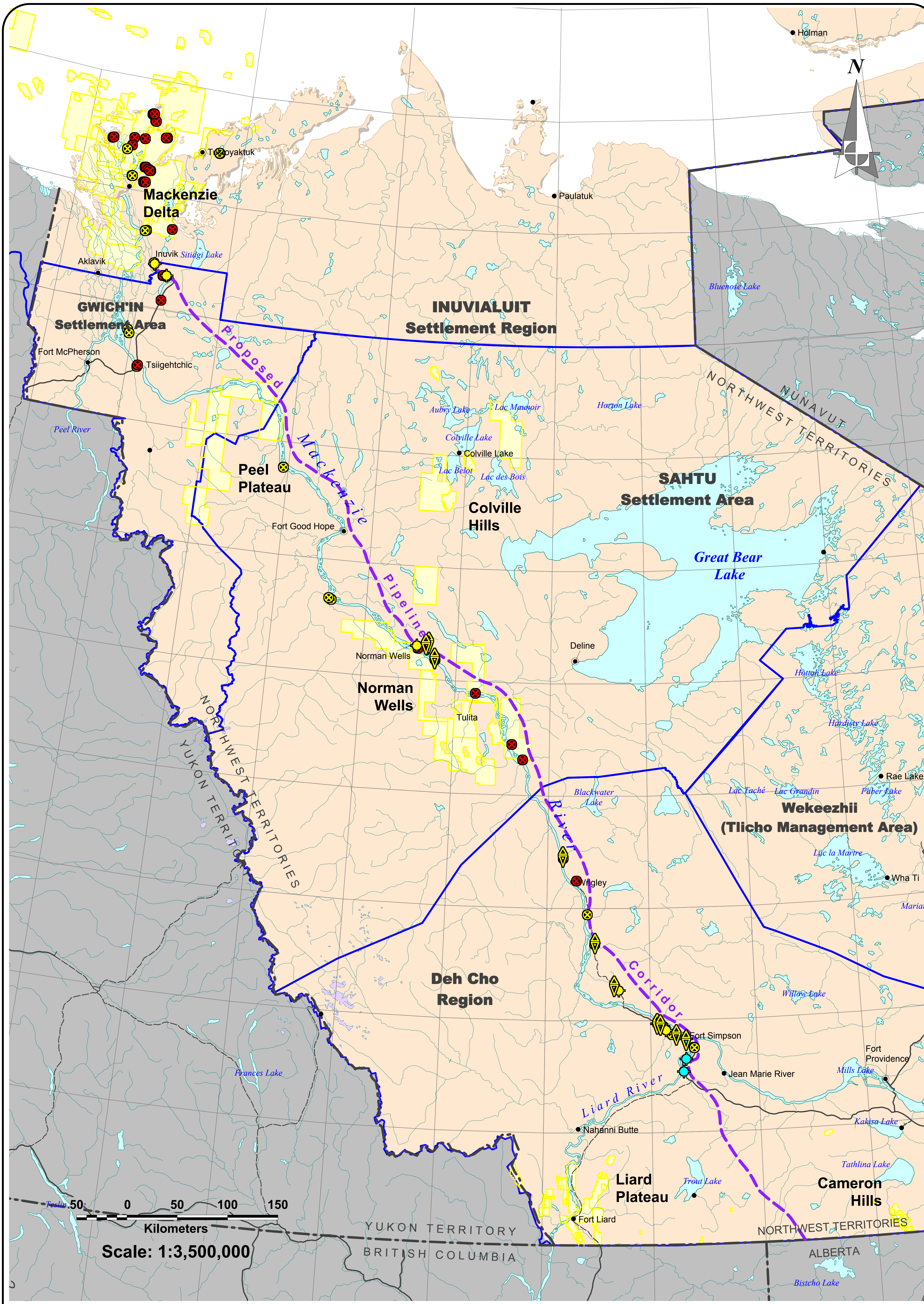
Continuous and discontinuous permafrost is present throughout the Mackenzie Valley (see Figure 4 above). Discontinuous permafrost is the dominant form in the Mackenzie Valley extending from approximately northern Alberta to just south of the Mackenzie Delta (Heginbottom 2000; M. Burgess pers. comm. 2003; Kwong and Gan 1994). However, the distribution of permafrost has been changing in the past century. The Mackenzie Valley of the NWT has experienced the greatest increase in air temperature in all of Canada, with a rise of 1.7^{o}C in the last decade (Dyke and Brooks 2000). This increase in temperature may lead to increased thawing of the permafrost in the Mackenzie Valley and an increase in subsidence features, such as thermokarst. Changes in air temperature will be transferred to the ground, although not necessarily directly, through buffering, for example by vegetation, soils, precipitation and snow. Permafrost will respond to these climatic changes, and the nature, rate and magnitude of these responses will also depend on the soil, ground ice conditions and thermal regime. Climate change may thus influence thaw settlement and frost heave, frozen/thawing slope processes and stability, river and coastal processes and stability. In turn, these could affect infrastructure integrity and thus will need to be considered over the design life of exploration/pipeline infrastructure. Research and documentation of permafrost below peat plateaus in the upper Mackenzie Valley has shown that these features are slowly degrading in response to the current climate conditions (Smith *et al*. 2001). In the central Canadian Arctic, a general northward retreat of the southern-most margin of discontinuous permafrost by about 100 km over the 20th century has been reported (Kwong and Gan 1994; French and Egorov 1998). This change may be attributable to changing land use and climate change (Dyke and Brooks 2000; Smith *et al*. 2001; M. Burgess pers. comm. 2003; Kwong and Gan 1994). Aboriginal communities in the Mackenzie Valley have been aware of, and have traditionally used permafrost but there are no known documented source of TK on permafrost that gives insight to the changes observed. See Section 4.10, for further discussion on climate change.

Watercourses have a major influence on permafrost distribution due to the impact of warmer temperatures (usually above $0^{o}C$) compared to the surrounding land. As a result, permafrost is generally absent from beneath rivers and waterbodies (ponds, lakes) that are greater than 2 metres in depth. These permafrost free areas are termed ‘taliks’. Furthermore, watercourses are capable of redistributing permafrost because of their dynamic nature (Burgess and Smith 2000; M. Burgess pers. comm. 2003; Dyke and Brooks 2000; Smith 1976). Proximity to waterbodies has been found to produce a warming effect on the surrounding ground temperatures on adjacent banks and shores (Burgess and Smith 2000).

The GSC has been collecting data on permafrost and geomorphic processes in the Mackenzie Valley since the early 1970s (Dyke and Brooks 2000; Smith *et al*. 2001). Regional studies in the NWT include those in Mackenzie Delta/Beaufort Sea and Tuktoyaktuk Coastlands and the Mackenzie Valley. The GSC’s Mackenzie Valley region study has concentrated on studying the permafrost-climate and permafrost-pipeline interactions, most notably along the Norman Wells pipeline (Dyke and Brooks 2000; GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html). As a result, extensive information exists on slope stability, ground thermal regimes, frost heave, drainage and erosion control (Dyke and Brooks 2000; R. Marshall pers. comm. 2003; GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html) along the existing pipeline corridor. Permafrost conditions north of Norman Wells to Inuvik have limited documentation.

Other regional studies in the Mackenzie Valley include active layer monitoring in relation to climate change (58 stations along 1,200 km transect, Nixon (2000)), ground temperature monitoring, and modelling permafrost distribution, thickness and temperature using GIS and also verified in 180 test sites along the Norman Wells pipeline ROW (GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html).

Over the last 15 years, the GSC has maintained a network of monitoring sites for measuring atmospheric and near surface temperatures, active layer monitoring, and shallow ground temperature cable. The data provides fundamental permafrost/engineering field data (air, surface and subsurface temperatures, ice content, thermal gradient and thermal conductivity, and active layer thickness) for permafrost terrain and underlying sediments. Some of the information from this monitoring is documented in Nixon and Taylor (1994), Nixon et al. (1995), Nixon and Taylor (1998), and Nixon (2000). Figure 5 shows the GSC’s permafrost monitoring locations.



Legend

- Approximate Location of Proposed Pipeline Corridor
- Oil & Gas Dispositions (Sept. 2002)

GSC Permafrost Monitoring Locations

- Air & Near Surface Ground Temperatures
- Shallow Ground Temperature
- Shallow Ground Temp & Air +/- Near Surface Temp.
- Active Layer Monitoring
- Active Layer & Air +/- Near Surface Temp.

Source of Data:
Terrain Sciences Division,
Geological Survey of Canada, 2003

Reviewed By: HK/GS
Drawn By: WJ/FKP
Date Issued: Jan. 2004
Project Number: 22-649
File Name: 22649-F5-R3.WOR
Revision: 2

GSC Permafrost Monitoring Locations

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No. 5

A ground temperature database has been compiled for northern Canada (http://sts.gsc.nrcan.gc.ca/permafrost/permafrostdatabases/national_permafrost_database.html), including both deep and shallow information for the Mackenzie Region. The ground temperature observations are concentrated along the existing/potential pipeline and transportation corridors in the Mackenzie Valley. A geotechnical database providing information on ice content and soil water contents has also been compiled, again with similar constraints in the spatial coverage. Much of the information compiled in these databases was collected 25 to 30 years ago and the quality and quantity of ground ice data can be limited (M. Burgess pers. comm. 2003). The majority of the ground temperature sites are inactive, and any changes in near surface ground temperature conditions that may have occurred in the last few decades are not known. Active shallow permafrost ground temperature monitoring (upper 30 metres) in response to anthropogenic and climate changes is more limited - and focused on the Norman Wells pipeline corridor and the Delta (M. Burgess pers. comm. 2003). Both ground temperature and geotechnical databases are being updated with Norman Wells pipeline corridor data. There is little ground temperature data between Norman Wells and Inuvik, as well as in the new (Ft. Liard, Cameron Hills and Peel Plateau) development areas (M. Burgess pers. comm. 2003). There is a need to establish ground temperature and ground ice conditions along the potential pipeline, especially for the area between Norman Wells and Inuvik.

Since 1990, there has been a general increase in active layer depth throughout the Mackenzie Valley of about 15 centimetres (M. Burgess pers. comm. 2003). Changes in the depth of the active layer provide an indication of climate warming or cooling trends (M. Burgess pers. comm. 2003). Modelling of potential changes to the depth of thaw as a result of climate change and a predicted doubling of carbon dioxide have been carried out at locations near Tuktoyaktuk, Norman Wells and Fort Simpson (Burgess *et al*. 2000).

DIAND has consolidated a database of geotechnical information in the Mackenzie Valley from 12,000 boreholes drilled during the 1970s, which describe the physical, geothermal and geotechnical properties of surficial materials along proposed and existing transportation routes. Attributes measured in the boreholes includes soil type, grain size, moisture content, density, Atterberg limits, and permafrost/ground ice conditions. Modelling of the potential changes in permafrost distribution, thickness and temperature between Fort Simpson and Norman Wells has been conducted using GIS and the models results compared against geophysical survey interpretation from the area (Wright *et al*. 2000).

In the five development areas information on permafrost has been collected, and includes soil moisture content, mapping of the locations of continuous and discontinuous permafrost, and temperature profiles (Taylor and Judge 1974; Young and Judge 1985; Dyke and Brooks 2000; Smith and Burgess 2000; Taylor *et al*. 2000; GSC website http://sts.gsc.nrcan.gc.ca/permafrost/index_e.html; R. Marshall pers. comm. 2003). Current knowledge of the distribution and characteristics of permafrost includes thickness and temperature regime (Taylor and Judge 1974; Young and Judge 1985, 1986; Smith and Burgess 2000, 2002; Taylor *et al*. 2000). Ground ice distribution has also been summarized (Smith *et al*. 2001). In 2000, the GSC studied shoreline permafrost along the Mackenzie River (Dyke and Brooks 2000).

4.2.1.1 Baseline Knowledge Gaps

1. Need to establish ground temperature and ground ice conditions, particularly along the potential pipeline corridor between Inuvik and Norman Wells.

4.2.2 Impact Assessment and Regulatory Processes

Oil and gas development and pipeline construction and operation could result in the thawing of permafrost and negatively impact surface sediments. For example, construction and operation results in the removal of vegetation that allows heat to penetrate surface sediments, which exposes frozen sediment to higher ambient temperatures during excavation (Williams 1986; Williams and Smith 1989; Dyke and Brooks 2000; Smith *et al*. 2001; Kavik-Axys and LGL 2001).

Subsidence of the ground surface is also a likely impact along any pipeline ROW that will be constructed across ice-rich ground. This is due to the increased heat absorption associated with compaction or removal of surface vegetation and the surface organic layers. These effects may be enhanced by climate change. When ice rich permafrost melts, there is substantial loss of ground strength and structure that may result in the collapse of the ground surface (Williams 1986, Williams and Smith 1989, Dyke and Brooks 2000, Smith *et al*. 2001). Up to one metre of subsidence has taken place along parts of the Norman Wells pipeline ROW and subsidence has also taken place over the pipeline trench due to compaction of loose, ice-rich fill. Information from ROW analysis along the Alaska Pipeline indicated that permafrost thaw and subsequent settlement was responsible for pipeline rupture (Lawrence 2003b). Based on the Norman Wells experience, there is a high likelihood that surface drainage will be re-directed into and along depressions formed by subsidence, even on very gently sloping terrain (M. Burgess pers. comm. 2003). Data from the trench excavation for the Norman Wells to Zama pipeline includes records of logged ice conditions and sediments along the route (Dyke *et al*. 1997; Burgess and Lawrence 2000).

Depending on the type of pipeline operated (i.e., buried, warm – above 0^oC or buried, chilled – below 0^oC) both have the potential to create permafrost related issues. Buried, warm pipeline operation has the potential to melt permafrost, leading to a loss of soil strength, soil movement, erosion, and possible loss of pipeline support. Alternatively, operation of a buried, chilled pipeline will mitigate the effects of pipeline temperature on existing permafrost; however it can potentially freeze previously unfrozen ground or further chill frozen ground, creating the potential for differential movement of the pipeline as a result of frost heave (Lawrence 2003b).

Research on permafrost degradation caused by the construction of pipelines in northern regions has been conducted by such authors as Foothills Pipe Lines Ltd. (1976), Northern Engineering Services Company Limited (1976), Smith and Williams (1990), Shen and Ladanyi (1991), Williams (1993), Ladanyi and Shen (1993), and White and Williams (1993). The topics of research addressed by the above authors, in relation to “chilled pipelines” include:

- the use of insulation to relieve frost heave problems,
- the effects of frost heave on pipeline construction,

- lense ice orientation around chilled pipelines,
- soil/pipeline interactions,
- stress and strain behaviour of frozen soil,
- microstructural genesis of frost susceptible soil adjacent to chilled pipelines,
- soil/pipeline interaction during frost heave events, and
- freezing pressure development on buried, chilled pipelines.

A critical component of engineering design of northern gas pipelines will be the frost heave design, to ensure chilled pipe can withstand differential movements. The unknown potential impact of frost heave on a chilled-gas pipeline was one of the technical reasons cited by Justice Berger for a moratorium on pipeline construction in the 1970s. Since the 1970s, advances in frost heave understanding and predictive capabilities have been made through, field observations, laboratory and controlled environment testing, and model development (M. Burgess pers. comm. 2003; C. Burn pers. comm. 2003). However, the potential deformation characteristics of this frozen material are inadequately known at present, but will be critical factors in pipe stability especially on the approaches to river crossings and at frozen/unfrozen interfaces in the discontinuous permafrost zone (C. Burn pers. comm. 2003) . Knowledge of the physical environment, soil conditions (thermal, frost susceptibility), transitions from frozen to unfrozen ground, drainage and moisture availability, and information on thermal mode of pipeline operation, depth of burial, will all be important parameters for assessing and determining frost heave design - such data are not in the public domain (M. Burgess pers. comm. 2003). It will be important to undertake a thorough and up-to-date review, synthesis of data and knowledge on frost heave, to improve the understanding of frost heave impacts on pipeline integrity and terrain.

Exploration and development of fields in the NWT require the use of drilling fluids, comprised of waste mud and drill cuttings in a chemically treated suspension . These fluids require disposal. Practice has been to require that the drilling fluids be totally contained in-situ in unlined sumps (pits) excavated in permafrost. This technique, however, may not be as effective as once thought. Dissolved salts originating from sumps in permafrost are capable of migrating considerable distances into the surrounding sediments (Dyke 2001). It is now also apparent that the construction of the sumps has in itself contributed to significant terrain disturbances (Geotechnical Science Laboratories 1998). In a survey of over 60 abandoned well sites in the Mackenzie Delta and Arctic Islands approximately 25% of the sites experienced terrain disturbances related to sumps excavation (blasting) in cold permafrost (French 1980). Kokelj and GeoNorth Ltd. (2002) concluded from an assessment of sumps at 24 abandoned well-sites that approximately 50% of sumps constructed in the Mackenzie Delta region have collapsed or are actively collapsing. ESRF-funded sump studies related to drilling waste management and thermal monitoring are currently taking place for the Mackenzie Delta region (D. Milburn pers. comm. 2003). CAPP is also studying the effects of sumps in the Mackenzie Delta (I. Scott pers. comm. 2003).

Increases in sump failures and associated permafrost terrain disturbances have also contributed to the need to construct larger sumps to accommodate increasing volumes of waste drilling fluids produced by increasingly deeper Arctic wells (White 1998). This study indicated that the containment of drilling fluids in permafrost may not be appropriate in regions characterized by either continuous or sporadic permafrost, due to the thermal degradation created by sump fluids containing high salt contents. One of the main problems with sumps is the failure to place the wastes in a form that can be frozen by the available ground thermal regime; thus, if sumps are to be used, the contents need to be placed at a moisture content and salinity that are appropriate for the expected ambient ground temperatures. (M. Burgess pers. comm. 2003).

Although new drilling techniques and technology has improved over the years, resulting in a reduction of total drilling waste volumes, there is an ongoing need to develop better sump construction techniques or to develop alternatives to using sumps for drilling waste disposal. Communities in the Mackenzie Valley are increasingly concerned over the stability of existing sumps, the effects of sumps with lost integrity, and the clean-up of leaking sumps.

4.2.2.1 Impact Knowledge Gaps

1. Need to understand the effects of frost heave on the integrity of a chilled pipeline in permafrost.

2. Drilling Waste Fluid (Mud) Containment Sumps:
   a) Need to establish the long-term viability and best practices of using permafrost excavated pits (sumps) for containing drilling muds.
   b) Need to research alternatives to using sumps for projects in the Mackenzie Valley.
   c) Identify the locations and conditions of existing sumps in the Mackenzie Valley, and determine which sumps need clean-up or remediation, and how this would be done.

4.3 Hydrogeology

In its broadest sense hydrology is defined as the study of “the occurrence, distribution, movement, and chemistry of all waters of the earth” (Fetter 1994). Hydrogeology is interrelated with hydrology and “encompasses the interrelationships of geologic materials and processes of water”(Fetter 1994). The Earth’s water is in continual motion as illustrated in Figure 6. The hydrologic cycle depicts the “cycle” through which water moves from the atmosphere, to the land and back to the ocean (Parker 1997). In the hydrologic cycle, some of the water that falls to earth as precipitation or melts from snow will flow across the land surface and into streams channels eventually returning to the ocean. This process is termed surface runoff. A portion of this water as it flows across porous land will seep into the ground through the process of infiltration. The soil below the surface is composed of both solid soil particles and spaces called pores in-between individual soil particles, which can be filled with either air or water. This unsaturated zone beneath the earth surface is called the vadose zone. Water stored in this zone is termed soil moisture and is utilized by plants Any excess water from the vadose zone will flow downwards, due to the effects of gravity, and into soil or rock where the pores are saturated with water. This area is referred to as the saturated zone. The surface of the saturated zone is called the water table. Water stored in this zone is called groundwater. Over time the flow of groundwater in the saturated zone will discharge into a stream, lake or ocean.

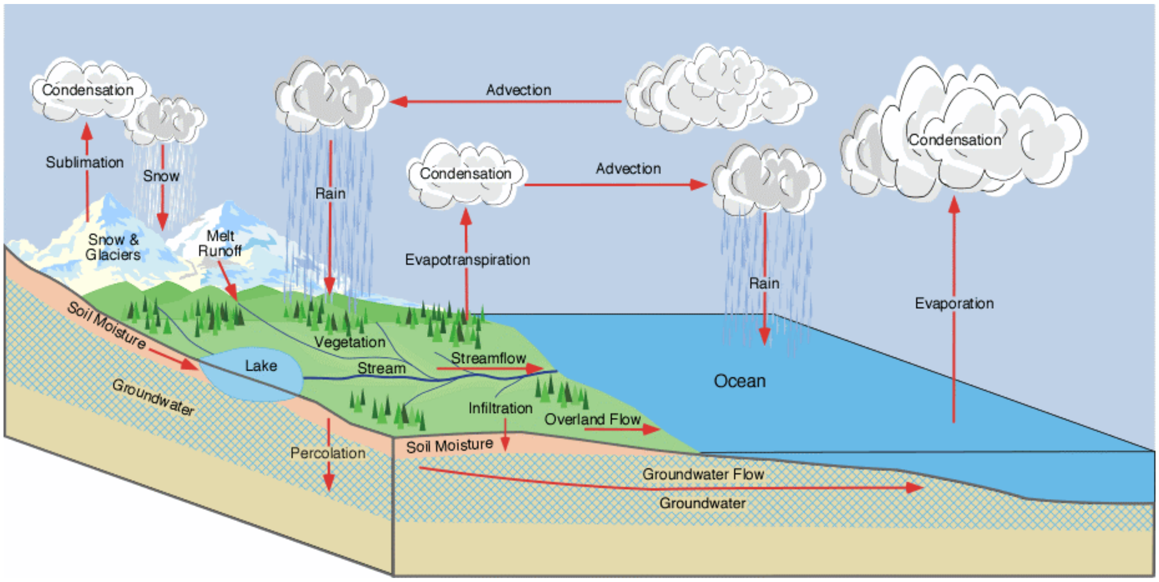


Figure 6. Schematic Section of Typical Hydrologic Cycle (Pidwirny 1991-2001)

Groundwater is the water found in the saturated zone of subsurface material such as gravel or till. These saturated zones are termed aquifers which may occur at very shallow depths in unconfined aquifers (e.g., surface seepage areas) or deeper areas in confined aquifers (e.g., bedrock) (Figure 7).

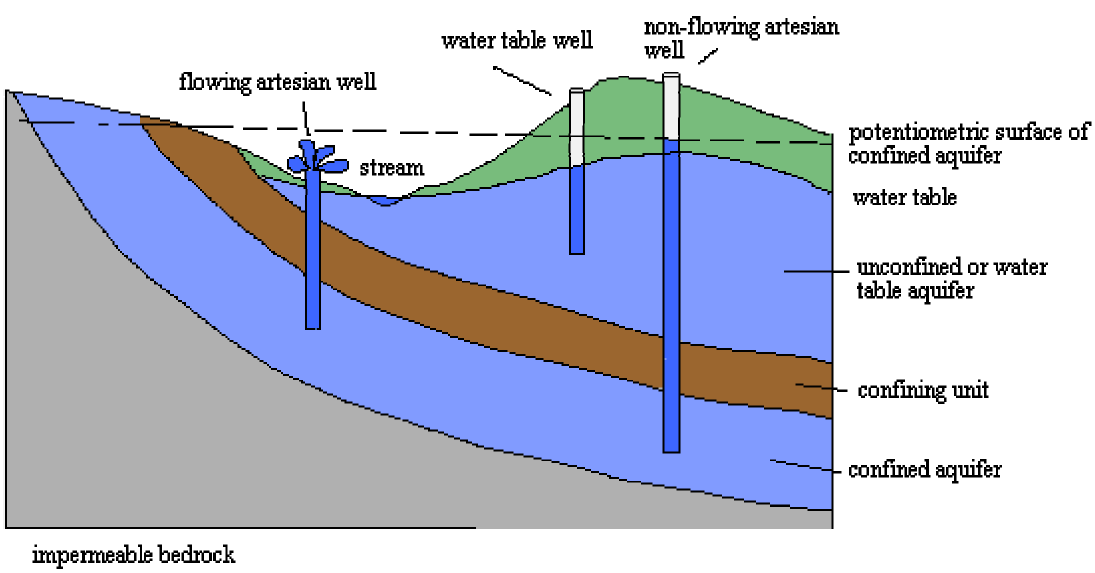


Figure 7. Illustration of Unconfined Versus Confined Aquifers (EPA Region 5 and Agricultural & Biological Engineering, Purdue University 1998)

The development and operation of oil and gas fields and the burying of a pipeline are known to have potential impacts by intercepting shallow groundwater flow. Drilling and seismic activities are also known to have the potential to impact groundwater sources. Contamination of groundwater through sump degradation or drilling through aquifers is a possibility.

One of easiest pathways for the potential contamination of groundwater and probably the most recognizable to the general public is the result of a surface spill. Spill prevention is especially important in permafrost regions. Frozen ground can act as an impermeable barrier keeping and accumulating hydrocarbon contaminants within the active soil layer. If contamination travels laterally on top of the permafrost layer, there is the greater potential of it leaching into surface water sources.

4.3.1 Baseline

The understanding of hydrogeology and groundwater in the NWT has been developed from a series of site specific studies frequently linked to development projects or independent studies by federal government or university researchers. The information is largely limited to some work done in the Nahanni area (e.g., not associated with an oil and gas development area or the pipeline). Some information has been maintained on community water sources and its quality.

Historically, the original Mackenzie pipeline project (mid-1970s) resulted in studies undertaken through the Environmental-Social Program Northern Pipelines of the Government of Canada, which produced maps containing information on groundwater hydrology (DIAND 1975). The Inland Waters Directorate, Environment Canada also produced a report on the hydrogeological considerations in northern pipeline development (Harlan 1974). This report considered groundwater movement and discharge under permafrost conditions and how this might adversely affect pipeline construction and operation.
There is limited current information on the near surface groundwater characteristics (quantity and quality) along the potential pipeline, which is considered to be the main concern of the scientists providing input on this gap analysis project, with respect to groundwater. An understanding of such information is required to assess the potential impacts (geotechnical, water, fish and wildlife) during and after pipeline construction. This information is required for the potential pipeline, and for buried pipelines associated with the Cameron Hills, Liard Plateau and Norman Wells oil and gas development areas. This information is most critical for the area between Great Bear Lake to Fort Simpson coming out of the Franklin Mountains (B. Grey pers. comm. 2003).

DIAND established a computerized groundwater database system for the NWT to improve the efficiency of the regulatory process, which could assist in understanding potential impacts to groundwater. The database is a compilation of a detailed groundwater resource inventory for the territory including all available data on water supply wells, monitoring wells, springs and seeps, and any other areas of hydrogeological interest (Piteau Engineering Ltd. 1990). The NWT database contains 564 records. Of the 564 records, 223 are of test holes drilled as part of the Norman Wells Pipeline project, and include geological log information and some water level and permafrost data. This database will be beneficial for environmental assessment of a potential pipeline.

4.3.1.1 Baseline Knowledge Gaps

1. Need to characterize (quality/quantity) near surface groundwater flow along the potential pipeline corridor.

4.3.2 Impact Assessment and Regulatory Gaps

While it is expected that pipelines will have little or no direct impact on groundwater (Kavik-Axys and LGL 2001), concern has been raised over the potential impacts of permafrost changes on existing groundwater conditions that may result from construction and operation activities and from climate change. In more recent years, attention in the NWT has turned to the potential of groundwater contamination from drilling activities and disposal of drilling wastes.

In the early 1970s, a study by Dames and Moore (1974) of surface and ground water quality impacts from drilling sumps was conducted based on the assumption that the disposal of drilling mud and related fluids and solids would be conducted by placement into below-ground excavations (during the operation phase), and by eventual burial in permafrost or controlled decanting into water bodies. Recommendations to minimize water quality and sensitive habitat degradation were expected to be achievable to acceptable levels of the day with design, construction and restoration methods using the most advanced knowledge in the fields of geotechnical engineering and environmental sciences. Recommendations on the location of sumps, design, excavation, dyke construction, supernatant disposal, reclamation of sumps, and revegetation were made specifically for the Mackenzie River Valley, related to ground-ice content, soil type and topography of a region.

One NWT field survey was conducted, utilizing geophysical soil conductivity measurements coupled with near-surface soil chemistry analyses, to determine if drilling wastes were migrating away from the boundaries of eight capped sumps abandoned over a range of permafrost conditions in the Mackenzie Valley (Hardy BBT Limited 1988a). Based on the collected evidence, six of these were rated as having some likelihood of leakage. It was predicted that poor drilling fluid containment results primarily from factors related to location. Based on this study, current practices for the disposal of waste drilling fluids comprised of waste mud and drill cuttings in a chemically treated suspension require that the drilling fluids be totally contained in situ in permafrost (White 1998). Further in 1988, DIAND assessed the performance of abandoned sumps in containment of waste drilling fluids and made suggestions to improve the practice of total containment (DIAND 1988). Section 4.2 (Permafrost) further discusses the potential environmental impacts of sumps

A common practice in the oil industry is the use of saline water for reinjection into spent reservoirs to maintain pressure and to flush reservoirs to enhance the oil recovery process (Maxim and Niebo 2001). Spills of saline water have been recorded at well heads, along pipelines and at central processing facilities. Maxim and Niebo (2001) reported spills of saline water on Alaska's north slope between the years 1977 and 1999.

The formation of icings adjacent to the pipeline corridor can cause serious problems. Icings are defined as a mass of surface ice formed during the winter by freezing by successive sheets of water that seep from the ground, from a river, or from a spring (Muller 1947; van Everdingen 1979). The trench fill material around the pipeline is likely to be more permeable than the surrounding soils, and therefore may act as a conduit, diverting both surface and groundwater flow. This condition may lead to erosion of the trench fill (i.e., piping or washouts), or possibly the formation of unnatural groundwater discharge zones. During cold periods, these areas may freeze and subsequently create icings that may cause confining conditions for drainage and increased hydraulic pressures at depth. This condition in turn may induce ground heaving or jacking of the pipeline.

Permafrost creation may impact area hydrogeology. In unfrozen ground a chilled pipeline would freeze water in the surrounding soil. This could potentially result in the formation of a frost bulb (an area of frozen soil in proximity to a pipeline) that may disrupt groundwater drainage patterns (Yarrow Holdings Limited 1985). Frost bulbs can potentially create problems at stream crossings and interfere with water flow, fish movement, erosion and pipeline integrity. Shallow groundwater flow can also be affected by the melting or degradation of frozen terrain . Further study is required to understand the near-surface groundwater conditions along the pipeline route (see Section 4.3.1), as well as the impacts of permafrost degradation and creation on groundwater flow regimes.

4.3.2.1 Impact Knowledge Gaps

1. Need to identify the effects of permafrost degradation and creation (e.g., frost bulb development) on groundwater flow regimes along the potential pipeline corridor and at stream crossings.

See Section 4.2.2 and 4.2.2.1 for information and research gaps related to drilling waste sumps.

4.4 Surface Water

Surface water abounds in the NWT in the form of streams, ponds, lakes, wetlands and rivers. For centuries, NWT surface waters were the primary means of transportation, and a primary source of drinking water.

Impacts on surface water can result from hydrocarbon development and pipeline construction:

- contamination from spills or sumps;
- siltation at stream crossings;
- waterflow redirection or damming; and
- water withdrawal for drilling.

Impacts to surface water in relation to oil and gas development can generally be placed in one of two categories - changes to water quality, and changes to water quantity. Water quantity information is important because of its use in estimating peak flows for temporary or permanent river crossings, defining the amount of scour to be expected in river channels, and determining dispersion and dilution of any contaminant spills or leakage.

Changes to water quality are of particular concern in the development of oil and gas reserves, and could result from the transportation of oil and gas, and the potential for spills. Spills can also occur from other related activities (e.g., the use of diesel, drilling fluids). Development activities can also impact surface water through sedimentation at stream crossings by pipelines and access roads, inadvertent damming of water courses with ice jams on winter access roads, rechanneling of water courses, and vegetation removal near water courses.

4.4.1 Baseline

The Gwich'in have been documenting TK for watercourses in the Gwich'in Settlement Area for some time. The river systems studied include the Mackenzie, Arctic Red and Peel. The Gwich'in Social and Cultural Institute and the Gwich'in Renewable Resource Board (GRRB) have both collected TK about Gwich'in use of these rivers. Parks Canada has also collected TK as part of its efforts to designate a portion of the Arctic Red River a heritage river. In the Gwich'in Settlement Area, inland lakes are less well studied. The only inland lakes and rivers well studied are those being considered for special conservation measures. Documented sources of TK about inland lakes and streams near the pipeline route are also limited in the Sahtu region.
In the Sahtu and Gwich'in regions, TK documentation is required to accompany land use permits or water license applications to the Sahtu Land and Water Board and the Gwich'in Land and Water Board. This knowledge has largely been gathered through community consultations conducted by developers. Access to these sources of TK is held with communities, i.e., the proponent may use the information for the project but not share it with others.

Some insights into the TK information that exists with respect to local water use, aquatic species and wildlife was discussed during regional workshops hosted by the RWED in the Gwich'in, Sahtu, and Deh Cho regions in 2002. Communities expressed concern over the lack of detailed information and understanding of baseline water quality and quantity regions in the watersheds of the oil and gas development areas.

Hydrological and Hydraulic Modelling

Hydrological information has been collected for the Mackenzie River and tributaries (e.g., Mackenzie Valley Pipe Line Research Limited 1971). However, there has been limited use of watershed and streamflow routing models in the Mackenzie River basin. In the 1970s, concern arose over the effect of upstream development on downstream flow regimes and ecosystems, particularly in sensitive deltas like the Mackenzie. Environmental studies were undertaken by the federal government, three provinces, and two territories in the Mackenzie River basin from 1978 to 1981, which produced new environmental information, and improved understanding of complex physical and biological processes in the basin. Development of a SSARR-based SIMPAC streamflow routing model provided the capability to route flows through the basin. Hydraulic models with physically-based routing algorithms, such as the 1-D

Hydrodynamic Model, have increasingly been used since 1981. Environment Canada, Headquarters completed an initial application of the 1-D model to the Mackenzie Delta in 1978/88. Since 1991, Environment Canada (Yellowknife) has continued development of flow routing capabilities for the Mackenzie River and the Mackenzie Delta, including:

- simulation of Mackenzie Delta channel water levels and flows using the 1-D Hydrodynamic Model;
- routing of mainstem Liard-Mackenzie flows using a SSARR-type streamflow routing model; and
- initial work towards simulation of mainstem Mackenzie River water levels and flows using the 1-D Hydrodynamic Model.

This modelling enables forecasting of high-water levels during navigation season (June 1 to mid-October, plus late May in upper part of basin), forecasting of low-water levels during low-water part of navigation season (August 1 to mid-October), defining high-water levels during break-up, period and analysis of winter flows (mid-October to noted break-up period, Jasper and Kerr 1994).

Hydrologic modelling is an important aspect of project planning and design. Hydrologic models have largely been developed for southern Canada, and need to be adapted to include permafrost regions, where the relative importance of hydrological processes are complex. Some work is underway through the Mackenzie Global Energy and Water Cycle Experiment Study (MAGS) which started in 1994 (MAGS 2003). MAGS emphasizes the cold region climate system, using the Mackenzie Basin as the focal point of research. The overall goals of MAGS are to understand and model the high-latitude energy and water cycles that play roles in the climate system, and to improve our ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change. Under the MAGS Program, there are projects that undertake aspects of atmospheric, hydrological and modelling research that are integral to the attainment of our overall goals.

Hydrologic models have also been developed for Alaska and other circumpolar countries, which could be considered.

A hydrological study was conducted in a small tributary to Manners Creek, situated in the zone of discontinuous permafrost near Fort Simpson to identify the origin, mixing history and pathways of runoff during snowmelt and storm runoff events. Peak freshet discharge was comprised of 50 to 60% active-layer water and 40 to 50% snowmelt. The high proportion of active-layer water observed in peak freshet discharge indicates the importance of subsurface flow paths in permafrost slopes during spring melt. Overland flow and saturated groundwater flow are inferred to be important pathways of rapid and delayed runoff, respectively, during the freshet period. Shallow active-layer water from permafrost slopes dominated the hydrograph throughout the freshet period despite the small areal proportion of permafrost in the tributary catchment (~10%) (Gibson *et al*. 1992).

Water Quality/Quantity Stations

Although the Liard River basin is currently characterized by stretches of essentially pristine wilderness, a number of ongoing land use activities have been identified that have significant potential to influence aquatic resources. A review of the available information indicates that mining, logging, and oil and gas developments in British Columbia have the highest potential to affect water uses in the NWT. The potential effects of municipal and linear developments, agricultural activities, hazardous waste sites, and long range transport of atmospheric pollutants on environmental quality in NWT was also evaluated by MacDonald Environmental Services Ltd. (1993) and considered to be of lesser importance. Of all the anthropogenic activities investigated, potential additional hydroelectric projects in British Columbia (Peace River Site 3 dam) have the greatest potential for affecting environmental conditions in the NWT portion of the Liard River, particularly flows in the summer and winter in addition to changes in thermal regime and water quality. Data from other river systems also suggest that the quality of fish tissues in the NWT may be degraded through the mobilization of mercury and other contaminants. Using the available information, a total of sixty-three priority variables have been identified for consideration in the Liard River monitoring program. Development and implementation of such a monitoring program would provide the data necessary to establish baseline conditions and assess trends in environmental quality in this region (MacDonald Environmental Services Ltd. 1993).

From 1938 up to the present time the Environment Canada’s Water Survey of Canada has operated hydrometric stations on many of the streams in the Deh Cho Region. The hydrometric network in the Deh Cho currently consists of 16 operating stations, and historical streamflow data are available from a total of 41 stations – six of the stations provide 30 or more years of flow data and 18 provide 20 or more years of data (Faria 2002). Faria (2002) presents the data collected from the current and historical stations using mean and extreme annual hydrographs, a summary of basin statistics, and frequency analyses of extreme annual events.

Beginning in 1933, Water Survey Division has operated up to 30 hydrometric stations on streams within the Gwich’in and Sahtu Settlement Areas, six of which are currently operating in the Gwich’in Settlement Area and six in the Sahtu Settlement Area (Kokelj 2001). In Kokelj (2001), hydrometric data from 30 current and historical stations are presented using mean annual hydrographs, extreme-year hydrographs and basic statistics. Flood frequency analyses using the Pearson theoretical distribution were completed for stations with twenty or more years of data.

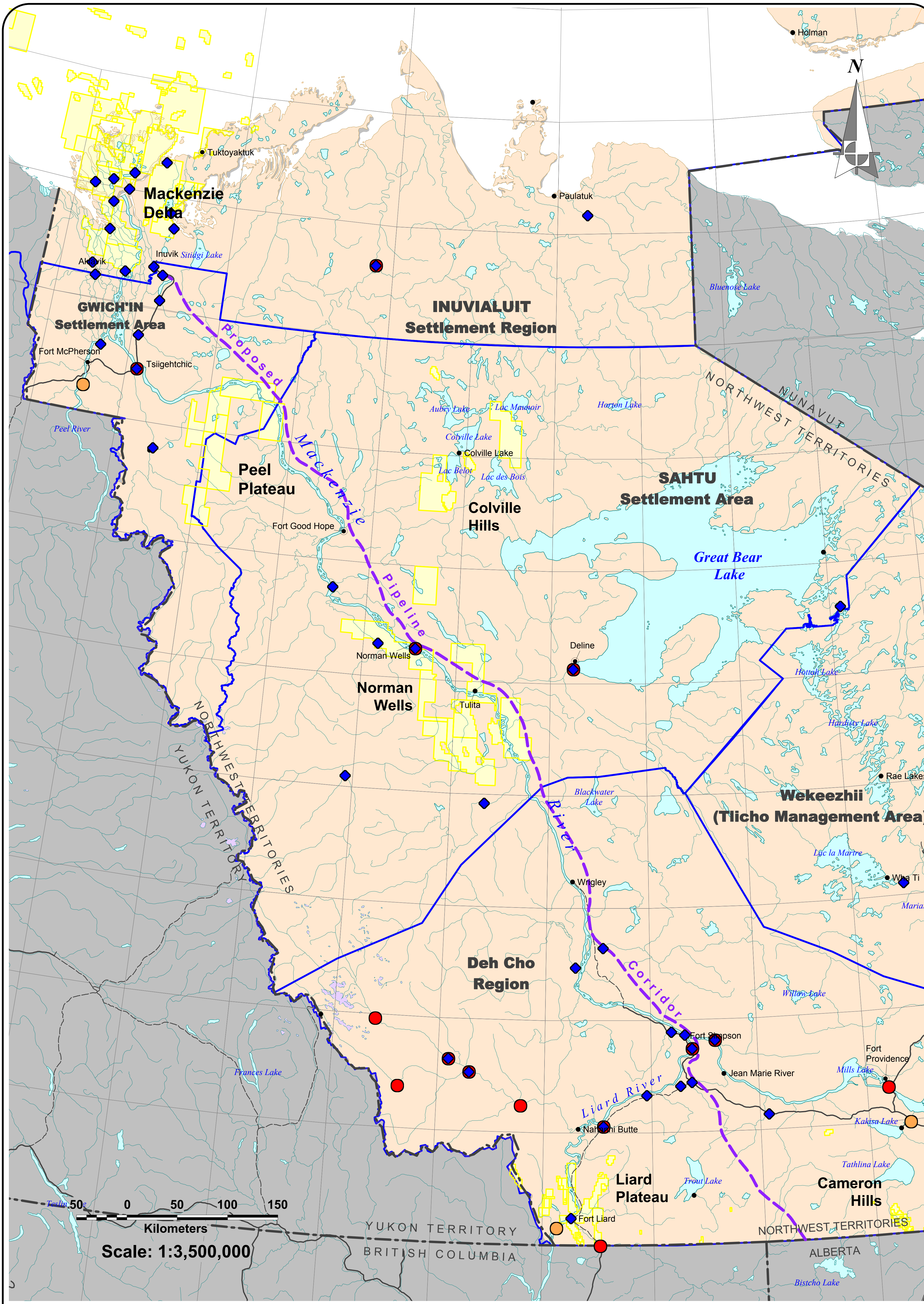
As mentioned above, information on water quantity (water levels and flows) is available from the 1930s, when collection of water level data began at a few stations on the Mackenzie River by Environment Canada. Additional stations were added after establishment of a Water Survey of Canada office in Fort Smith in 1960, and the mid-1970s signing of federal/provincial cost sharing agreements for operation of water quantity monitoring stations. Stations are currently operated on a sparse network of major tributaries to the Mackenzie River, a few mainstem Mackenzie River sites, and a few other sites of interest to highway design/operation and other interests. While many of the remaining stations have records exceeding 25 years, some are only operated seasonally for the Mackenzie River navigation forecast. In addition, stations formerly operated on about 10 to 12 smaller watersheds in the Mackenzie Valley for highway and pipeline design purposes were shut down in the 1990s, due to lack of funding. As a result, the current water quantity monitoring network is therefore sparse on the Mackenzie east bank tributaries along the pipeline route from the Mackenzie Delta to the Alberta border (B. Reid pers. comm. 2003). The region from the south end of the Delta to Norman Wells lacks any data on river flows and levels, and winter low flow regimes are lacking for all areas (B. Reid pers. comm. 2003).

Figure 8 shows the currently operating hydrometric and water quality stations (Environment Canada and DIAND) in the general study area for this project. Appendix G lists the currently operating and historical hydrometric stations by land claim region, and indicates the station name, location, and operating period of the station. The information was obtained from the 2003-04 Historic Network Database maintained by Environment Canada.

The Water Survey of Canada Division and the Ecosystem Health Assessment Section, Ecological Research Division (Environment Canada) provide access to collected hydrometric data through the annual publication of the HYDAT CD.

Water quality data are compiled by Environment Canada, Prairie and Northern Region using (the national EnviroDat Model) Aquatic Chemistry and Biological Information System (ACBIS) and various versions of EcoAtlas IMS/GIS display application. The locations of water quality stations maintained by Environment Canada and DIAND within the general study area for this project are shown in Figure 8.

Table 9 outlines information on the water quality stations operated by DIAND. The stations at Liard River above Kotaneelee River, Kakisa River at Highway 1 Bridge, and Peel River above Fort McPherson are shown on Figure 8.



Legend

- Approximate Location of Proposed Pipeline Corridor
- Oil & Gas Dispositions (Sept. 2003)
- Hydrometric Stations (Environment Canada)
- Water Quality Stations (DIAND)
- Water Quality Stations (Environment Canada)

Source of Data:
DIAND Water Resources Division, and Environment Canada, Environmental Conservation Branch, Yellowknife NT, 2003

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2004

Project Number: 22-649

File Name: 22649-F8-R2.WOR

Revision: 2

Active Surface Water Quality and Hydrometric Stations

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No. 8

Table 9. Water Quality Stations Operated by DIAND

Station Name	Activation Date	Sampling Program	Status	No. Samples/Year	Analysis*
Slave River at Mouth	1982	On-going	Inactive	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Tazin River at the Mouth	1982	On-going	Inactive	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Yellowknife River upstream of Yellowknife Bay	1960	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Cameron River below Reid Lake	1992	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Marian River at Frank's Channel	1998	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Liard River above Kotaneelee River (NWT/BC transboundary site)	1992	Project Specific/On-going	Inactive	~8-9 times a year for 5 years from 1991-1995. Now only 3 times a year every 5 years	Routine, Major Ions, Nutrients and Metals, Organics
Slave River at Fort Smith (NWT/Alberta transboundary site)	1990	Project Specific/On-going	Active	~8-9 times a year for 5 years from 1990-1995. Now only 3 times a year every 5 years	Routine, Major Ions, Nutrients and Metals, Organics
Kakisa River at Highway 1 Bridge (Cameron Hills area)	1982	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Salt River at Highway 5 Bridge (NWT/Alberta Border site)	1982	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Little Buffalo River at Highway 5 Bridge (NWT/Alberta transboundary site)	1982	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Hay River at West Channel Bridge (tributary to Great Slave Lake)	1982	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals

Station Name	Activation Date	Sampling Program	Status	No. Samples/Year	Analysis*
Buffalo River at Highway 5 Bridge (tributary to Great Slave Lake)	1982	On-going	Active	2 (Spring and Fall)	Routine, Major Ions, Nutrients and Metals
Peel River above Fort McPherson (Yukon/NWT transboundary site)	1960	On-going/Project Specific	Inactive	~4 times/year	Routine, Major Ions, Nutrients and Metals, Organics

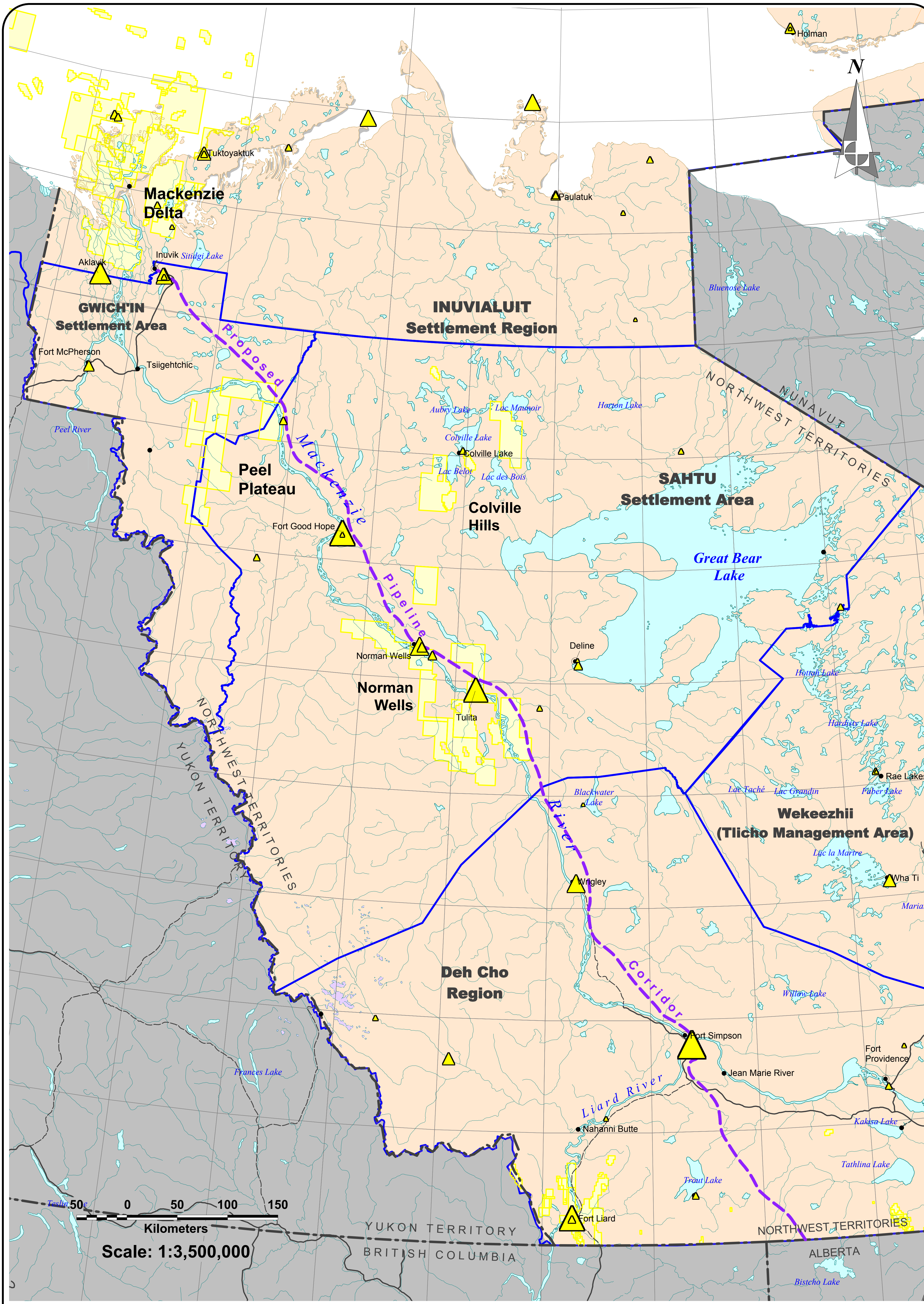
**Routine: pH, turbidity, TSS, TDS, conductivity, alkalinity, hardness, colour*
Major Ions: K, Na, Ca, SO4, Mg
Nutrients: NH3, T Phos, D Phos, NO3+NO2
Metals: full suite of metals including As and Hg
Organics: Organochorines Suite, Polyaromatic Hydrocarbons Suite, Herbicides, Dioxin and Furans, and Chlorophenol Suite

The Mackenzie River Basin Board is expected to release its State of the Aquatic Ecosystem Report by early 2004. The report will describe the state of the aquatic ecosystem environment within the five major sub-basins that make up the Mackenzie River basin. The report is expected to compile data from Environment Canada, DIAND, and the governments of the NWT, Yukon, Alberta, British Columbia and Saskatchewan (D. Halliwell pers. comm. 2003). Previously, under the Arctic Environmental Strategy (1991 to 1997), baseline information was collected about water quality and quantity in the NWT including areas of oil and gas development e.g., Petitot River, Liard Valley, and summarized in such reports as the *Final Report: Liard River Water Quality Monitoring Program* 1998.

During the *Norman Wells Workshop* and community visits, communities expressed concern over the lack of information and understanding of baseline water quality and quantity regimes in the watersheds of the oil and gas development areas. This information would assist in regulation and management of water quality in these areas.

Snow Survey Data

In the NWT, snow data are collected at about 50 locations by DIAND and at about 40 Environment Canada weather stations. The snow survey network is sparse and is focused on basins with hydroelectric developments and major communities. No snow data has been collected in the Mackenzie Mountains and little in the oil and gas development areas (B. Reid pers. comm. 2003). Some of the existing data are for end-of-season snowpack only. Active climate stations (Environment Canada) measuring temperature and precipitation (hydrologic inputs) are located in communities, usually at the airports (Figure 9). Main airports (e.g., Inuvik) have 24 hour climate monitoring, while smaller airports (e.g., Fort Good Hope) have less frequent monitoring, in the order of 8-12 hours/day and usually only on weekdays.



Legend

Approximate Location of Proposed Pipeline Corridor

Oil & Gas Dispositions (Sept. 2002)

Active Climate Stations
(Length of Record)

100 years

50 years

10 years

Source of Data:
Environment Canada, 2003

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2004

Project Number: 22-649

File Name: 22649-F9-R3.WOR

Revision: 3

Active Climate Stations

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No.

9

Snow pack contributes to overall surface and ground water quantities each year. By monitoring snow pack, more accurate hydrological modelling can be completed, predictive models/assessments of the affects of climate change can be determined (as climate change affects snow pack and overall precipitation), and ground thermal regime changes as a result of changes in snow pack can be understood.

Baseline Hydrocarbon Levels

Several published NOGAP reports evaluate naturally occurring hydrocarbon levels and suspended sediments in water. A study of the Mackenzie River evaluated hydrocarbons in sediments and suspended sediments, and determined downstream trends (Nagy *et al*. 1988). Results indicated the presence of n-alkanes and polycyclic aromatic hydrocarbons (PAHs) in the sediments and water column throughout the study area. Organic loading was shown to correlate significantly with the seasonal variation of the flow of the river (Nagy *et al*. 1988). Naturally occurring hydrocarbons (including PAHs), compared to anthropogenic hydrocarbons, predominate in the Mackenzie River (for samples collected in the Inuvialuit Settlement Region) and on the Mackenzie shelf, and a correlation exists between hydrocarbon type and geological characteristics (Yunker *et al*. 1993). These hydrocarbons include biogenic alkanes and triterpenes, and PAHs from oil seeps and/or bitumens, and combustion PAHs that are likely relict in peat deposits. The study concluded that the season has a strong influence on the concentration and composition of hydrocarbons in the Mackenzie River.

Carey *et al*. (1989) conducted investigations in 1985 and 1986 extending from the confluence of the Liard and Mackenzie Rivers to the Mackenzie Delta near Inuvik. The study examined the sources and transport of hydrocarbons (alkanes and PAHs) to the lower Mackenzie River. Carey *et al.* (1989) concluded that inputs of hydrocarbons due to anthropogenic activities are relatively minor compared to inputs from natural processes or long-range transport of atmospheric soot particles; and that the results provide a baseline against which future impacts can be assessed.

Other studies have also examined the distributions and sources of PAHs, alkanes and hopanes in samples from the Mackenzie River delta (Yunker and MacDonald 1995; Yunker *et al*. 1991, 1994, 1995 and 1996).

Sources of petroleum-associated hydrocarbon in surface waters around Norman Wells include natural seepage, wastes and effluents from exploration, production and refining at Norman Wells and spills (Lockhart *et al*. 1992). Hydrocarbons can also originate from combustion of carbon-based fuels, generally at lower latitudes and then reach the Arctic with air movements. Organochlorine compounds also move throughout the hemisphere by aerial pathways and have become distributed widely in Arctic fish.

Some research on hydrocarbons in surface waters has occurred in Mackenzie Delta/Lower Mackenzie River region, but little has occurred in the Mackenzie River valley, and its associated streams and lakes. As hydrocarbons can occur naturally in surface waters in the Mackenzie Valley area, and also have the potential to result through anthropogenic means from oil development, it will be important to determine baseline hydrocarbon levels, sources and potential effects for streams and lakes in the oil development areas and along potential oil pipeline corridors.

Rapid Lake Drainage

Following a cooling trend that started approximately 4500 BP, thousands of thaw lakes[15] in the Mackenzie Delta area have been lost from the landscape due to erosion of drainage channels through ice-rich permafrost (Mackay 1992), and the complete emptying of the lakes. This phenomenon can occur where lakes are surrounded (dammed) by ice-rich permafrost. There is potential for such rapid drainage events to occur south of the delta, where appropriate conditions exist (P. Marsh pers. comm. 2003). It appears that drainage is initiated during periods of high water in the spring runoff periods of heavy rain, or in the spring due to the existence of a snow dam at the normal lake outlet (Marsh and Neumann 2001). However, the processes controlling the drainage are not well understood (P. Marsh pers. comm. 2003). Recent research has shown that a naturally drained lake has sufficient energy in the lake water to melt ice-rich permafrost (Marsh and Neumann 2001). This could in turn create issues (e.g., ground subsidence) to pipeline integrity and other oil and gas infrastructure. Future changes to the climate in the Mackenzie Valley region could influence the processes controlling drainage of these lakes, and have implications on (for example) channel erosion, water quality, riparian vegetation and aquatic fauna (Marsh and Neumann 2001).

At the *Scientists' Workshop* it was identified that there is a need for an improved database (including grain size) on geomorphology settings at stream crossings. This information will enable a comparison with post construction conditions for determining potential impacts, and will allow for determination of unstable geomorphic conditions that may require avoidance or special construction techniques to be used. Information on sediment size materials is required to determine appropriate pipeline burial depths, and is important for hydraulic modelling.

4.4.1.1 Baseline Knowledge Gaps

1. Need to determine natural background hydrocarbon levels (e.g., polyaromatic hydrocarbons – PAHs) in streams and lakes in oil development areas and along potential oil pipeline corridors.

2. Existing hydrologic models need to be adapted to Mackenzie Valley conditions.

3. Additional hydrometric data for tributaries of the Mackenzie River are required.

4. Expansion of the snow survey data collection program is required.

5. Requirement to understand the natural processes that lead to rapid lake drainage and identify areas where there is potential for this phenomenon to occur in relation to oil and gas activities.

---

[15] Lakes that developed during a postglacial warm period between 13,000 BP and 8,000 BP when increased active layer depths resulted in thawing of the upper layers of ice-rich permafrost (Mackay 1992)

6. Improved database (including grain size) on geomorphology settings at stream crossings is required

7. Need to determine the baseline water quality and quantity regimes by improving upon the available data in oil and gas development areas.

4.4.2 Impact Assessment and Regulatory Processes

Impacts to surface water quality and quantity have the potential to impact the aquatic environment. Further information on surface water/aquatic-related impacts is provided in Section 4.5 (Fish and Fish Habitat).

As noted above, potential impacts on surface water from pipeline and hydrocarbon development can result from: contamination from spills or sumps, erosion and siltation at stream crossings, waterflow redirection or damming, and water withdrawal for drilling. For the latter three potential impacts, standard mitigation measures exist or are regulated, and are therefore not discussed in depth.

Current industry practice of water crossings by pipelines is described in Water Course Crossings (Canadian Pipeline Water Crossing Committee 1999). However, the cumulative length of pipeline constructed in non-permafrost terrain is overwhemingly greater than the relatively few kilometres constructed in permafrost terrain. Sections 4.1 and 4.2 (Terrain and Surficial Geology, and Permafrost) describe the knowledge gaps related to pipeline construction in permafrost terrain.

A significant issue related to potential water quality impacts from hydrocarbon development activities relates to past, present and future disposal of drilling waste (T. Paget pers. comm. 2003). There are over 1,400 sumps presently located in the combined areas of the Yukon, NWT, Nunavut and high arctic islands. Traditionally sumps have been located adjacent to drilling rigs to allow, for direct discharge from the rig to the sump. As drilling rigs are often located adjacent to water bodies for easy access to water resources required for drilling operations, sumps are often located adjacent to or in proximity to water bodies. Section 4.2.2 discusses permafrost terrain impacts resulting from sumps – these impacts are closely related to potential impacts to surface water, as the movement of hydrocarbon contaminants from failing sumps have the potential to migrate to nearby surface waters. Most of the research conducted on sumps has been focused in the Mackenzie Delta and little, if any, research has been conducted to assess how these drilling wastes and associated sumps impact surface water quality (T. Paget pers. comm. 2003). ESRF-funded studies are currently taking place in the Mackenzie Delta. Information and research gaps related to sumps are outlined under Section 4.2.2.1.

There are relatively few documented sources of TK concerning the impact of oil and gas development on water in the five development areas. More TK has been collected along a corridor for a possible pipeline. A recent science and TK study about the impact of ferry landing operations on water quality in the vicinity of Tsiigehtchic and Fort McPherson in the Gwich'in Settlement Area was carried out (GeoNorth 2001).

Anecdotal or community information on reduced water quality was raised at the 2002 workshops in the Gwich'in, Sahtu and Deh Cho regions (RWED 2002a). A common concern was the potential or actual contamination of drinking water and the impact on the health of wildlife, fish and people. In addition, development impacts on the Deh Cho watershed were raised as a concern at the Deh Cho Wildlife Needs Workshop in 2002.

Monitoring of watercourse crossings along the Norman Wells to Zama pipeline was initiated in 1984 to identify any physical conditions which may result in negative impacts to the aquatic resources along the pipeline route (Fernet 1986). Specifically, the approaches and instream ditchline of watercrossing were examined for stability, any pipeline-related alterations to the watercourse were evaluated, upstream/downstream areas were compared to evaluate potential sedimentation concerns, and watercrossings were assessed to determine whether the ROW was contributing to the degradation of water quality or aquatic habitat. One of the most common concerns identified during 1984, 1985 and 1986 monitoring was subsidence of ditch backfill on stream approaches and stream crossings, which was often associated with ponding at the stream crossing. Erosion was noted at many stream crossings although in the vast majority of cases it was minor in nature. Water was also noted to be seeping from several wood-chip protected slopes, which was identified as a potential concern if seepage is indicative of permafrost degradation in the slope and thus potential slope instability.

BGC Engineering Inc. (2003) completed a report entitled Standards of Practice Water Course Crossings with focus on the crossings required for a potential Mackenzie Valley pipeline. The report considers the three broad categories of pipeline stream crossing methods: trenchless methods (horizontal directional drilling or boring), open cut with isolation method to control stream flow and open cut without flow control. The horizontal directional drilling method will only be practical for small (up to 10 m wide) and intermediate sized streams (e.g., 10 to 100 m wide) because large diameter pipelines require relatively long drilled lengths to accommodate minimum radii of pipe curvature. Open-cut methods will be required on small and intermediate sized streams, in which case the trench within a channel should be backfilled with excavated spoil material. Because most of the stream crossings will occur during the winter period, thawing of frozen trench backfill material during the following spring period will typically result in thaw settlement and sloughing of backfill material. The report indicates that it will likely be necessary for the contractor to return the following winter to complete backfilling, remove unacceptable backfill material and to install additional surface drainage measures. This suggestion speaks to the issues identified above by Fernet (1986).

EVS Consultants Ltd. (1986) completed a study to provide a comprehensive characterization of chemical constituents within crude oil and refinery effluents at Esso Resources Ltd. Norman Wells site. In addition, a review of the literature and ongoing research regarding the effects of similar developments in northern areas, the probable environmental pathways of those constituents most likely to have a deleterious impact on aquatic biota and a research program to establish research needs and priorities was completed.

The high pressure waterjet concept for controlling oil on the surface of water was tested for use in broken ice in Norman Wells where usual response techniques are not effective. This method was found efficient in both calm water and choppy waves. Optimum values from the tests were used to build a 30.5 metres (100 ft) long prototype in order to evaluate the operational efficiency of such a barrier (Laperriere 1985).

The long-term impacts on surface water from existing oil and gas development activities in the Mackenzie Valley are not well understood. An understanding of existing impacts and effectiveness of mitigation measures would help in the understanding of future project impacts and cumulative impacts. The developments and associated impacts in the Cameron Hills, Liard Plateau and Norman Wells areas could be used as case studies. This conclusion was drawn from the *Scientists' Workshop*.

4.4.2.1 Impact Knowledge Gaps

1. Need to research how stream and lake water quality is affected by natural hydrocarbon seeps.

2. Need to determine how background hydrocarbon levels in streams and lakes can be distinguished from those resulting from exploration and development activities.

3. Requirement to understand long term environmental impacts to surface water as a result of oil and gas development activities in existing oil and gas development areas

4.5 Fish and Fish Habitat

Like wildlife and wildlife habitat in the Mackenzie Valley, fish and fish habitat reflects the transition environment that they inhabit. Caught between boreal and sub-arctic conditions, most of the species in the Mackenzie Valley migrated north after the retreat of the last glaciers (French and Slaymaker 1993) and therefore, may be at the limit of the range.

Potential impacts to fish and fish habitat as a result of hydrocarbon development and pipeline construction may include:

- disruption and destruction of habitat;
- changes to water quality and quantity;
- removal of riparian vegetation;
- damming at water crossings;
- contamination;
- acoustic impacts from blasting;
- disruption of sensitive life stages (e.g., spawning and rearing); and
- increased harvesting pressure caused by increased access to otherwise pristine areas.

4.5.1 Baseline

There are approximately 60 fish species present in the Mackenzie Valley portion of the Mackenzie River drainage Basin. Species include anadromous species from the Beaufort Sea, and resident species from adjacent tributary systems. In general, the tributary rivers on the east side of the Mackenzie River contain more diverse communities than those on the west side, possibly attributed to the differences in water quality (Kavik-Axys and LGL 2001). In the Mackenzie Valley most fish have specific migration routes and limited spawning, over wintering, nursery and feeding areas. In the Mackenzie River, 62% of the fish populations are fall spawners, laying their eggs in the river gravel to overwinter (Berger 1977). Spring spawners constitute 35% of the fish populations; depositing eggs at spring break-up with young emerging within a few weeks.

TK with respect to fish and fish habitat has been documented in the Mackenzie Valley. Harvest studies in the Gwich'in and Sahtu Settlement Areas provide valuable insight to the importance of a variety of fish species to the local diet. Through traditional land use and occupancy studies, some mapping of important traditional and present day fishing areas in the Gwich'in, Sahtu and Deh Cho regions has been carried out.

Additional TK has been documented with respect to fish and fish habitat by the GRRB, and includes information on broad whitefish (*Coregonus nasus*), inconnu (*Stenodus leucichthys*), cisco (*Coregonus* sp.), burbot (*Lota lota*) and Dolly Varden char (*Salvelinus malma*). For the purposes of resource management and protected areas planning, TK about whitefish in some areas of the Gwich'in Settlement Area has been documented.

Limited site-specific TK research describing species presence, utilization, movement and harvest rates is recorded for:

- Travaillant Lakes;
- Arctic Red River;
- Peel River;
- Road River; and,
- Tree River.

Some TK about fish and fish habitat in the Sahtu Settlement Area and Deh Cho Region has also been documented through the land use planning and protected areas planning processes; however, there are no comprehensive sources of TK about fish and fish habitat for these areas.

Scientific baseline fisheries studies have been completed since the 1970s within the hydrocarbon development areas and along the Mackenzie River. In addition to scientific studies, harvest data has been used to complement existing databases. Fisheries information has been studied and summarized by species or by watershed and is discussed below.

Inconnu are present in the Mackenzie River and tributaries such as the Arctic Red, Slave, Liard and Brackett Rivers as separate stocks (Howland 1997). Inconnu are andromous migratory whitefish that migrate between salt water and freshwater, after spending one to six years in freshwater. They are important to subsistence and commercial fisheries in the western Arctic. Extensive baseline data on inconnu was collected along the Mackenzie Valley pipeline route proposed in the 1970s but requires updating today. Although both freshwater and anadromous migratory forms are thought to exist in the Mackenzie River system, little detailed information has been available to substantiate this. Historical information was synthesized and an intensive field study conducted, involving long-term seasonal gillnetting and radio telemetry in two representative rivers, the Arctic Red and Slave, to determine inconnu migratory patterns within the Mackenzie system. The study revealed substantial differences in the timing and extent of spawning migrations in these two rivers and strontium analysis of otoliths confirmed the existence of the two migratory forms (Howland 1997; Howland *et al*. 2000, 2001). In the area of the Mackenzie River around Tulita, Norman Wells and Fort Good Hope, the information is not as comprehensive as that for the northern and southern portions of the river. The life history (anadromous or resident), number of distinct stocks and spawning locations are not known. Little is known of the stocks of inconnu caught in the Brackett River and Liard River systems, including life history and spawning locations (G. Low pers. comm. 2003).

Chum salmon (*Oncorhynchus keta*) migrate up the Mackenzie watershed as far as the Liard River and the Slave River at Fort Smith to spawn. The run is not considered large and is not an important food species in the Mackenzie River drainage at this time[16]. Due to the small size of the run destruction of chum spawning habitat or disruption of spawning activities could have negative consequences for this species in the Mackenzie watershed (G. Low pers. comm. 2003). Chinook salmon (*Oncorhynchus tshawytscha*) have also been reported for the Liard River by McLeod and O'Neil (1983); however, this was the first reported incident of chinook salmon in the Liard River, and it was assumed to be a stray fish that had accompanied a run of chum salmon.

The NWT Cumulative Impact Monitoring Program (CIMP) Working Group (2002) indicates that Dolly Varden char and bull trout (*Salvelinus confluentus*) both occur in the Mackenzie River drainage. Anadromous stocks of Dolly Varden (in the northern portion of the system) return to the same over-wintering locations annually and therefore, stocks are relatively easy to assess for this species (NWT CIMP 2002). Previous reports of char or Dolly Varden in the Liard and in the Mackenzie River as far north as Norman Wells were probably bull trout. It is known that bull trout are sparsely distributed in the southern Mackenzie basin, and are sensitive to anthropogenic disturbances. Baseline data on bull trout is sparse as they were only recognized as a distinct species since the 1970s (G. Low pers. comm. 2003); however, this species has been identified in four locations in the Sahtu Settlement Area (Reist *et al*. 2002). Distribution and habitat requirements studies are underway in the Liard and Mackenzie River basins (NWT CIMP 2002).

Various aspects of broad whitefish ecology have been studied between the northern portion of the Mackenzie River basin to Fort Good Hope. Including parasite scarring (Reist *et al*. 1987), genetics and

---

[16] The most important species for fisheries in order of priority are broad whitefish, inconnu, lake trout, Dolly Varden char, northern pike, lake whitefish, Arctic and least cisco. The species most vulnerable to increased access resulting from development will be lake resident species. In order of vulnerability these include lake trout, lake whitefish and northern pike or jackfish.

stock identification (Treble 1994), commercial and subsistence harvest trends (Treble 1994), migration, reproduction and feeding (Strange 1985) and life history variation (Chudobiak *et al*. 1994). This is an important harvested species with a substantial economy based upon it. There is also a subsistence fishery where it is estimated that close to 300,000 fish are harvested in some years (R. Tallman pers. comm. 2003). A 1994 workshop on this species in Inuvik covered fisheries management issues, TK, life history, stock structure, migration, abundance, the relationship of vital rates of population dynamics, the effects of experimental exploration on vital rates, parasites, cumulative impacts and multi-species considerations (Tallman and Reist 1997).

A study was completed looking at migration, reproduction and feeding in lake whitefish (*Coregonus clupeaformis*), broad whitefish and Arctic cisco (*Coregonus autumnalis*) (from the Mackenzie River). These species are fall spawners that move from overwintering areas to spawning grounds upstream in the Mackenzie River and its tributaries. The study assessed the importance of delta, freshwater and coastal systems (Strange 1985). In addition, several other studies have extended our knowledge of Arctic cisco distribution and spawning habitats. McLeod and O'Neil (1983) identified Arctic cisco spawning in the Liard River, as far upstream as the Grand Canyon of the Liard, and Dillinger *et al*. (1992) determined that distribution, migration and spawning activities in tributaries of the Mackenzie River were more extensive than previously reported.

Just prior to the pipeline proposals in the 1970s, fish species distribution studies were initiated in the NWT. Results of one study (Pivnicka 1970) identified a sub-species of burbot (*Lota lota lacustris*) distributed from Siberia through to the Mackenzie River system that differs from a southern subspecies. In addition, an unusual occurrence of brook stickleback (*Culaea inconstans*) was noted in the Mackenzie River (Falk 1972). Limnological studies, life history of Arctic char (*Salvelinus alpinus*) and Arctic grayling (*Thymallus arcticus*) and fall spawning and overwintering data were collected in preparation for pipeline applications in the Norman Wells area (Aquatic Environments Limited 1974).

Several early fisheries studies were conducted for the Mackenzie Highway. The critical velocities of 16 freshwater and one anadromous fish species from the NWT were determined to ensure that the expected velocities through culverts being designed for the Mackenzie Highway would permit the passage of fish (Jones *et al*. 1971).

In May 1971 the Department of the Environment, Fisheries Service began a four-year investigation into possible effects of northern pipeline construction and other northern development on the fish resources of the Mackenzie River Valley. Fish were captured at sampling stations on the Mackenzie, Liard, Great Bear, Arctic Red and Peel main stems and all significant tributaries crossed by the proposed pipeline routes. The study included determining which species were present, species distribution, age and growth, feeding, length-weight and spawning characteristics were summarized. Baseline data on heavy metals and pesticides in fish tissue were also collected (Hatfield *et al.* 1972). The compilation of a stream catalogue, covering chemical and physical water quality, water flows, spawning gravel areas and major obstructions to fish migration was also completed as part of this study. Aquatic Environments Limited (1973) carried out late winter lake and stream surveys along the proposed Mackenzie Valley gas pipeline routes to determine presence or absence of water, examine water quality, and record any evidence of presence of overwintering fish. Dryden (1973) as well as Stein (1973) reported on the fish resources along the Mackenzie Valley pipeline route.

Construction of artificial islands in the Mackenzie River were proposed as part of the expansion of the Norman Wells oil development in 1980. Samples of benthic macroinvertebrates and shallow water fish populations were collected in the vicinity of the artificial islands to formulate qualitative conclusions about the effects of artificial island construction and water intakes on invertebrate communities and fish (Envirocon Ltd.1980). The results of the study were interpreted with caution due to sampling efficiency problems and time of year. The results, however, suggested that the effects of artificial island construction on macroinvertebrate production in the Mackenzie River near Norman Wells would be localized and minor since the total area of riverbed potentially disturbed would be small and the number of organisms inhabiting the substrate are few. Due to lack of available data, the potential impact of artificial island and intake construction on the fish populations was uncertain.

Management problems noted for the anadromous coregonid species (broad whitefish, lake whitefish, least cisco (*Coregonus sardinella*), Arctic cisco and inconnu) in the northern portion of the Mackenzie River include: international implications resulting from migrations, competing resource users fishing the same species at different locations, intense localized impacts (fisheries and industrial) on migratory riverine populations passing through geographically restricted corridors, several life history types present with unknown contribution to the impacted population(s) and population structuring into distinct genetic stocks that exhibit different life-history patterns and use different habitats.

In general, stock size of fish populations is difficult to obtain for both harvested and non-harvested species. Stock status is determined by analyzing parameters such as growth, size and age structure, sex and maturity, mortality and condition factor. However, no continual monitoring and assessment of fish communities are conducted across the NWT. There are no population estimates for fish in Mackenzie River tributaries. (R. Tallman pers. comm. 2003). Fish stocks in the thousands of inland lakes in the NWT are lightly to moderately exploited. Few have been studied in detail, but few problems have been reported. Stock surveys were conducted on lakes most used in the Deh Cho Region and Sahtu Settlement Area. Fish resources of the Mackenzie River near Fort Good Hope were also surveyed (NWT CIMP 2002). Within the Gwich'in Settlement Area, a fish stock survey was completed in 1999 to provide a preliminary assessment of the fish species present, size of fish, number of fish, and growth rate to determine whether Sandy Lake and Sunny Lake could support a Sport Fishing Lodge (GRRB 2003).

A fish net index study from 1999 to 2001 was completed by Department of Fisheries and Oceans (DFO) to monitor the abundance of fish species in the northern Mackenzie River within the Inuvialuit, Gwich'in, and Sahtu land claim areas (GRRB 2003). Rivers to be potentially crossed by the pipeline that have been considered important include Travaillant, Tieda, Loon, Hare Indian, Great Bear, Blackwater, Ochre, Willowlake, and the Mackenzie (near Fort Simpson) (Kavik-Axys and LGL 2001).

Many lakes within the proposed pipeline corridor are used for subsistence harvesting for lake trout (*Salvelinus namaycush*), lake whitefish, broad whitefish, inconnu and Arctic cisco. A key sensitive area for fish includes lakes in the east Gwich'in Settlement Area. Fish stocks in Travaillant Lake are currently being studied (GRRB 2003). This is the largest lake in the Gwich'in Settlement Area and is an important area for fish and wildlife harvesting. However little is known about the fish populations in the lake and it is unclear whether the fish are landlocked or migratory[17]. There is significant potential for development activities near the lake (pipeline and transportation corridor) that may affect the lake and the fish. During the *Norman Wells Workshop* (held for this project), participants expressed concern regarding potential impacts to fish in the lake. In 2002, multiple fish species in Travaillant Lake were live captured and tagged. The return of tags and fish harvest location information over the following years will provide fish movement information that will help determine whether fish populations in the lake system are migratory or land-locked (GRRB 2003).

A moderately diverse community of fish (18 species) is present in the Peel River, with least cisco and Arctic cisco the most abundant. There have been recent concerns regarding Arctic char stocks in the Peel River and the overexploitation of that stock (MacDonald Environmental Sciences 1995). Inconnu, broad whitefish, lake whitefish, Arctic cisco, and least cisco were monitored at two sites on the Peel River from 1998 to 2002 to determine the timing of migration and to locate spawning sites for species. Length, weight, sex, maturity stage were noted, otoliths collected for ageing and eggs collected to determine fecundity (GRRB 2003).

Within the Sahtu Settlement Area, various fisheries studies have been completed in a number of systems, including Carcajou, Donnelly, Loon, Kelly, Dal and Brackett lakes, Hume, Loon, Mountain, Ontaratue, Ramparts, Snafu, Tsintu, Tieda, Big Smith, Dahadinni, Great Bear, Keele, Little Bear, Porcupine, Redstone and Saline St. rivers, as well as Charles and Stick creeks (Stewart and Low 2000). Some of these fall within the Norman Wells development area.

DFO is in the process of preparing data reports on some Sahtu lakes, to be published in the spring of 2003. Data will include catch per unit effort (CPUE), species composition, size and age data and levels of heavy metals in the flesh (mainly for mercury levels). The Sahtu lakes include Aubry, Bandy, Lac Belot, Colville Lake, Lac à Jacques, Kelly, Loon, Manuel, Rorey, Tagatui, and Turton. The SRRB has harvest data available for the Norman Wells area (G. Low pers. comm. 2003).

Within the Deh Cho Region, various fisheries studies have been completed on aquatic systems, including Cormack, Goose, Greasy, Highland, Mustard and Blackwater lakes, Mackenzie, Trail, Jean Marie, Rabbitskin, North Nahinni, Ochre, River Between Two Mountains, Root, Poplar, Blackwater, Martin, Willowlake, Wrigley and Johnson rivers, and Hodgson, Smith and Whitesand creeks (Stewart and Low 2000). DFO is in the process of preparing data reports on some Deh Cho lakes, to be published in the spring of 2003. Data will include CPUE, species composition, size and age data, and levels of heavy metals in the flesh (mainly for mercury levels). The lakes in the Deh Cho area to be discussed include: Deep, and 6 unnamed lakes locally known as Ekali, Gargon, Sanguez, McEwan, McGill, and Reade.

[17] The exception is broad whitefish studied by both Chudobiak and Van Gerwyne-Toyne.

However, there is very little harvest data for First Nation fisheries in the Deh Cho Region (G. Low pers. comm. 2003).

Data is available on the fisheries resources of the Liard River, the watershed that encompasses the Liard Plateau hydrocarbon development region. A total of 33 species have been recorded in the basin and 21 have been reported in the development region (Lornel Consultants 2002). Anadromous fish in the system include inconnu, chum salmon, chinook salmon, Arctic cisco and least cisco (MacDonald Environmental Sciences 1995). Resident species in the development area include Arctic grayling, mountain whitefish (*Propsopium williamsoni*), round whitefish (*Propsopium cylindraceum*), lake whitefish, lake trout, bull trout, Dolly Varden char, inconnu, lake chub (*Couesius plumbeus*), spottail shiner (*Notropis hudsonius*), longnose dace (*Rhinichthys cataractae*), spoonhead sculpin (*Cottus ricei*), slimy sculpin (*Cottus cognatus*), longnose sucker (*Catostomus catostomus*), northern pike (*Esox lucius*), trout-perch (*Percopis omiscomaycus*) and burbot. Within the region, fisheries studies have been completed on the Liard River, Fisherman Lake, Muskeg River, Petitoit River, Bovie Lake, Rabbit Creek, Netla River, south Nahanni River and several unnamed creeks (Stewart and Low 2000).

Northern pike, Arctic grayling, walleye (*Stizostedion vitreum*), lake whitefish, lake trout, white sucker (*Catostomus commersoni*), longnose sucker, lake chub, and spoonhead sculpin are some species present in the Cameron Hills development region (MVEIRB 2001). Fisheries studies have been completed on Tathlina Lake (Stewart and Low 2000), the Cameron River and tributaries. Fisheries studies have been conducted at Aubry Lake, Colville Lake, Lac Belot, Lac des Bois, Lac Maunoir, Bluefish R, Hare Indian R, Wolverine Creek and Nivelin Lake, among others in the Colville Hills hydrocarbon development area (Stewart 1996).

The GRRB has developed a database for all known records of fish research undertaken in the Gwich'in Settlement Area (last updated in 1999). The database is searchable by fish species, location of research, type of data collected, and other parameters. Research locations have been mapped using a Geographic Information System (GRRB 2003). Mapping has been completed for critical and important fish areas in the Sahtu (Sahtu Land Use Planning Board website www.sahtulanduseplan.com/gis/maps/index.html).

Biological assessment of aquatic systems has gained importance over the last two decades relative to other physical or chemical tests. Baseline invertebrate information collected for watersheds at relatively pristine conditions can provide a powerful tool for cumulative assessment for various developments in the watershed. Aquatic plants and invertebrates were collected and identified in the Mackenzie River system in a 1971-73 study (Freshwater Institute 1975). Within the Peel River system, upstream of the Peel Plateau (west), benthic invertebrates data are available for one sampling event in 1998 (Environmental Canada Benthic Information System – Yukon, www.ec.gc.ca/bisy). There is also benthic data for Stony Creek, Vittrekwa River and Satah River within the Peel System in the NWT (MacDonald Environmental Sciences 1995).

4.5.1.1 Baseline Knowledge Gaps

The above information was considered at the *Scientists' Workshop*, and the following gaps were identified by the fisheries experts at the workshop. The identified gaps are based on the overall conclusion by fisheries experts that there is a general lack of current baseline knowledge, which in turn creates uncertainty regarding the effects of oil and gas development.

1. Baseline Surveys:

   a) Need abundance and distribution information on fish and invertebrates, and the following lakes and rivers should be considered in addressing this gap:

Lakes[18]

- Gwich'in Settlement Area: North Caribou, Caribou, Hill, Sandy, Tregnantchiez, unnamed lake (67 51'N; 131 33'W), and Travaillant.
- Sahtu Settlement Area: Tutsieta, Yeltea, Loon, Ontadek, Chick, and Mio.
- Deh Cho Region: Eentsaytoo, Goodall, McGill, unnamed lake (61 05'N; 120 30'W), and Trainor.

Rivers[19]:

- Gwich'in Settlement Area: Travaillant R. and Thunder R.
- Sahtu Settlement Area: Oscar Ck., Donnelly R., Hare Indian R., and Loon R.
- Deh Cho Region: Trail R. and Willow Lake R.

   b) Need information on distribution of contaminants (associated with oil and gas development) in sediments and in harvested fish, especially for known spawning grounds, areas of fishing for human consumption, exploration areas and seeps[20].
   c) Need to gather information on the ecological characteristics of inland lakes and the natural variability, vital rates and status of fish populations (pre-pipeline) in these lakes, particularly for the lakes listed above in part a).
   d) Aquatic surveys (which should include game fish, forage fish and invertebrates) need to be conducted at stream crossings.

---

[18] These lakes are based on proximity to the proposed pipeline route (within 10 km of pipeline route), importance to communities, and lake size (assuming larger lakes are more likely to be of importance to communities, to contain harvested fish populations and have greater biodiversity)
[19] The selection of these rivers is based on: proximity to pipeline route, likelihood of suitability for spawning or being used as a migratory corridor for spawning, rearing or over-wintering migrations and existing information suggests important species occur in these rivers.
[20] Background information to support this gap is found is also found in Section 4.5.2

2. Ecological Knowledge Gaps:

a) Need to identify important spawning, rearing and over-wintering habitats for fish and invertebrates, particularly for the lakes and rivers listed in the above gap (Baseline Surveys, Gap 1, part a).
b) Need to identify the key migration (spatial/temporal) corridors and habitats for harvested fish and invertebrates, particularly for the lakes and rivers listed in the above gap (Baseline Surveys, Gap 1, part a).
c) Need to identify the factors that govern the abundance of economically important and rare species (following baseline data collection).
d) Need to identify the critical trophic linkages that may be affected by developments.

4.5.2 Impact Assessment and Regulatory Processes

Fish and fish habitat impacts may occur from such activities as pipelining across a body of water, access road construction, vegetation removal, slope slumping into a water body, and contamination through spills. The Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee (2002) outlined in the *Consolidated Information Requirements* the impacts that may be associated with development: direct removal of fish habitat, indirect disturbance to fish habitat through changes in water quality or flows (particularly in winter) and mortality of fish due to changes in habitat.

Through the *Norman Wells Workshop*, held for this project, the Sahtu, Gwich'in and Deh Cho identified fish as an important part of the aboriginal diet and culture and indicated that impacts on fish and fish habitat are of concern. Currently fish are thought to be smaller than they used to be and unhealthy, with visible abnormalities (no known cause).

Impacts on fish and fish habitat along the pipeline route have been assessed and mitigation recommended since the early 1970s for the earlier pipeline proposal and the Mackenzie Highway. For example, sources of potential physical impacts on all streams to be crossed by sections of the Mackenzie Highway were identified and recommendations were proposed to minimize impacts on the aquatic systems (F.F. Slaney & Company 1974). Potential impacts from the proposed pipeline were noted and mitigation measures recommended at a general level (Jessop 1974). Data gathered along gas pipeline routes proposed by CAGPL and Alaskan Arctic Gas Pipeline Company were used to assess potential watercourse-specific impacts on the aquatic environment (Aquatic Environments Limited 1974). The potential impact of the Norman Wells to Zama pipeline construction on fish populations was assessed and mitigative measures were incorporated into the design, construction and timing of the construction (Interprovincial Pipe Line Ltd. and Aquatic Environments Limited 1982).

Various studies noted in the DIAND Pipeline Application Assessment Group's (PAAG) environmental assessment (1974) include: studies of aquatic conditions under ice in northern water bodies, gravel removal from streams, underwater blasting, the long-term effects of small oil spills into streams, and fish distribution and movements in some areas (Stein 1973, and Jessop 1974).

Methanol toxicity in northern fish and effects of long-term hypoxia on respiration in larval Arctic char were studied as part of the 1970s pipeline applications (Aquatic Environments Limited 1974). Effects on benthic invertebrate communities around the Norman Wells area were assessed in one study (Aquatic Environments Limited 1974).

Arctic grayling stocks in parts of the Mackenzie River system were adversely affected by a warm water outbreak of waterborne pathogens in 1989. Grayling, which spawn in the Grayling River, were decimated. The Kakisa grayling stock and presumably others appear to have recovered to former levels (NWT CIMP 2002).

From 1972 to 1973, fish sampling was conducted in 103 creeks crossed by the proposed highway ROW around the Willowlake River (between Fort Simpson and Wrigley). Streams with fish populations were distributed throughout the study area with the greatest concentrations of fish streams between Willowlake River and Mount Gaudet. Sources of potential physical impacts on each stream were identified and recommendations were proposed to minimize impacts on the aquatic systems (F.F. Slaney & Company 1974).

A seismic study was conducted in the Liard and Nahanni Rivers during the summer of 2002. Electroshocking fish was raised as a potential mitigation measure to deter fish during airgun operations but sufficient and reliable data was not available to determine the effectiveness of this method (Lornel Consultants 2002). Ramping up is a mitigation measure recommended by DFO and airgun manufacturers. This involves the gradual release of increasing blasts of compressed air to produce a field of (fish and semi-aquatic fur-bearer) avoidance over a 10-minute period and is considered a standard operation for marine seismic surveys (Lornel Consultants 2002). Other non-mechanical deterrent techniques include electrical screens, artificial light arrays and acoustics.

Another mitigation measure for seismic activities in lakes and large rivers involves the use of bubble curtains (sometimes in conjunction with ramping up) to minimize auditory and vibrational impacts on fish and semi-aquatic fur-bearers. This involves bubbling air around the air gun resulting in a decrease in velocity at which acoustic waves are travelling, thereby absorbing energy and decreasing noise. As 180 dB has been set as a safe noise level for fish, a monitoring program was proposed to determine distance at which 180 dB is obtained, using no mitigation as well as a bubble curtain. The objective of this study is to set safe distance guidelines for the use of air guns (Lornel Consultants 2002).

Construction and operation of ice roads can potentially impact fish if appropriate mitigation measures are not used. Crossing watercourses when frozen results in less of an overall impact on habitat than crossing during the open season (Paramount and Golder 2001). Ice roads may impact over wintering fish by causing erosion in the vicinity of the approaches and increase sediment inputs, delay ice break-up, entraining fish in water intakes during flooding operations, or releasing deleterious substances into the water. Ice-road related potential impacts to fish can be mitigated through the use of proper ice bridge construction techniques (Applied Ecosystem Management Ltd. 2002b), including:

- where required geotextile cloth should be placed along the approaches to ice bridges to protect soils and reduce the potential for erosion;
- during flooding, pump intakes should be screened as per Fisheries and Oceans Canada (1995) Guidelines to prevent entrainment, entrapment or impingement of fish;
- all pumps should be placed within secondary containment to prevent accidental release of deleterious substances;
- any debris left on the ice surface should be cleaned off on a regular basis to prevent entry into the watercourse during spring melt;
- to reduce the potential for the ice bridge to cause an ice jam and potentially increase bank erosion ice bridges should be removed using an excavator, prior to break-up; and
- if complete removal is not feasible then the upstream side of the ice bridge should be notched to increase water flow past the bridge and promote break-up (MVEIRB 2001; Applied Ecosystem Management Ltd. 2002b).

Two potential impacts of ice bridges that are more difficult to mitigate are the restriction of water flow as a result of the ice freezing to the bottom (Applied Ecosystem Management Ltd. 2002b) and creating under-ice pressure and sound disturbances (Stewart 2001). Water crossings should be evaluated prior to ice bridge construction to determine the potential for the ice to freeze to bottom. If freezing to bottom is a potential problem then a single-span bridge structure should be considered. With respect to underwater noise impacts, Stewart (2001) found that noise from winter construction activities on lakes and rivers was audible as far as 1.6 km away from the source and was within the hearing range of fishes. Sound waves could not be detected at a 3.2 km distance.

Potential impacts to fish habitat may include increased sediment loading, alteration to bank vegetation and disturbance to banks from ATV fording and construction and in-stream habitat disturbance (MVEIRB 2001 and NWT CIMP 2002). These impacts have been studied extensively in the south and a number of mitigation measures have been established. The potential for sediment issues during pipeline construction was considered low with respect to fish habitat impacts (Kavik-Axys and LGL 2001). Channel trenching during winter in small tributaries, using isolation of flows with erosion control measures in place is often completed. Retention of streamside buffers, drainage control and sediment control are standard practice (proposed in the 1970s pipeline construction plans - NEB 1977). Rehabilitation of channel bed, re-vegetation and bank stabilization are required. The use of ice roads and placement of logs at fording locations minimizes bank erosion. Directional drilling of important watercourses, under the right conditions, is one technique to minimize a variety of in-stream impacts; however, the risk of an in-stream drilling fluid release under the ice must be carefully examined before committing to this technique. Sediment inputs due to bank erosion from road or pipeline construction in conjunction with permafrost thawing are of concern and warrant further investigation.

Many of the Mackenzie River fish species undergo extensive migrations to and from the coastal areas from their spawning grounds and therefore the loss of a river spawning habitat will have long term and geographically widespread effects on the fish populations and subsistence harvest in many communities (R. Tallman pers. comm. 2003). Direct in-stream work and increased sediment inputs are generally the sources of impacts to spawning habitat and eggs. In-steam dredging increases suspended sediments in rivers and can affect fish and fish habitat (filling in spawning areas). One study on gravel sources and impacts of dredging on fish and habitat concluded that considerable research effort will be required before the potential value of the riverbed alluvium as a resource material can be firmly established (EBA Engineering Consultants Ltd. 1987).

Construction timing can play a big part in mitigating for impacts on fish and habitat. Winter is the time for most hydrocarbon construction due to difficult ground conditions when thawed. This timing also avoids fish migration and spawning periods[21]. In-stream seismic work has been proposed between spawning and peak migratory periods. A 2002 study in the Liard and Nahanni rivers proposed work during August (Lornel Consultants 2002).

The introduction of hydrocarbons to rivers and the effect of reduced water quality on fish health and palatability was a topic studied in the 1980s in the Norman Wells development area, coincident with operations to expand oil production at Norman Wells. Residents of Fort Good Hope commented that the quality of fish from the Mackenzie River had deteriorated during this time. The liver of burbot was reported to have become small and dark in colour, with the result that people would no longer eat them. The muscle of whitefish was reported to have become excessively "watery" with the result that these fish were less palatable than in the past (Lockhart *et al*. 1989).

ESL *et al*. (1988) found no statistically significant relationship between burbot liver problems and hydrocarbon exposure. It was observed that effluent from the Norman Wells refinery did not make a significant difference to hydrocarbon levels which occur naturally in the river system. Another study looking at effluent concluded that the cause of the liver condition is unlikely to be exposure to petroleum hydrocarbons and that the condition of the fish seems more likely to be of natural origin through factors related to nutrition or parasitism, but also noted that pollution could not be ruled out conclusively (Lockhart *et al*. 1987). The study noted contamination of Mackenzie River fish with low levels of several compounds, notably toxaphane, chlordane, and PCBs.

Lockhart *et al*. (1997) examined chronic toxicity of the 'water-soluble fraction' of Norman Wells crude oil to juvenile fish. The study noted that mortality was light for the first few days of the 55 day exposure, and continued with more rapid and increased mortality at the higher exposure levels, and exacerbated mortality in the presence of oil dispersants. Surviving fish showed severe fin erosion and apparent flooding. The authors hypothesized that the oil affected the ability of fish to regulate their water content.

Composite and grab samples of the hydrocarbon constituents of produced oil, refinery effluent and cooling water from the Norman Wells refinery indicated that effluent water quality was good in comparison with most other oil refinery effluents in terms of conventional parameters (e.g., phenols, total organic carbon, ammonia) (EVS Consultants Ltd.1985). The most prominent compound in the refinery effluent (also found in the cooling water) was morpholine. As fish detect and imprint this compound at extremely low concentrations, it is possible that this constituent may be acting to "imprint" and/or

[21] Need to confirm the absence of eggs in gravel first.

chemically attract fish into the effluent plume. Analysis of the Norman Wells crude oil suggests that any impacts from short term spills would be minimal due to the volatilization and biodegradation of many of its constituent hydrocarbons (EVS Consultants Ltd. 1985).

Morgan *et al*. (1986) placed burbot and Arctic grayling in cages for 10 days at sites upstream and downstream from known point sources of hydrocarbon inputs (refinery effluent, natural oil seeps). After the period of exposure, fish bile was analyzed and the results compared with analysis of muscle tissue for volatile aromatic compounds by a purge and trap technique, examination by members of the local communities for fish acceptability (i.e., colour of liver, watery flesh) and river water and sediment quality. Laboratory bioassays were also undertaken to confirm results of the field studies and to assess any enhanced impacts of simulated conditions of ice cover on fish survival and bile PAH levels. It was concluded that bile analysis of resident fish populations, and experimentally exposed fish, is a promising biochemical/enzymatic indicator of hydrocarbon contamination in freshwater fishes (Morgan *et al*. 1986).

Release of emissions from hydrocarbon development can end up in water and snowpack and degrade water quality for systems inhabited by fish. These water quality impacts can affect aquatic biodiversity and fish. During the Paramount drilling program in Cameron Hill, Paramount and Golder (2001) completed a review of existing studies on this topic and concluded that by meeting NWT and Alberta air quality standards this project would have no significant effects on fish and amphibians if proposed flaring was in place.

A long-term issue related to hydrocarbon and other development is increased access of remote areas. Many fish populations in NWT cannot sustain high rates of harvesting. The effect of long-term increased fishing pressure as a result of increased access is undetermined, but has the potential to be substantial on fish populations (R. Tallman pers. comm. 2003; J. Reist pers. comm. 2002).

Berger (1977) relates that every fish cannot be protected; however, areas where fish populations concentrate must be protected, particularly during sensitive life stages. One of the major gaps in managing potential impacts of development is the lack of clearly defined “sensitive areas” and clearly defined “sensitive timing windows” (R. Tallman pers. comm. 2003). Many of the proposed mitigation measures revolve around avoiding sensitive areas or sensitive times for fish. However, although spawning migrations are known for a number of the major subsistence and commercial fish species within the larger water bodies, the majority of smaller streams and lakes have not been adequately assessed to identify where sensitive habitats exist and what time of year these habitats are used. Information on sensitive areas is needed most for watercourses north of Norman Wells.

4.5.2.1 Impact Knowledge Gaps

The above information was considered at the *Scientists’ Workshop*, and the following gaps were identified by the fisheries experts at the workshop:

1. In existing oil and gas development areas and along existing pipeline corridors, need to identify and quantify impacts on fish and fish habitat as a result of development.

2. In existing oil and gas development areas and along existing pipeline corridors, need to determine what mitigation measures have been implemented and determine their effectiveness.
3. Need sensitivity mapping in particular for fish habitat and other important environmental attributes of the Mackenzie River and its tributaries north of Norman Wells
4. Monitoring Programs:
   a) Need to identify the impacts of projects on vital rates (reproduction, growth, mortality) and abundance of populations, and in harvest rates.
   b) Need to identify project-related changes in abundance and species composition of invertebrates.
   c) Need to identify project related spatial and temporal trends of contaminants (associated with oil and gas development).

See Section 4.5.1.1 above for baseline information gaps specifically related hydrocarbon contaminants.

4.6 Vegetation and Forests

Vegetation in the Mackenzie Valley is a reflection of species that migrated northward after the retreat of the glaciers and species that have been introduced with development and establishment of communities.

Loss of vegetation cover and forests may result from oil and gas activities. Loss of vegetation has the potential to affect the nutrient cycle, change surface water drainage patterns increasing the chance of siltation, change soil properties including disturbing permafrost stability, increase the risk of fire, and reduce the availability of habitat for wildlife. Indirectly, removal of vegetation also increases the opportunity for the introduction of non-native species and changes in species composition.

4.6.1 Baseline

The NWT has six ecozones of the Canadian ecozones as defined by the National Ecological Framework established between Environment Canada and Agriculture Canada in 1996. The five oil and gas development areas and the pipeline corridor are situated within the Taiga Plains ecozone[22] dominated by the Mackenzie River. The landscape is comprised of plateaus and lowlands with widespread permafrost and poor drainage. The dominant vegetation include black spruce (*Picea mariana*), white spruce (*Picea glauca*), jack pine (*Pinus banksiana*), tamarack (*Larix laricina*), paper birch (*Betula papyrifera*), trembling aspen (*Populus tremuloides*), and balsam poplar (*Populus balsamifera*). White spruce and balsam poplar may also grow bordering rivers where the soils are more developed. Willow (*Salix* spp.) and alder shrubs (*Alnus* spp.) are commonly found. Lichens and mosses dominate the ground cover. Low shrubs are abundant and include many species such as Labrador tea (*Ledum palustre*), berry-producing species such as cranberries and blueberry (*Vaccinium* spp.).

[22] The exception is the most southwestern corner of the NWT where some seismic work has taken place. This ecozone is the Taiga Cordillera.

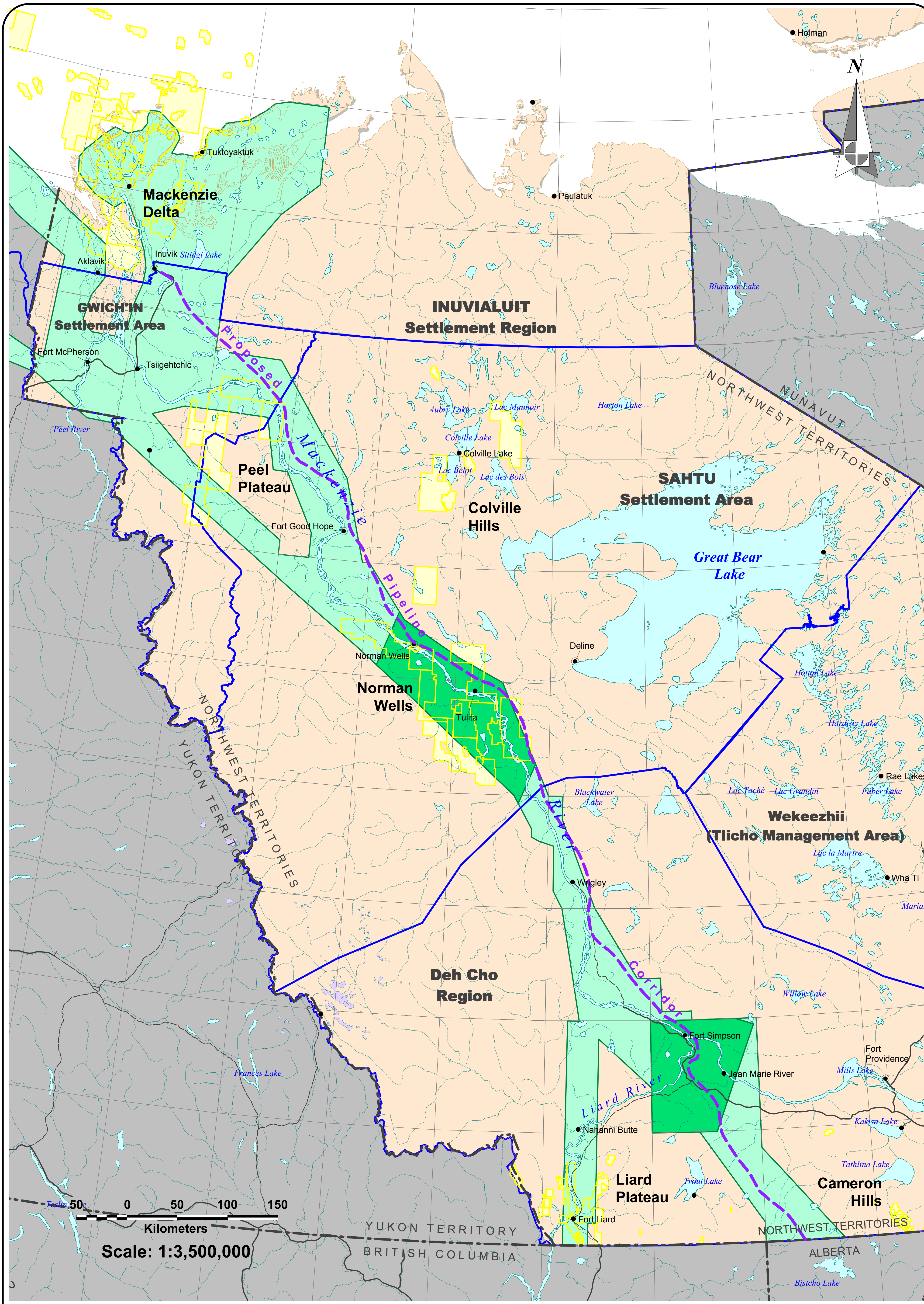
Documented TK on vegetation and forests is generally reflected in information on traditional foods and building materials. One such source of work has been carried out through the Gwich'in Social and Cultural Institute about traditional uses of roots, berries, mushrooms and other plants. Also, a number of studies about traditional use of timber and non-timber forest products have been carried out through the GRRB. Included are studies on traditional uses of wood (e.g., for building cabins, crafts), cloudberry (*Rubus chamaemorus*) harvesting, and traditional uses of driftwood.

Vegetation and forestry surveys have been completed within portions of the development areas to varying degrees. Along the Mackenzie River, the major types of plant communities in each physiographic region were assessed and mapped in the 1970s for the proposed CAGPL pipeline project (NEB 1977). In the late 1970s to early 1980s, mapping of the vegetation communities within a 5 to 10 km corridor along the Mackenzie River augmented previous information. The scope of this mapping is not adequate for cumulative effects assessment work (R. Case pers. comm. 2003). The GNWT Remote Sensing Centre has recently compiled spatial data on vegetation in the Mackenzie Valley corridor in the Norman Wells area (Kavik-Axys and LGL 2001). Ecological classification and mapping was undertaken by GeoWest Environmental Consultants Ltd. (1997) for the Liard River forest region, which was commissioned by RWED, Forest Management, in 1996.

Wright *et al.* (2003) recently completed a digital compilation of vegetation types of the Mackenzie Valley transportation corridor, which extends along the Mackenzie River from the Alberta border to the Beaufort Sea. The compilation was based on 1974 hard copy mapping (1:125,000) originally prepared by the Forest Management Institute of the Canadian Forestry Service for the Environmental Social Program of the Task Force on Northern Oil Development. Vegetation was originally interpreted from black and white aerial photographs taken between 1970 and 1972, with additional infra-red colour photography taken in 1971 and 1972 to cover a small area. Field checks of the maps took place at 314 sites in 1971 and 1972. Included in the dataset are information on species composition, canopy height and density of forest cover, and landform modifiers for tundra vegetation. The extent of the mapping compiled by Wright *et al.* (2003) is shown in Figure 10. Figure 10 also shows enhanced vegetation classification for areas centred on Norman Wells and Fort Simpson. This classification was produced by the GSC through integration of classified TM imagery and the 1974 map series produced by the Canadian Forest Service, mentioned above.

Landcover classification mapping for Canada by Cihlar and Beaubien (1998) at a 1 km spatial resolution also covers the Mackenzie Valley. It was produced by the Canada Centre for Remote Sensing based on multi-spectral AVHRR imagery.

Ducks Unlimited Canada and partners have been mapping portions of the Mackenzie basin since 1997 using a standardized LandSat 7 TM imagery approach for land- or earth-cover images centred on the Peel Plateau, Norman Wells, Fort Good Hope and Inuvik areas through projects referred to as the Peel Plateau Project, Sahtu Project, and the Lower and Middle Mackenzie Projects (Figure 11). The Lower Mackenzie and Sahtu Projects are completed, the Peel Project is expected to be completed by end of January 2004, and the Middle Mackenzie is expected to be completed in approximately one year. Each image scene is



Legend

Approximate Location of Proposed Pipeline Corridor

Oil & Gas Dispositions (Sept. 2002)

1974 Vegetation Classification (1:125,000 scale)*

Enhanced Vegetation Classification (GSC)

*Originally prepared by Forest Management Institute of the Canadian Forestry Service.

Source of Data:
Terrain Sciences Division,
Geological Survey of Canada, 2003

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2004

Project Number: 22-649

File Name: 22649-F10-R3.WOR

Revision: 3

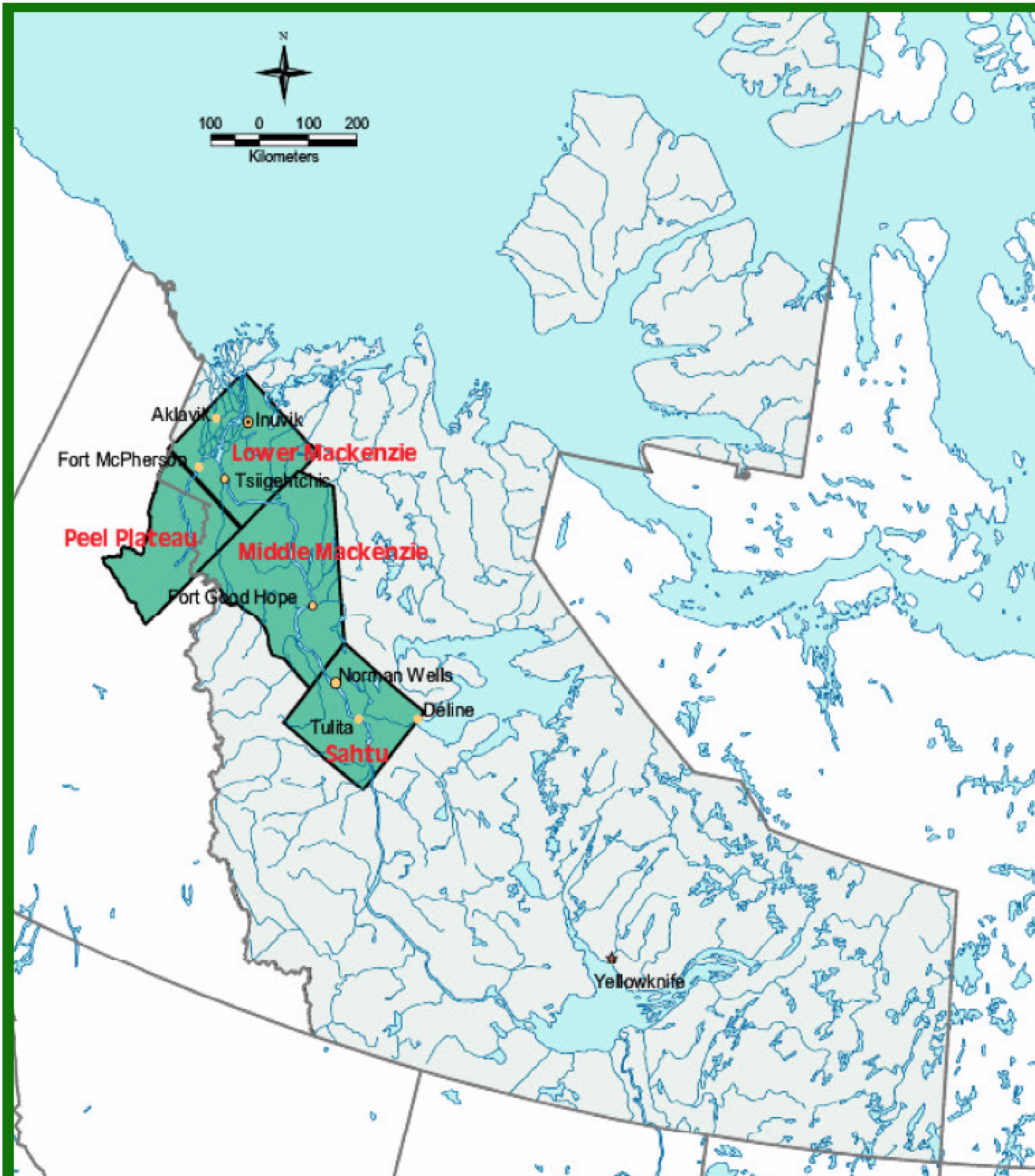
GSC Vegetation Mapping Compilation

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No.

10



Gartner Lee Limited

Extent of Landcover Mapping
Ducks Unlimited

Figure 11

approximately 32,000 km^2 in area. This method provides a detailed desktop vegetation and wetland map useful for cumulative effects assessment and long-term monitoring. Drawbacks include the expense and the requirement of field verification for some information. For instance, it is difficult to accurately define submergent and emergent vegetation in wetlands using this imagery approach (B. MacDonald pers. comm. 2002). Landcover mapping has not been completed for the Deh Cho Region and the Colville Hills area in the Sahtu. Mapping of this nature is essential to understanding impacts and detecting landscape level changes as may occur from cumulative impacts. This information also provides a basis for linking vegetation types to wildlife habitat preferences and requirements, and may provide a basis for documenting fire history and recovery rates and patterns of vegetation. During the *Norman Wells Workshop* and *Scientists' Workshop*, communities and scientists identified the need to have a complete landcover inventory of the Mackenzie Valley.

The distribution of peatlands in the Mackenzie basin has been outlined by type. Peatlands noted include widespread poor fen, peat plateaus with thermokarst pools, low-boreal bogs, bogs and peat plateaus without thermokarst pools, low-boreal dry poor fens, moderate rich fens and extreme rich fens (Cohen 1997). A peatlands database and digital map for the Mackenzie Valley was recently compiled by Tarnocai *et al*. (2003). This work is based on various studies on soils and peatlands conducted in the 1970s and 1980s.

Some vegetation classifications systems exist, but there is no standardized, NWT-wide system for the evaluation of land within an ecological framework. A common ecosystem classification system is required to assist with land management planning, including protected area identification, biodiversity, environmental assessment of development activities and for sustainable forest harvesting and wildlife habitat conservation. Ecoregions, provisional Ecodistricts and Soil Landscape Classification units exist as mapped units, but there is no integrated format of these coverages. An ecosystem classification system could be used as a tool for assessing wildlife habitat and understanding biodiversity.

GNWT (RWED) is currently planning for the development of an ecosystem classification system, which includes consideration of the NWT PAS goals. It is anticipated by the GNWT (RWED) that the SLCs will be aggregated into Landscape Units using a standardized and ecologically-based set of rationales and rulesets, which are currently being developed and tested (EBA Engineering Consultants Ltd. 2003). The GNWT are making efforts to develop the system such that it will be compatible with classifications in neighbouring jurisdictions as well as with national classification efforts. The landcover mapping by Ducks Unlimited and the existing Peatlands mapping by Tarnocai *et al*. (2003), mentioned above, may be used in developing the ecosystem classification system for the NWT, along with other existing information (e.g., climate surface models, digital elevation models) (EBA Engineering Consultants Ltd. 2003).

Environment Canada maintains a database noting sightings of orchid, fern, lichen and moss species at risk (endangered, threatened or special concern). The database does not indicate known presence of any plant species at risk in the development areas (Environment Canada website www.sis.ec.gc.ca/msapps/ec_species/htdocs/ec_species_e.phtml). However, ongoing monitoring by volunteers and researchers can be promoted through programs such as Plantwatch NWT to verify and update the database. Communities and scientists providing input on this project have indicated the need to compile TK about rare and medicinal plants and to map known occurrences of these species to avoid disturbance to these plants. This information will help in the planning phases of construction and development.

The Liard Plateau region is located in a transition area between the boreal and tundra ecozones where the vegetation changes from mixed-wood montane subalpine vegetation in the south to taiga, sub-arctic vegetation in the north (Lornel 2002). A study on the Liard River identified aquatic macrophytes, wetland vegetation and browse vegetation as selected ecosystem maintenance indicators (specific to hydrological changes) (MacDonald Environmental Sciences Ltd. 1995).

The Cameron Hills development area contains some merchantable timber, including large black spruce trees. Due to previous clearing, there is some information on the capability of forest regeneration (Paramount and Golder 2001).

The GRRB in co-operation with RWED began work in 1996 to inventory forest stands in the Gwich'in Settlement Area with potential for commercial harvesting. Aerial photographs were taken of the forest stands and aerial photo interpretation conducted to mark forest stand boundaries, identify tree species and measure stand heights. Following field verification, this information was used to develop finalized forest inventory maps of the area. The remote sensing-based vegetation classification and mapping currently underway by RWED will provide a useful addition to the maps created through the forest inventory for the Gwich'in Settlement Area. Habitat unit mapping was selected as a key ecosystem maintenance indicator (specific to hydrological changes) for the Peel River system (MacDonald Environmental Sciences Ltd. 1995).

A forest plot located in the Gwich'in Settlement Area is part of Canada's National Forest Health Monitoring Plot Network, originally designed to detect early signs of air pollution damage to Canada's forests. A separate one-hectare plot is part of the Ecological Monitoring and Assessment Network project that monitors tree diversity as part of national and international efforts. Within this plot, the condition of trees is assessed annually based on the extent of leaf and branch damage by various agents (including insect pests and environmental factors). In addition, general tree measurements (height, diameter, etc.) are made every five years (GRRB 2003).

A number of studies have been conducted in the Gwich'in to assess boreal forest recovery following logging and fire. For example, one study found that seeds of white spruce were viable following a fire in July or later in the summer season, but not before. Another study examined the age distribution in fire-origin upland white spruce and found that the major tree establishment period is within 40 years of a fire (Wein *et al*. 2001).

Baseline information on frequency, size and intensity of forest-insect outbreaks and diseases is available from aerial surveys in the NWT. Spruce budworm (*Choristoneura fumiferana*) is a serious forest insect pest in the Mackenzie Valley. Other insects observed at outbreak levels include large aspen tortrix (*Choristoneura conflictana*), larch sawfly (*Pristiphora erichsonii*), aspen serpentine leaf miner (*Phyllocnistis populiella*), forest tent caterpillar (*Malacosoma disstria*) and willow leaf miner (*Mircrurapteryx salicifoliella*). Monitoring of spruce budworm and other insect outbreaks is conducted on an annual basis (NWT CIMP 2002).

The distribution and general ecology of 314 microlichen taxa for 230 000 km^2 of coniferous forest, open fens, and alpine terrain along the Mackenzie River and the Peel River was summarized in 1981 (Bird *et al*. 1981).

4.6.1.1 Baseline Knowledge Gaps

1. Need landcover (vegetation) mapping including identification of terrestrial and wetland vegetation types.

2. An ecological land classification (ELC) system needs to be developed.

3. Need to identify and map locations of rare and medicinal plants.

4.6.2 Impact Assessment and Regulatory Processes

Losses of vegetation communities, rare species and merchantable timber have been noted as potential impacts from pipeline developments and seismic studies. Seismic exploration practice may contribute to repeated clearing of vegetation. Other potential impacts include hydrocarbon spills on vegetation and introduction of non-native invasive plant species (an indirect effect of vegetation removal).

There is currently a lack of TK documentation on potential project effects on vegetation and forests, especially in relation to burning (including forest fires), spills and leaks, and land clearing.

The use of existing linear corridors, routing around sensitive areas and minimizing the width of clearing (for seismic lines, roads, well leases, pipelines) are mitigation measures used to minimize the impact on vegetation (Hardy BBT Limited 1990). Survey lines during seismic studies can use low impact seismic techniques to limit the extent of clearing between drill points to brushing and limbing a walking trail for survey. This method is currently being utilized for projects in the Liard Plateau area (MVEIRB 2000). The use of multiple directional wells from a single pad or lease will minimize the area of vegetation disturbance during hydrocarbon extraction.

Numerous research reports and projects regarding impacts of development in boreal forest have been completed through the Sustainable Forest Management Network. The Canadian Wildlife Service (CWS pers. comm. 2003) indicate that these projects have included impacts of hydrocarbon development and analysis of re-vegetation of seismic lines. These studies are predominantly from Alberta and the application of this work to the NWT development areas can be considered.

Localized acidification of soil and fumigation of sensitive vegetation (especially lichens) can result from emissions of sulphur dioxide and nitrogen oxides from gas processing and compressor stations. The Paramount drilling project in Cameron Hills (Paramount and Golder 2001) reviewed studies and concluded that by meeting NWT and Alberta air quality standards, the project would have no significant effects on vegetation (including lichen) within the study area (and therefore on habitat).

Losses or modification of small-vegetated communities from fuel spills have been noted as potential impacts of the pipeline development but were considered minor in importance (Kavik-Axys and LGL 2001). Hardy Associates (1980) concluded that winter spillage of water/methanol solutions can result in substantial long-term damage to vegetation cover. Hutchinson and Hellebust (1978) found that crude and diesel oil experimental spills in spruce taiga at Norman Wells can cause severe above-ground effects to vegetation, but that such spills do not cause complete elimination of below-ground storage organs. Certain species were capable of survival or of producing new shoots in the first few years following a spill. However, a follow-up study (Hutchinson 1984) of the spill sites 6-9 years later showed marked effects of the spills.

Simmons *et al*. (1983) studied the sensitivities of saline water spills on the tundra plant communities. Research found that as expected the higher the concentration of salt in the water, the greater the effect on the surrounding plant communities. Flushing of the effected plant communities with freshwater was found to reduce the physiological stresses associated with salt water spills (Walker 1996).

Salvaging native soil, allowing for natural re-vegetation, re-planting with native species, seeding erosion prone areas (with approved mix) and preventing human access to cleared areas are means of allowing for regeneration of vegetation. Information is required regarding the availability of appropriate seed stock to mitigate appropriately for areas cleared and exposed during the pipeline construction (Kavik-Axys and LGL 2001). The use of clean equipment and mechanical weed control along a ROW could minimize the potential for the introduction of invasive species (Paramount and Golder 2001).

Re-vegetation and impact assessment studies established in the Mackenzie River Valley region in the early 1970s were evaluated by Hardy Associates (1980). It was concluded that re-vegetation of highly disturbed areas in the Mackenzie Region by seeding and fertilizing is a practical means of assisting in erosion control and re-establishment of the natural plant community. It was noted that success is dependent on geographic location (climate) and soil texture. It was also concluded that re-vegetation in tundra by sod replacement will assist the rate at which the natural plant community will re-establish and aid in retarding permafrost thaw.

The chronic disturbance of moss-lichen layer (especially in poorly drained areas or adjacent to creek crossings) from continued ATV traffic can preclude re-vegetation. The use of corduroy bridges, balloon-tired, four-wheel ATVs and responsible ATV operations can mitigate for this impact during construction (Paramount and Golder 2001).

A simulated pipeline ROW was used as a revegetation test site 10 km north of Fort Norman, NWT (Maslen and Kershaw 1987). The study tested success of planting native shrub cuttings ("whips") from several shrub species including littletree willow (*Salix arbusculoides)*, grey-leaved willow (*S. glauca*), bog blueberry (*Vaccinium uliginosum*), dwarf birch (*Betula glandulosa*), green alder (*Alnus crispa*), shrubby cinquefoil (*Potentilla fruticosa*). The first growing season showed littletree willow and grey-leaved willow to be the most successful based on vigour ratings and rooting success. Canopy removal from a 25 metre wide corridor north of Fort Norman did not affect the growth rate of littletree willow (De Grosbois *et al.* 1987).

For the proposed CAGPL pipeline, field research sites were established in the Peel Plateau, Norman Wells, Fort Simpson and northern boreal forest of the Mackenzie Valley to determine impacts related to construction and maintenance of a pipeline. The terrain types selected were intended to be representative of the most difficult conditions under which a pipeline might have to be constructed and maintained. Both CAGPL and Foothills Pipelines provided a re-vegetation program in their project development applications primarily to provide initial erosion control and secondarily to aid in the re-establishment of plant cover and restore soil thermal conditions. CAGPL stated that some commercial species could be used for re-seeding without a threat to the ecosystem and that this could speed up the natural re-vegetation process (NEB 1977).

A recent inventory of plant species along the existing Norman Wells to Zama oil pipeline was carried out by Cody *et al*. (2000). The study documented 34 alien (non-North American) taxa along the pipeline ROW: 15 were new to the flora of the mainland NWT, 19 were previously known from other areas of continental NWT including the aggressive weedy grass. Thirteen native North American taxa of invasive habitat, but uncommon in the Continental NWT were also recorded. At the time of pipeline construction, the pipeline owners used a combination of seeds composed of predominantly native North American species from certified stock to help reduce the risk of introduction of alien species.

Total plant cover averaged 66% and 55% on seeded areas along the Norman Wells to Zama pipeline, four and five years after seeding, respectively (Hardy BBT Limited 1988b). Erosion control was maintained, however. Methods of accelerating (seed and fertilizer treatments) the establishment of plant cover on organic terrain along the pipeline route was also examined (Interprovincial Pipe Line (NW) Ltd. 1988a). First-year establishment of a blanket fen-bog was comparable to that on mineral soils, but a peat plateau bog had minimal success. Annual reports on monitoring of construction and operation of the Norman Wells to Zama pipeline indicate that revegetation with respect to cover continues to be successful and brushing is required to address shrub and tree encroachment onto the ROW (Interprovincial Pipe Line (NW) Ltd. 1987, 1988b, 1989, 1991, 1993).
More research is required on revegetation in the Mackenzie Valley to determine long-term recovery rates of disturbed vegetation communities, to examine the potential use of native and non-native plant species for revegetation purposes with respect to success in revegetation, feasibility, seed supply, and potential invasiveness. Communities and scientists have expressed concerns regarding the spread of non-native plant species into undisturbed areas. Native seeds and seedlings are currently not available for re-vegetating disturbed areas so non-native species are typically used for erosion prevention and re-

vegetation purposes. Non-native species are often used as a nurse crop to provide short term coverage for erosion control purposes on disturbed areas allowing native species to become established. However, non-native species have the potential to spread into adjacent (undisturbed) areas in an invasive manner and also have the potential to inhibit the establishment of native species. Communities attending the *Norman Wells Workshop* pushed for more research into the use of native species may result in a reduced need for the use of non-native plant species for revegetation of disturbed sites. Information on the current locations of non-native species, the means by which non-native species are introduced and the potential for non-native species to invade areas will assist in developing prevention measures against their introduction.

4.6.2.1 Impact Knowledge Gaps

1. Need to document TK with respect to project effects on vegetation and forests.
2. Need to determine long-term recovery rates of disturbed vegetation communities.
3. Native Seeds:
    a) Need to research the use of native plant species (seeding and natural recovery) and their success for re-vegetation of disturbed land in the Mackenzie Valley.
    b) Need to develop methods/standards for obtaining a native seed supply, and identify facility needs for storing the seed (seed bank[23]).
    4. Need information for the Mackenzie Valley on non-native species, including current locations of non-native species, the means by which non-native species are introduced into an area, the potential for non-native species to invade areas and where they may become a concern.

4.7 Wildlife and Wildlife Habitat

Wildlife and wildlife habitat in the Mackenzie Valley region reflects the boreal and sub-arctic conditions they inhabit. As an area of north-south transition, the Mackenzie Valley features many species typically found in other parts of Canada. This means that there are many species at the limit or edge of their range (French and Slaymaker 1993) e.g., porcupine (*Erethizon dorsatum*), little brown bat (*Myotis lucifugus*), black scoter (*Melanitta nigra*), ruddy duck (*Oxyura jamaicensis*) and bull trout. There are an estimated 30,000 species in the NWT with insects making up over half of the species list.

Wildlife is an important part of the fabric of the lives of people in the NWT - wildlife has been a source of food (subsistence); clothing, tents, boats, and tools; as well as a source of income through the sale of furs, hides, and meat. Changes to wildlife and wildlife habitat may affect the lives of northerners and first nations people in particular.

Oil and gas activities have the potential to impact wildlife and wildlife habitat. The primary impacts that may occur include:

[23] The meaning of seed bank in this case context: usually a temperature- and humidity-controlled facility used to store seed (or other reproductive materials) for future use.

- direct mortality;
- displacement of individuals and populations;
- disruption and reduction of home range (movement);
- habitat loss and fragmentation;
- habitat change (e.g., in favour of one species over another);
- changes in predator-prey relationships;
- food-web disruption/change;
- introduction of foreign/non-native species; and
- ecosystem level changes (The Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee 2002).

Wildlife species vary in their level of sensitivity to change/disruption. There are direct links between wildlife and wildlife habitat and geomorphology, water, air, and vegetation. Changes in one or more of these biophysical attributes may have direct or indirect effects on wildlife and wildlife habitat.

4.7.1 Baseline

There is a growing body of documented TK about wildlife and wildlife habitat in the Gwich'in, Sahtu Settlement Areas and Deh Cho Region. The most comprehensive sources of TK on wildlife species are available in the Gwich'in and Sahtu regions through the Renewable Resource(s) Board Harvest Studies. Here, TK and local knowledge has been useful in selecting study areas, understanding seasonal range use by species, and understanding animal - hunter dynamics. TK is also captured and interpreted for the preparation of the draft land use plans for the Gwich'in and Sahtu Settlement Areas. In the Deh Cho, extensive TK has been collected as part of the land claims efforts and was used in selecting areas for interim withdrawal and working towards setting aside the Horn Plateau as a protected area.

The GRRB has documented baseline TK for a range of wildlife species including caribou (*Rangifer tarandus*), moose (*Alces alces)*, small furbearers, fish and waterfowl. Also, through the Gwich'in Harvest Studies, information has been collected from Gwich'in hunters, trappers and fishers for 5 years. This information is the main source of mortality data for population modelling, and for understanding the distribution of mortality on the landscape. In the Sahtu, TK regarding caribou has been collected from interviews with elders (GRRB 2003). Further TK information on wildlife species is also collected in the Sahtu and is available from the Renewable Resource Board Harvest Studies. Information includes harvesting data detailing species harvested, number, location of harvest, age and sex of wildlife harvested. In the Deh Cho, however, there is no record of long-term harvest study research. Recently, however, the Deh Cho First Nations has completed traditional land use mapping for all Deh Cho communities (except Fort Liard) covering hunting, trapping, and fishing on a species-specific basis (P. Cizek pers. comm. 2003). In the Gwich'in, Sahtu and Deh Cho, as well, wildlife habitat important for Dene harvesting has been documented through land use and occupancy studies. This documentation is both site-specific and general for the region. Some TK relating to wildlife ecology, such as the caribou herd migration has also been recorded (Anderson 1998) and is used in wildlife management efforts.

TK has also been collected by project proponents (i.e., Chevron, Paramount, Ranger) in the Liard Valley, Cameron Hills and Colville Hills regions. This TK collection and presentation has been part of environmental assessment and regulatory processes for oil and gas projects. Most of this information falls into the category of presence and absence of species and archaeology surveys.

Traditional harvesting is a large part of community life in the Mackenzie Valley. Through the *Norman Wells Workshop* and community visits, concerns were raised over the potential for increased levels of contaminants in the environment, their effects on wildlife species, and how bioavailable contaminant levels in harvested species may be. To understand the potential effects to wildlife from hydrocarbon contaminants, the current levels of hydrocarbon contaminants need to be studied for harvested wildlife species.

Eleven species at risk (endangered, threatened, or special concern), according to Committee on the Status of Endangered Wildlife in Canada – COSEWIC (2002), may occur within the proposed development areas or along a potential pipeline route. These species are:

Endangered (a species facing imminent extirpation[24] or extinction[25]):

- eskimo curlew (*Numenius borealis*).

Threatened (species likely to become endangered in Canada if limiting factors are not reversed):

- wood bison (*Bison bison athabascae*);
- woodland caribou (boreal population) (*Rangifer tarandus caribou*);
- anatum peregrine falcon (*Falco peregrinus anatum*); and
- short jaw cisco (*Coregonus zenithicus*).

Special concern (species that have characteristics that make it particularly sensitive to human activities or natural events):

- grizzly bear (*Ursus arctos*);
- wolverine (*Gulo gulo*);
- short-ear owl (*Asio flammeus*);
- woodland caribou (Northern Mountain population) (*Rangifer tarandus caribou*);
- northern leopard frog (*Rana pipiens*); and,
- western toad (*Bufo boreas*).

[24] a species no longer existing in the wild in Canada, but occurring elsewhere
[25] a species that no longer exists

There are, within the NWT, a considerable number of wildlife and vegetation monitoring programs (Table 10). Many are specific to the Slave Geological Province and diamond mining activities, but with the renewed interest in oil and gas, there are also a growing number of programs in potential oil and gas development areas.

Table 10. Wildlife and Vegetation Monitoring Programs in the NWT (NWT Biodiversity Team 2003)

Notes: *Wildlife includes any animal or plant. Monitoring was defined as an activity undertaken at regular intervals and expected to continue on a long-term (e.g., 10+ years) or undetermined basis. The objective of monitoring is to detect changes -- sometimes still of an unknown nature, whereas the objective of research is to test hypotheses. Research was defined as project that is expected to end when hypotheses were tested or when the objectives were completed. Research projects were not included in the monitoring list. Satellite tracking was considered research, and hence was not included in this list. If tracking is done to investigate specific questions on, for example, movement or habitat use, then tracking is research. If tracking is expected to continue indefinitely so that it can be used as a tool to monitor movement, use, dispersion, population parameters etc. in a changing environmental context, then tracking may be considered monitoring (S. Carrière pers. comm. 2003).*

Title	Schedule	Collaborators*
• **Ungulates and Associated Predators**		
Moose Population Estimates and Population Composition (Fort Good Hope, Tulita, Norman Wells)	Every 5 years	• RWED, Sahtu Region
Photocensus - Barren-ground Caribou (Cape Bathurst and Bluenose-West)	Every 5-6 years	• RWED, Inuvik Region • RWED, Sahtu Region • GRRB • SRRB
Productivity - Barren-ground Caribou (Cape Bathurst and Bluenose-West)	Annually	• RWED, Inuvik Region • Parks Canada, Western Arctic Field Unit
Recruitment - Barren-ground Caribou (Cape Bathurst and Bluenose-West, Bathurst herd)	Annually	• RWED, Inuvik Region • Parks Canada, Western Arctic Field Unit • GRRB • SRRB • RWED, Headquarters
Fall Composition - Barren-ground Caribou (Cape Bathurst and Bluenose-West)	Every 5-6 years	• RWED, Inuvik Region • Parks Canada, Western Arctic Field Unit • RWED, Headquarters
Commercial Harvest Survey - Barren-ground caribou (Inuvialuit Settlement Region and	Annually	• RWED, Inuvik Region

Title	Schedule	Collaborators*
Gwich'in Settlement Area)		
Contaminants - Barren-ground caribou (Cape Bathurst and Bluenose-West)	Every 5 years	• RWED, Inuvik Region • RWED, Yellowknife
Environmental Contaminants in Caribou (Bathurst, Beverly & Cape Bathurst herds)	Every 5 years	• RWED Wildlife & Fisheries • RWED Inuvik Region • RWED North Slave Region • RWED South Slave Region
Population surveys – Bison (Nahanni herd)	Every 5 years	• RWED South Slave Region • RWED Deh Cho Region
Composition (calf productivity & yearling recruitment) - Bison (Mackenzie, Slave River Lowlands, Hook Lake herds & Nahanni)	Annually	• RWED South Slave Region • RWED Deh Cho Region • RWED Wildlife and Fisheries
Population Survey – Muskoxen (Mainland in Inuvialuit Settlement Region)	Every 5 years	• RWED, Inuvik Region • Parks Canada, Western Arctic Field Unit • RWED Sahtu Region (usually)
• **Fur-bearers, Carnivores and Small Mammals**		
NWT Small Mammal Survey (across NWT)	Annually	• RWED Wildlife and Fisheries • Government of Nunavut • RWED Regions • RWED Forest Management • University of Alberta • University Laval • University of British Columbia • GRRB • University of Alaska Museum
Hare Survey (Forested NWT)	Annually	• RWED Wildlife and Fisheries • RWED Regions • RWED Forest Management • GRRB
Beaver Lodge Densities (Willow Lake, Oscar Lake, Ramparts River)	Every 4 years	• RWED Sahtu Region
Harvest monitoring (problem bears killed, subsistence harvest, and sport hunts) - Grizzly bears (Inuvialuit Settlement Region and Gwich'in Settlement Area)	Annually	• RWED, Inuvik Region • Department of Renewable Resources, Dawson • GRRB
Problem bear monitoring - Grizzly bear, polar bear, and black bear	Annually	• RWED, Inuvik Region • RWED, North Slave Region

Title	Schedule	Collaborators*
		• RWED, Deh Cho Region • RWED, South Slave Region
Population surveys – Grizzly bear (Inuvialuit Settlement Region and northern Gwich'in Settlement Areas)	Every 20-25 years	• RWED, Inuvik Region • GRRB • Department of Renewable Resources, Dawson
Harvest Monitoring – Polar bears (Inuvialuit Settlement Region) problem bears killed, subsistence harvest, and sport hunts	Annually	• RWED, Inuvik Region • Wildlife Management Advisory Council (NWT)
Carcass Collection – Marten (Fort Good Hope area)	Annually	• RWED Sahtu Region
Carcass Collection – Lynx (all regions)	Annually	• RWED Wildlife and Fisheries • RWED Sahtu Region • RWED South Slave Region • RWED North Slave Region • RWED Inuvik Region
NWT-wide Rabies Monitoring	Annually	• RWED Wildlife & Fisheries • RWED Regions • GNWT Health & Social Services
• **Fish, Amphibians and Aquatic Invertebrates**		
Frog Watch NWT	Annually	• Ecology North • Ecological Monitoring and Assessment Network (including EMAN – North) • GNWT • Private volunteers (Lead: Mike Fournier)
Rat River "Char" Monitoring – Dolly Varden stock (Rat River watershed)	Annually	• GRRB • DFO
• **Vegetation – Forest and Tundra**		
Tree Phenology study (Inuvik Region)	Annually	• RWED Forest Management - Inuvik Region
Acid Rain National Early Warning System (ARNEWS), Forest Health Plot (4 plots in the NWT)	Annually first 5 years, every 5 years following	• RWED Forest Management - Inuvik Region • GRRB • Canadian Forest Service
Smithsonian Institute /Man and the Biosphere - Forest Plots (Inuvik Region)	Every 5 years	• RWED Forest Management - Inuvik Region • GRRB

Title	Schedule	Collaborators*
		• Aurora College Inuvik Campus
Forest - Permanent Sample Plots (Inuvik Region)	Every 10-15 years	• RWED Forest Management - Inuvik Region
Forest - Regeneration plots (Inuvik Region)	Annually first 5 years, every 5 years following	• RWED Forest Management - Inuvik Region
Post-fire Vegetation plots - (in various burns throughout Inuvik Region)	Annually	• RWED Forest Management - Inuvik Region • GRRB
• **Insects**		
Native Forest Insect Monitoring - Spruce budworm (all forested regions)	Annually	• RWED Forest Development - Hay River • RWED Forest Management - Inuvik Region • Canadian Forest Service
Native Forest Insect Monitoring -Forest tent caterpillar, large aspen tortrix, spruce beetle (some forested regions)	Annually	• RWED Forest Development • RWED Forest Management - Inuvik Region • Canadian Forest Service
Survey of Invasive Alien** Insects - Larch sawfly (across forested regions in the NWT)	Annually	• RWED Forest Development
• **Birds**		
Duck banding project (Willow Lake)	Annually	• U.S. Fish and Wildlife • RWED Sahtu Region
Duck banding project (Mills Lake)	Annually	• U.S. Fish and Wildlife
Trumpeter Swan Survey	Every 5 years	• CWS, Yellowknife
Boreal Songbird monitoring – population and habitat use (Liard Valley)	Annually	• CWS, Yellowknife • GNWT • DIAND • Acho Dene Koe First Nation • Industry
Christmas Bird Count 3 (Norman Wells)	Annually	• RWED Sahtu Region • Private volunteers
Christmas Bird Count 3 (Fort Simpson)	Annually	• Parks Canada, Nahanni National Park • Private volunteers
Peregrine Falcon Survey (Mackenzie River)	Every 5 years	• RWED Wildlife and Fisheries • RWED Regions (Sahtu and

Title	Schedule	Collaborators*
		Inuvik) • RWED Forest Management • CWS (part of North American-wide surveys)
Breeding Bird Survey (Norman Wells)	Annually	• RWED Regions (Sahtu) • CWS • Private volunteers (co-ordinator A. Veitch)
NWT-Nunavut Bird Checklist Survey-Incidental observations of birds are recorded for the NWT-Nunavut Bird Checklist Survey (NWT-wide)	Annually	• CWS • Parks Canada • Private volunteers
Arctic Shorebird Monitoring Program (currently in test phase- anticipated start in next 2-3 years)	Annually, rotating among zones of BCR 3	• CWS
Boreal and Taiga Shorebird Monitoring Program (currently in development phase- anticipated start of test phase in 1 year)	Annually, rotating among zones of BCRs 6 and 7	• CWS
• **Multi-species - General**		
General Status Ranks of Wild Species in the NWT– part of Accord for the Protection of Species At Risk in Canada (NWT-wide)	Every 5 years	• RWED Wildlife and Fisheries • Government of Nunavut • RWED Regions • DFO • CWS • SRRB • GRRB • Wildlife Management Advisory Council (NWT) • Fisheries Joint Management Committee • Private volunteers
Community-based Ecological Monitoring – multi-species and bio-physical (Gwich'in Settlement Area)	Annually	• GRRB • Arctic Borderlands Ecological Knowledge Society (Co-op) • Private volunteers
Resident Hunters Harvest Survey (NWT-wide) - associated fur-bearer and migratory birds information.	Annually	• RWED Wildlife and Fisheries
Pipeline Wildlife Monitoring - Enbridge Pipeline ROW (Norman Wells to Zama, AB)	Weekly	• Enbridge • RWED Sahtu Region

Title	Schedule	Collaborators*
		• RWED Deh Cho Region
Deh Cho Territorial Parks Wildlife Observations (Territorial parks in Deh Cho Region)	Annually	• RWED Deh Cho Region
Wildlife Disease Monitoring - Harvested Wildlife (NWT-wide)	Annually	• RWED Wildlife & Fisheries • RWED Regions • Canadian Cooperative Wildlife Health Centre

* *Shared budget or provided in-kind help.*
** *Alien or not native species to North America.*

In the NWT, non-governmental organizations or private citizens supervise Christmas Bird Counts locally. Birds Studies Canada supervises Christmas Bird Counts at the Canadian level (http://www.bsc-eoc.org/national/cbcmain.html), whereas the Audubon Society supervises them at the North American level (http://www.audubon.org/bird/cbc/index. html).

4.7.1.1 Mammals

Caribou

Barren-ground caribou (*Rangifer tarandus groenlandicus*) and woodland caribou can be found in the oil and gas development areas or along the potential pipeline route. Generally more information exists for the barren-ground caribou than for woodland caribou.

Barren-Ground Caribou

Satellite tracking and DNA studies completed in the late 1990s indicated that there are three separate herds within the area formerly known as the range of the 'Bluenose Caribou' herd, which includes the Cape Bathurst, and Bluenose-East and Bluenose-West herds (SRRB website: www.srrb.nt.ca/research/). The seasonal ranges of these herds continue to be studied. The Cape Bathurst herd is most likely to interact with the gathering systems in and around the Mackenzie Delta, which is north of the study area for this project (R. Case pers. comm. 2003). The Bluenose-East herd has been documented wintering in the Deline area, but not as far west as the potential pipeline route (R. Case pers. comm. 2003). The Bluenose-West herd utilizes habitat within and surrounding the Colville Hills development area, and the potential effects from hydrocarbon development on the herd is unknown (R. Case pers. comm. 2003). The Bluenose-West herd has only occasionally wintered in the area transected by the pipeline north of Fort Good Hope (R. Case pers. comm. 2003).

In 1992, estimates for the Cape Bathurst and Bluenose-West herds were 88,000 to 106,000, and 14,000 to 19,000 for the Bluenose-East herd. Radio-tagging and census studies have been completed on the herds. Studies on the 'Bluenose Caribou' herd have also looked at genetics, post-calving productivity surveys, parasite infections, diet and long-term fall body condition (Nagy *et al.* 2002).

The documented ranges for the Porcupine and Bathurst herds do not overlap with any portions of the development scenario. However, community reports suggest that, prior to scientific monitoring, the Bathurst herd had wintered in the Wrigley area and the Porcupine herd had moved through the southern Delta. The range of the Porcupine herd largely occurs within the Yukon and Alaska, and extends west slightly into the NWT in the Mackenzie Delta area and through the northern Mackenzie Mountains roughly along the NWT-Yukon border. The range of the Bathurst herd extends from east of Bathurst Inlet to the east side of Great Bear Lake. Hall (1989) noted that the winter ranges of the Bluenose and Bathurst herds may overlap slightly, and there may be some interchange of animals between them.

Following a low estimate of 111,000 animals in 1979, the Bathurst herd recovered in the 1980s and has been considered stable since 1990 at a population of approximately 350,000 (surveyed 1996) (NWT CIMP 2002). Due to increased mining interest, herd movements were studied in the 1990s by satellite tracking collars placed on cows. Population and energetic simulation modelling is underway for the Bathurst herd and a co-management plan is also currently being developed.

The Porcupine caribou herd was estimated at approximately 129,000 animals in 1998 http://www.pcmb.yk.ca/pcmb/upsdowns.html. The herd has been declining since 1998; however, the rate of decline appears to be slowing for reasons not know yet (http://www.pcmb.yk.ca/pcmb/upsdowns.html) A census is planned for summer 2003. Monitoring and research is being undertaken through the Porcupine Caribou Management Board. Development and industrial activities are a concern throughout the herd's range in Alaska, Yukon and western NWT (NWT CIMP 2002).

Research and monitoring of the Porcupine caribou herd has been conducted almost continuously since the early 1970s. Studies have included: genetics, cow body condition, productivity, fall and late winter herd composition, and movements in relationship to the Dempster Highway (Nagy *et al*. 2002). Energetic, growth and harvest models for the Porcupine caribou herd have been developed that predict metabolizable energy intake on a daily basis, the weight gain and loss throughout the year and demographics of the herd over a number of years. These models are intended to aid in evaluating the present data, to help guide future research, and to provide some insights into the potential impact from development (Hovey *et al*. 1989).

Although there is some information on the parasite and pathogens of barren ground caribou, no experimental studies or long term monitoring has been done to determine how pathogens/parasites affect the health of these populations.

Woodland Caribou (boreal and northern mountain populations)

Woodland caribou can be found in the Liard Valley, Cameron Hills, Norman Wells, Colville Hills, and along the potential pipeline corridor. Boreal woodland caribou occur throughout the Mackenzie River valley and northern mountain caribou inhabit the Mackenzie Mountains to the west.

Northern mountain woodland caribou migrate in late winter from treed areas to areas above the treeline for calving and rutting before returning to the forests in late summer/fall. The NWT shares the Bonnet

Plume, Redstone (possibly three herds), the South Nahanni, Coal River and possibly the La Biche herds with the Yukon. Some TK information is available for northern mountain woodland caribou are TK studies (Nagy *et al*. 2002), but no scientific knowledge exists on for this caribou.

Boreal woodland caribou remain within the boreal forest throughout the year. They are found at low densities (1-3 caribou per 100 km^2) and remain in small groups on large home ranges (Nagy *et al*. 2002). Bogs and fens in black spruce or lichen areas and open jack pine forests are preferred habitats for foraging and predator avoidance. Populations are vulnerable to predators such as wolves (*Canis lupus*) and grizzly bears. Boreal woodland caribou studies were initiated in 2002 and include satellite tracking, habitat use and vegetation mapping (Nagy *et al*. 2002). At the present time, information on critical habitat in the NWT is either not compiled or not known (NWT CIMP 2002). Little information on parasites and diseases in woodland caribou is available (S. Kutz pers. comm. 2002).

Some work on habitat use by caribou in the Mackenzie Mountains has been undertaken (Ion and Kershaw 1989); however, information on extent of occurrence, area of occupancy, population structure and demographics and habitat use is required for both boreal and northern mountain woodland caribou (R. Case pers. comm. 2003). No studies have been conducted on northern mountain woodland caribou in the Peel or Liard Plateau areas, so the importance to these areas to caribou currently cannot be assessed (R. Case pers. comm. 2003). Information on boreal woodland caribou is required for Cameron Hills, Sahtu (NW) and Colville Hills and for the potential pipeline (R. Case pers. comm. 2003).

Moose

The NWT is the northern extent of the range for moose and densities are low (1 to 17 moose per 100 km^2) compared to other areas in North America (Stenhouse *et al*. 1995; RWED 2002a). In the NWT, moose are widely distributed south of the treeline, and more scattered near the treeline and on the tundra. Two subspecies exist, the Alaska-Yukon moose (*Alces alces gigas*) in the Mackenzie Mountains and the northwestern moose (*Alces alces andersoni*) in the remainder of the territory (NWT CIMP 2002).

Based on mapping in the Sahtu Settlement Area, patches of moose habitat (including winter habitat) exist in the Norman Wells development area and abundant habitat exists along the length of the Mackenzie River (Walton-Rankin 1977; Jingfors 1984; Sahtu Land Use Planning Board website www.sahtulanduseplan.com/gis/maps/index.html). Moose surveys have been completed at selected sites but generalizations of presence or densities cannot be made for regions based on this data (R. Case pers. comm. 2003). Population estimates remained stable (at approximately 500) from the mid-1980s to 1999 in the Norman Wells area but dropped to less than 200 animals in 2001 with a trend to decreasing calf survival and low calf/cow ratio (Veitch 2001; NWT CIMP 2002). Populations around Fort Good Hope and Tulita are considered to be stable (Veitch 1997a; Veitch 1998a).

In the Gwich'in Settlement Area (including the Peel Plateau) moose densities are low therefore results of population surveys are highly variable. Moose studies in this region have assessed browse, population and age/sex of harvest since 1990s (Nagy *et al*. 2002). One study determined the relative abundance of moose in burns of different ages in the Sahtu (Latour and Maclean 1994). Further, sightings of moose and other wildlife were recorded as part of archaeological surveys conducted for the proposed Mackenzie Valley pipeline (Thomson 2001).

In the Deh Cho Region, in the vicinity of the Liard Valley highway, moose surveys were conducted in the winter of 1978 by the then NWT Wildlife Service, now RWED. In all, three (3) aerial transect surveys along the highway route were undertaken to gather baseline data on moose populations. Habitat was mapped according to four levels of utilization based on the relative abundance of moose tracks observed. The results of the survey indicated an estimate of 440 moose (0.06 moose /km^2) for the 7,390 km^2 study area. Densities ranged from 0.24 moose/km^2 to 0.01 moose/km^2. Since then, moose have been noted as part of surveys for oil and gas development in the Liard Valley and Cameron Hills, as well as the Norman Wells to Zama pipeline.

TK presented at an RWED workshop in the Deh Cho indicated an observed decline in caribou and moose near Providence, a decline in moose around Wrigley and a change in some animal populations along the highway.

Information on moose population, distribution and movement, habitat, harvest management and the use of TK were noted as important in a recent Gwich'in wildlife workshop (Nagy *et al*. 2002).

With the exception of the Sahtu, moose population data are dated, and data on predation rates and effects of increased access are lacking in the vicinity of the hydrocarbon development areas (R. Case 2003 pers.comm.). Baseline information on population data (population size, productivity, habitat status) and predation rates, and information on the effects of increased access resulting from development are required for Norman Wells, Liard Plateau, Peel Plateau, Cameron Hills and the potential pipeline (conclusion drawn from *Scientists' Workshop*).

Dall's Sheep

Dall's sheep (*Ovis dalli dalli*) are found in the Mackenzie and Richardson Mountains along the Yukon border (including the Peel Plateau). Population estimates have ranged from 14,000 to 26,000 based on a compilation of surveys of various mountain blocks (NWT CIMP 2002). Studies have included mineral lick and seasonal range use mapping in the early 1970s (Nolan and Kelsall 1977; Simmons 1982), radio-collars studies on rams in the mid-1980s, range surveys, forest block surveys and lungworm infection investigations from mid 1980s to 2001 (Ferguson *et al*. 1985; Barichello *et al*. 1987; Case 1989; Oestreich 1998; Nagy 2001). The GRRB is initiating a long-term monitoring program on Dall's sheep habitat use in the Mount Goodenough area of the Richardson Mountains, including winter use, grazing pressure and vegetation classification.

The Dall's sheep population has been noted to be stable and in good condition (NWT CIMP 2002); however, additional research to determine a population with a greater level of confidence may be warranted, especially within the Liard (R. Case pers. comm. 2003). Responses of Dall's sheep to development activities has been studied but has not been examined with current population and distribution data. Communities have noted a lack of population dynamics, health and abundance information for Dall's sheep in the Liard area.

Although there is some information on the parasite and pathogens of Dall's sheep, including lungworm infection investigations, no experimental studies or long term monitoring has been conducted to determine how pathogens/parasites affect the health of these populations (S. Kutz pers. comm. 2002). In 1999, the first documented deaths of Dall's sheep anywhere across their range in North America as a result of pneumonia were discovered in the north Mackenzie Mountains (SRRB, http://www.srrb.nt.ca/research/r2000.html).

Mountain Goats

Mountain goats (*Oreamnos americanus*) are a species at the limit of their range in the NWT. They are found only in the southern Mackenzie Mountains and therefore may not be influenced by oil and gas development activity in the next five to fifteen years. Their population is estimated to be between 400 to 1,000 individuals, though population trends are unknown (NWT CIMP 2002).

Bison

Two bison (*Bison bison athabascae*) populations are in proximity to the potential pipeline and development areas: the Liard River / Nahanni and the Mackenzie populations. The Liard River / Nahanni bison range throughout the Liard River Valley in the NWT and have expanded their movements into British Columbia and the Yukon. Suitable habitat for bison is extremely limited in the Liard River Valley. The herd was estimated at between 50-100 individuals in 1994. First Nations in the Deh Cho are interested in further monitoring of this herd (RWED 2002a).

In 1973, 18 bison were introduced into the Mackenzie Bison Sanctuary, located on the north side of Great Slave Lake roughly between Ft. Providence and the north arm of Great Slave Lake. From 1973 to 1989, the Mackenzie bison population was estimated to have grown to approximately 2,000 animals (Gates and Larter 1990) and now occupies the area between Cameron Hills and Fort Providence. The herd continues to be monitored by RWED for calf survival, bull:cow ratio and the presence of brucellosis and tuberculosis (Nishi 2001).

Although there is sufficient information on abundance, productivity and habitat association, it is unclear how the development of a potential pipeline corridor down the Mackenzie Valley may affect the re-colonization of Bison. As pointed out at the *Scientists' Workshop*, there is potential that it may promote bison recolonization, which may not be desirable.

Muskox

Based on a stratified systematic strip transect survey flown in March 1997 to determine muskox (*Ovibos moschatus*) abundance and distribution, RWED estimated that there are 1,460 ± 920 (95% confidence interval) muskox in the Sahtu Settlement Area north of Great Bear Lake (Colville Hills) (Fournier and

Gunn 1997). Comparisons to previous surveys in the late 1950s to 1987 (Case and Poole 1985; McLean 1992) indicate that muskox have spread west and increased in number. Unfortunately the trend in population size cannot be statistically verified owing to survey method differences (Veitch 1997b). Recent survey information indicates that muskox maybe expanding their range further south below treeline; however, limited historical data makes this difficult to confirm (Fournier and Gunn 1997; Shank 1990).

Grizzly Bears

Grizzly bears are found predominantly north of the treeline and in the Mackenzie Mountains. Monitoring by radio-collar in the central barrens has shown that grizzly bears can have very large home ranges (averaging 7,200 km^2 for males and 2,100 km^2 for females) (McLoughlin *et al*. 1999; NWT CIMP 2002). The population of grizzly bears is thought to be stable (NWT CIMP 2002), but few population studies have been conducted recently within the proposed development areas to confirm this.

Grizzly bear studies in the Gwich'in area have included population estimates and productivity (Branigan 1999), harvests and kills. A database is kept to include information on captures. Concerns about grizzly bear populations, habitat and problem bear management were recently noted by the Gwich'in people (Nagy *et al*. 2002). Grizzly bear traditional and local knowledge has recently been compiled by RWED for Gwich'in and Inuvialuit communities.

Black Bear

Black bear (*Ursus americanus*) are found primarily south of the treeline in the NWT. There appears to be no population or habitat related studies undertaken for these species in the proposed development areas and as a result any population level information is limited to harvest records (RWED status report, www.nwtwildlife.rwed.gov.nt.ca). Two studies dealing with problem black bears around landfills have been undertaken at Norman Wells. These studies have developed useful techniques for reducing problem bear numbers (www.nwtwildlife.rwed.gov.nt.ca).

Wolves

Wolves are found throughout the NWT and include tundra populations (within Colville Hills and Peel Plateau development areas and the very northern portion of the pipeline route) (Heard and Williams 1992; Walton *et al*. 2001) and boreal populations (located within all development and pipeline areas) (Heard 1981). Wolves are being studied extensively in the Slave Geological Province (Cluff *et al*. 2001; NWT CIMP 2002) and wolf studies have included genetic testing and carcass collection for health, condition and diet measurements in the Gwich'in area (NWT CIMP 2002). Concerns about wolf population, habitat, interaction with other species and public safety have been noted for the Gwich'in Settlement Area (Nagy *et al*. 2002).

Wolverine

Wolverine population estimates are not known. Wolverines are sparsely distributed, mainly on the tundra in the NWT. They are a species at risk (special concern) according to the COSEWIC, and although there appears to be limited population or habitat related studies undertaken for this species in the Mackenzie Valley, (Addison and Boles 1978) it is considered secure in the NWT (NWT CIMP 2002).

Lynx

Lynx (*Lynx canadensis*) are found mainly south of the tree line in the NWT. Lynx are specialist predators feeding primarily on snowshoe hares (Krebs *et al*. 2001). As a result, lynx abundance follows the 10-year population cycle of snowshoe hare (*Lepus americanus*), lagging behind by 1 or 2 years (Stenseth *et al*. 1999; Krebs *et al*. 2001). Peaks and lows in lynx numbers can be predicted using snowshoe hare survey data. Populations in the western NWT appear to be increasing and are considered healthy (NWT CIMP 2002). Age distribution, sex ratios and body condition are monitored through lynx pelts and carcass collections throughout the NWT (Mulders 2001). Live trapping and radio-collar programs have been completed to examine home range size, habitat use, dispersal rates and survival rates (Poole 1992). The age composition of harvested lynx has been collected in the Gwich'in Settlement Area (Nagy *et al*. 2002).

Coyote

A limited number of harvest records exist for coyote (*Canis latrans*) and there are no current population estimates available for the proposed development areas in the NWT RWED status report, www.nwtwildlife.rwed.gov.nt.ca.

Red and Arctic Foxes

Red fox (*Vulpes vulpes*) and Arctic fox (*Alopex lagopus*) are found in all regions of the NWT. Red fox are more abundant in the boreal forest while arctic fox are most common on the tundra. There have been no population or habitat related studies undertaken for these species in the proposed development areas as a result any population level information is limited to harvest records.

Beaver

Beaver (*Castor canadensis*) are found primarily south of the tree line in the NWT and are considered to have stable populations with population increases occurring in some regions (NWT CIMP 2002). Beaver make extensive use of high-density lake complexes in glacial-lacustrine basins, hilly ground moraines and river deltas and are vulnerable to water level fluctuations and to localized over harvest (NWT CIMP 2002).

Beaver studies completed along the proposed pipeline route in the 1973 focussed on surficial landform features, current beaver population and accessibility. Study results showed that small streams in the southern and central regions were frequented to a much greater extent than the streams in the northern Mackenzie Valley (Dennington and Johnson 1974). This may be related to relatively high fluctuations in water levels in areas of permafrost. Willow species are the most frequently utilized food for beaver, but in some areas birch and pond lily were used exclusively (Dennington and Johnson 1974). The relative quality of habitat (reflected in population density) appeared to be enhanced by an optimum distribution of land and water (maximum available shoreline), stable water levels and sufficient quantities of one or more food species (Dennington and Johnson 1974).

Results from an active lodge surveys over 25 years covering an area of 2059 km^2 in western NWT indicated that active lodge densities are similar to those found in northern boreal habitats elsewhere and suggest that beaver trapping could be promoted and encouraged in most areas (Poole and Croft 1990).

Although no accurate estimate of beaver numbers is available for the proposed development areas, active beaver lodge counts have been undertaken in the Sahtu area to provide some information (Popko 2001).

River Otter

River otter (*Lutra canadensis)* a limited number of harvest records exist for river otter, and there is no current population estimate available for the proposed development areas, the pipeline corridor, or for the NWT (RWED status report, www.nwtwildlife.rwed.gov.nt.ca).

Fisher

Fisher (*Martes pennanti*) a limited number of harvest records exist for fisher, and there is no current population estimate available for the proposed development areas, the pipeline corridor, or for the NWT (RWED status report, www.nwtwildlife.rwed.gov.nt.ca).

Marten

Marten (*Martes americana*) are found throughout forested areas of the NWT. Population cycles are largely influenced by prey availability. Populations are thought to be stable, but habitat loss and potential over harvesting are key concerns (RWED status report, www.nwtwildlife.rwed.gov.nt.ca).

Age composition of marten harvest has been collected in the Gwich'in area (Nagy *et al*. 2002). One RWED study determined the relative abundance of furbearers (primarily marten and lynx in forest burns of different ages in the Sahtu District (Latour and Maclean 1994). Another RWED study determined the location and structure of dens where the young are born, the time of birth, the timing, direction, and distance of dispersal of male and female marten in the Sahtu (Colville Hills and Norman Wells development areas) (Veitch 1998b). In addition, Douglas *et al*. (1983) conducted a study of habitat selection and food habits of marten in the Sahtu area.

Mink

Mink (*Mustela vison*) are found throughout the NWT, primarily associated with aquatic habitats. Their populations are believed to be stable, but are vulnerable to water pollution and localized over trapping (NWT CIMP 2002). They are considered to be a sensitive indicator of ecosystem health as they readily bioaccumulate environmental pollutants (NWT CIMP 2002).

Ermine

Ermine (*Mustela erminea*) harvest records exist for ermine, and there is no current population estimate available for the proposed development areas, pipeline corridor, or for the NWT (RWED status report, www.nwtwildlife.rwed.gov.nt.ca).

Muskrat

Muskrat (*Ondatra zibethicus*) abundance is unknown for the NWT; however, reports indicate a decline in numbers in the Sahtu area (RWED status report, www.nwtwildlife.rwed.gov.nt.ca). Apart from harvest records there appears to little information on muskrat populations collected in the proposed development areas.

Other Small Mammals

Other small mammals are distributed widely throughout the NWT. Within the proposed development area the most common species include: snowshoe hare, Arctic hare (*Lepus arcticus*), porcupine, red squirrel (*Tamiasciurus hudsonicus*), Arctic ground squirrel (*Spermophilus parryii*), woodchuck (*Marmota monax*), least weasel (*Mustela nivalis*), lemmings (*Dicrostonyx kilangmiutak* and *Lemmus sibiricus*), voles (*Clethrionomys* spp. and *Microtus* spp.), deer mouse (*Peromyscus maniculatus*) and shrews (*Sorex* spp.)

Larger carnivores prey upon these species and many undergo dramatic population fluctuations that occur on a 4 to 10 year cycle (e.g., voles, lemmings, snowshoe hares). In turn, these cycles influence the population and distribution of predators, including lynx, coyote, fox and marten.

The first 7 years of a program designed to monitor small mammal population abundance throughout the NWT utilized standardized methods designed to provide sufficient accuracy to establish major between-year/within-site trends at minimal effort and expense (Shank 1997). In total, 126 snap-trapping sessions were undertaken in 27 locations throughout the NWT. Results show that peaks in collared lemming abundance occurred in 1993 and 1996 and possibly in 1990 in some areas. Brown lemming numbers peaked in 1996 with evidence for peaks in 1993 and 1990. Rough-legged Hawk numbers from 1981 - 1996 correlate with small mammal capture indices and indicate regular small mammal peaks at intervals of 4 years. Below the treeline, voles peaked at all locations in either 1994 or 1995. Deer mice showed no geographic synchrony in numbers (Shank 1997).

Extensive reconnaissance surveys along various pipeline route alternatives to collect data on important fur-bearer species populations and habitat were initiated in 1971. A preliminary study of the trapping economy in all communities along the route was also included to evaluate fur resources of small mammals (in addition to beaver, otter, lynx, wolverine, marten and mink) along the proposed pipeline and highway route to aid in formulating management plans (Ruttan and Wooley 1974). In the Sahtu region, snowshoe hare and small mammal populations, fur auction data, age of lynx harvest, snow track counts and harvest collection are monitored (SRRB and RWED 2002). Some areas in the Mackenzie Valley are very productive for fur.

4.7.1.2 Birds

Song, Forest and Raptorial Birds

The NWT/Nunavut Bird Checklist Survey contains records from all across the NWT for bird species for at least the past 10 years. Specific areas with intensive data include Nahanni National Park, Fort Liard area and, to a lesser extent, the Norman Wells area. The CWS has collected breeding bird survey data for the Fort Liard, Fort Simpson and Norman Wells areas (CWS pers. comm. 2003).

Some preliminary information is available on population trends for song/forest birds, but it is not statistically rigorous (CWS pers. comm. 2003). Observation records exist for the broad-winged hawk (*Buteo platypterus*), the connecticut warbler (*Oporornis agilis*), and other bird species for the Liard Valley (Machtans 2000). In addition, a winter bird survey of the Rae and Heart Lake areas has been undertaken (Carbyn 1968) and recorded 13 species.

The CWS has been working on studies of the boreal forest songbird communities within the Liard Plateau development area. These include data collection on songbird relative abundance and habitat use, detailed vegetation data for the areas surveyed and the completion of stand-level models for the abundance of some songbird species. Five years of data have been entered into a database and a report is expected in 2003. This research has identified significant songbird habitat in Liard Valley, including the northern most extent of boreal-mixed wood forests and valuable habitat for boreal songbirds. The mature mixed-woods and dense old-growth coniferous stands within the Cameron Hills development area (located along the Cameron River and large tributaries) are expected to support the highest densities of breeding birds in the study area (Paramount and Golder 2001). There is a lack of density estimates for migratory forest birds north of the Liard Valley (CWS pers. comm. 2003).

Baseline information is available for some raptor species in the NWT, such as the threatened anatum sub-species of peregrine falcon (81 nesting pairs were observed in 2000 throughout the Mackenzie River Valley) (NWT CIMP 2002). Raptor monitoring has included documenting nest site occupancy (raptors tend to nest at historical nest sites from year to year), reproduction rates and production of fledglings within a geographic area.

In the 1970s, the peregrine falcon and gyrfalcon (*Falco rusticolus*) populations in the Mackenzie Valley made up significant portions of the surviving North American populations (Berger 1977). Nesting sites for these and other raptor species existed all along the Mackenzie Valley, in particular in the Campbell Hills and Franklin Mountains. With the reduced use of organochlorine based pesticides in North America over the last 20 years, most populations of raptors, including peregrine falcons, are stable or increasing and are considered to be healthy throughout the NWT (Murphy 1990; White *et al*. 1990; Carrière 2000). A survey of gyrfalcon nests undertaken between 1982-1991, estimated populations across the NWT to be stable at approximately 1,300 breeding pairs (Shank and Poole 1994). It is unclear how development activities associated with a potential pipeline may affect raptor nesting success rates and nest site abandonment.

Key migratory bird areas and raptor nest sites have been mapped within the Norman Wells development area and the Sahtu portion of the Mackenzie Valley. Key migratory bird areas occur along most of length of Mackenzie River in the Sahtu region (www.sahtulanduseplan.com).

Aquatic Birds

The Mackenzie Valley is a migratory bird flyway with important nesting, staging and moulting areas documented prior to the Berger Inquiry to include the Ramparts River, Mackay Creek, Bracket Lake, Mills Lake and Beaver Lake (Berger 1977). Annually, CWS along with the U.S. Fish and Wildlife Service conduct waterfowl surveys. Fixed-wing surveys are carried out annually throughout the western NWT by U.S. Fish and Wildlife Service as part of the annual co-operative spring population waterfowl surveys (J. Hines pers. comm. 2003). The surveys are used for long-term monitoring of waterfowl populations and setting hunting seasons and bag limits. It is the understanding of the CWS that the status and trends for most species of ducks are based on these surveys. In the NWT, the data from the surveys are based on relatively few transects scattered over broad areas, and if mapped out, would show areas of general importance to different species – but are not useful for site-specific evaluations. The results of these surveys are used to set the annual hunting regulations.

Aquatic birds, including gulls, terns, loons, ducks, geese and swans are generally abundant and widespread in the NWT. The abundant lakes, ponds and wetlands in the forested areas of the NWT provide important breeding habitat for aquatic birds. Although baseline information is lacking for most species, some information is available through monitoring programs and surveys for specific species (mostly in key breeding areas) (NWT CIMP 2002). Populations of some species of ducks: long tailed duck (*Clangula hyemalis*), lesser scaup (*Aythya affins*), surf scoter (*Melanitta perspicillata*), white-winged scoter (*Melanitta fusca*), and northern pintail (*Anas acuta*) have declined recently. Large-scale continental surveys are taking place; however, they do not provide quality data that can be applied at the local level. Two species of aquatic birds may be at risk in the NWT: the harlequin duck (*Histrionicus histrionicus*) and the American white pelican (*Pelecanus erythronhynchos*) (NWT CIMP 2002); although Fournier and Bromley (1996) indicate that harlequin ducks have a wide distribution in the NWT with hundreds of breeding pairs.

Scaup and scoters are currently experiencing long-term declines in their populations for unknown reasons (B. MacDonald pers. comm. 2002). The life histories of scaup and scoters are not well understood. The core breeding range of these species is the northern Mackenzie Valley. Ducks Unlimited and partners are conducting a long-term ground study to identify the reasons for the decline (B. MacDonald pers. comm. 2002).

Three-year waterbird surveys have been completed by Ducks Unlimited for areas centred around Norman Wells (“Sahtu Project”)and Inuvik (“Lower Mackenzie Project”), and surveys are to commence in 2004 and 2005, respectively, for the Peel Plateau area (“Peel Plateau Project”) and the area centred around Fort Good Hope (“Middle Mackenzie Project”). These data will be used to develop a predictive model to determine where waterbird hotspots are throughout portions of the Mackenzie Valley. Water chemistry work is also being carried out simultaneously by Ducks Unlimited in these areas.

A waterfowl density study in the 1970s along the proposed Mackenzie Valley pipeline and lateral pipeline routes was completed to determine potential impacts on waterfowl (Boothroyd 1987). Aerial surveys were conducted along the proposed routes. The highest bird density was noted in the northernmost segment of the main pipeline route, particularly Richards Island (Boothroyd 1987).

Within the Mackenzie River Valley, islands and sandbars on the river from Wrigley to Arctic Red River are key resting and mating sites for migrating swans, geese, ducks and shorebirds in spring (May and June) (Kavik-Axys and LGL 2001; SRRB and RWED 2002). Important spring staging areas for aquatic birds are located along the Mackenzie River from Fort Good Hope to the Tree River. Sandbars and mudflats of islands host almost the entire western arctic population of lesser snow geese (*Chen caerulescens caerulescens*), several thousand tundra swans (*Cygnus columbianus*) and tens of thousands of other waterfowl. Upstream of Fort Good Hope (to the Redstone River), lesser snow geese use the open water and exposed shorelines early to mid-May. Greater white-fronted geese (*Anser albifrons*), Canada geese (*Branta canadensis*), tundra swans and ducks use the open water during spring and fall migration (Kavik-Axys and LGL 2001; SRRB and RWED 2002). Aquatic bird studies have been completed in areas of the Sahtu region and three migratory routes for waterfowl have been noted (Kavik-Axys and LGL 2001; SRRB and RWED 2002).

Kavik-Axys and LGL (2001) identified shallow, marshy areas east of the Mackenzie Valley including Beaver Lake and Mills Lake as attracting waterfowl during migration. The Ramparts River and Camkay Creek were also identified as important waterfowl nesting, moulting and staging areas, as were lakes north and south of Norman Wells and 50 km SE of Fort Simpson. The Brackett (Willow) Lake area, composed of forested bogs and wetlands, supports 5,000 to 10,000 breeding ducks (scaup) and thousands of staging waterfowl (greater white-fronted geese, tundra swans) and unknown numbers of shorebirds (long-billed dowitchers, pectoral sandpipers, lesser yellowlegs) (Kavik-Axys and LGL 2001).

It was concluded at the *Scientists’ Workshop* that despite the above information on aquatic birds for the Mackenzie Valley, there is limited information on breeding behaviour and habitat use by waterfowl and shore birds in the Mackenzie Valley, especially for inland lakes. Most of this research has been conducted in the Mackenzie Delta.

4.7.1.3 Amphibians

Both boreal chorus frogs (*Pseudacris maculata*), wood frogs (*Rana sylvatica*) and American Toads (*Bufo boreas*) are found in the Mackenzie Valley (K. Larsen pers. comm. 2003; Larsen and Gregory 1988). Although there has been limited research on these species in the proposed development areas, both species are well adapted for northern climates, and are likely found throughout most of the proposed development areas (K. Larsen pers. comm. 2003). The long-toed salamander (*Ambystoma macrodactylum*) may be present in the Liard Plateau development area, but this has yet to be confirmed (www.nwtwildlife.rwed.gov.nt.ca).

4.7.1.4 Reptiles

The red-sided garter snake (*Thamnophis sirtalis parietalis*) is the only reptile species known to occur in the NWT. However, this species distribution does not extend to any of the proposed development areas (Larsen and Gregory 1988).

4.7.1.5 Baseline Knowledge Gaps

1. Need to research the baseline level of contaminants (associated with oil and gas development) in harvested wildlife species and assess the potential for release of contaminants.

2. Boreal Woodland Caribou - Need information on extent of occurrence, area of occupancy, population structure and demographics, and habitat use and effectiveness.

3. Northern Mountain Woodland Caribou - Need information on extent of occurrence, area of occupancy, population demographics and habitat use.

4. Bluenose West Caribou Herd - Information on movements and winter range use is needed.

5. Furbearers - Estimates of furbearer distribution and abundance need to be developed based on habitat type, existing access and harvest data, with focus on key harvested species (lynx, marten, wolverine, beaver and muskrat).

6. Dall's Sheep - Need information on population dynamics, health and abundance in the Liard Plateau.

7. Moose - Need population abundance, trend and resilience data for Moose, including information on productivity, predation rates, and habitat status.

8. Forest Birds:
   a) Information is required on population presence, density and inventory, and population-habitat association data of forest birds.
   b) TK information on forest birds is required.

9. Waterfowl and Shore Birds - Need information on breeding behaviour and habitat use in the Mackenzie Valley.

4.7.2 Impact Assessment and Regulatory Processes

Impact on wildlife and wildlife habitat from oil and gas development and pipeline construction has been studied extensively in areas such as Alberta, British Columbia and Alaska where there has been considerable development pressure. Potential impacts on wildlife and wildlife habitat may be:

- direct mortality;
- displacement of individuals and populations;
- disruption and reduction of home range;
- habitat loss and fragmentation;
- habitat change;
- changes in predator-prey relationships;
- food-web disruption/change;
- introduction of foreign/non-native species; and
- ecosystem level changes (The Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee 2002).

A number of studies have been completed in northern Alberta regarding impacts of all phases of oil and gas development on wildlife. Mitigation measures have been established to reduce or eliminate some potential impacts (Bott 1999; Hardy BBT Limited 1987, 1990; Hardy Associates 1994; Spencer Environmental Management Services 1986). Some of this work may form the basis for the development of an understanding of impacts and the preparation of mitigation in the Mackenzie Valley area. Specific refinements could be made to these measures for each of the five hydrocarbon development area (R. Case pers. comm. 2002).

4.7.2.1 Direct Wildlife Mortality

Direct wildlife mortality may result from hydrocarbon development activities or activities/structures associated with development (CWS pers. comm. 2003; Kavik-Axys and LGL 2001; J. Nagy pers. comm. 2003):

- hunting due to increased access to remote areas via ROW;
- animal control actions;
- vehicular collisions with wildlife;
- bird collisions with structures such as towers or power lines;
- mortality of young birds and eggs from vegetation clearing or traffic over wetlands during the breeding season;
- destruction of mammal den/nest sites (bears, marten, squirrels, beaver etc.) shortly after parturition or during hibernation, as a result of vegetation clearing or water level changes (i.e., dam removal); and

- ingestion or inhalation of oil-related contaminants during construction, operation or accidental releases.

The following mitigation measures have been noted to reduce or prevent direct wildlife mortalities:

- prevent human access to newly cleared areas and ROWs (CWS pers. comm. 2003);
- implement strict control of firearms at facilities and ban hunting in areas (NEB 1977);
- prevent vehicular access along ROWs (NEB 1977);
- conduct nest surveys prior to clearing or conduct clearing outside of the breeding season;
- utilize satellite communication systems to minimize the placement of tall towers, a hazard for flying birds and light towers to allow them to be visible (NEB 1977);
- place barriers around hazard areas;
- conduct flaring to minimize gas emissions;
- have an emergency response plan in place and conduct regular inspections and repairs to deal with accidental releases of liquid or gas toxicants; and
- separate power line conductors to prevent electrocution of birds standing on the wire (NEB 1977).
- scheduling construction and other associated activities so that barriers to migrating caribou herds are minimized;
- monitoring the seasonal distribution and day-to-day movements of caribou during critical periods before and during construction;
- approved measures designed to prevent caribou from being obstructed or entrapped by project-related activities (including but not limited to: minimizing the time gap between trenching and backfilling, construction of earthen plugs in open trenches to permit animals to pass over or escape trenches, and the skewing of stacking of pipe strung out along the ROW to allow animals to move freely);
- approved measures to minimize any disturbance of caribou that approach the construction site (e.g., shutting down operations, backfilling parts of the trench, and moving pipe strung-out along the ROW);
- roads be maintained so that snow fences or snow drifts from clearing roads are not continuous so caribou can pass easily;
- restricted access to the pipeline ROW and related facilities to personnel directly associated with the project;
- implementation of controlled flying heights and frequency of project related aircraft activity; and
- contingency plans for fire suppression and priority for fire prevention and control in areas of important caribou habitat.

4.7.2.2 Habitat Loss and Fragmentation

During the 1970s pipeline proposals, recommendations were made regarding how to avoid or mitigate disturbance to wildlife and habitat during construction and operation of the pipeline. Suggestions, at that time, were made for an environmental surveillance program and an ornithological monitoring program (Gunn and Tull 1976) to monitor for impacts as a result of habitat loss and fragmentation. Habitat fragmentation studied in Alberta's boreal forests (Hobson and Bayne 2000) found that forest fragment size had little effect on species richness but correlated significantly with abundance for all migratory and edge-sensitive groups. Predation and brood parasitism were also higher for ground and shrub nesting species in fragmented forests.

Concern for habitat loss and fragmentation also arose at community workshops in the Gwich'in, Sahtu and Deh Cho regions in 2002. This anecdotal knowledge covered concerns for effects on wildlife from development, climate change and other activities. This included, but is not limited to, changes in wildlife movement, migration, health, contamination and species presence. Site and development specific information varies in each region as the context of the workshops varied. Aboriginal community members have also noted both positive and negative effects from seismic lines on wildlife hunting and trapping.

Habitat loss and fragmentation may result from the following hydrocarbon development activities (CWS pers. comm. 2003; Kavik-Axys and LGL 2001; J. Nagy pers. comm. 2003):

- clearing for various ROWs (for seismic surveys, pipeline developments, transportation and electrical routes);
- development; and
- forest fires from human activities.

Information on the effects of linear projects on many wildlife species (including survival, fecundity and dispersal) exists from studies in the northwestern United States, Alberta and Alaska. The Paramount pipeline development in the Cameron Hills area noted that vegetation clearing will result in altered habitat and a displacement of species that favour mature forest (such as woodland caribou) and an increase in species that favour an early successional forest stage (MVEIRB 2001).

Impacts of roads and seismic lines on boreal caribou are currently being studied in Alberta (S. Boutin pers. comm. 2002) and the Liard Plateau. Statistically significant avoidance of ROWs (roads, seismic lines and well sites) has been documented. Road densities of 0.6 to 0.9 km/km^2 have resulted in declines in caribou density by 86% (Applied Ecosystem Management Ltd. 2002a). Habitat loss through clearing of vegetation also allows for easy movement by predators (such as wolves) and therefore increased predation on species such as caribou. The GRRB has initiated a project with RWED to evaluate the impact of seismic line cutting on woodland caribou habitat quality by looking at caribou movements in relationship to the lines and by measuring regrowth in vegetation on the seismic lines (GRRB April 2003 presentation at *Scientists' Workshop*).

Fragmentation of mature or climax habitat may have a localized, negative effect on songbirds that depend on this habitat, including increased nest predation and nest parasitism and decreased dispersal (CWS pers. comm. 2003). Declines in breeding success of birds followed by declines in populations of birds have been recorded after removal of habitat for development (CWS pers. comm. 2003).

Like many mammals, birds are reluctant to cross wide ROWs (CWS pers. comm. 2003). Impacts of roads and seismic lines on forest birds are currently being studied in Alberta (S. Boutin pers. comm. 2002) and the Liard Plateau (Boutin pers. comm. 2002; Machtans and Latour 2003). Two seasons of data has been collected to determine direct impacts of a pipeline corridor on songbirds for the Shiha (Paramount) Pipeline (Cameron Hills) and the Chevron Pipelines (Liard Plateau) and further data will be collected in 2003, five years following the developments (CWS pers. comm. 2003). The CWS has recommended that a study be conducted along the existing pipeline ROW from Norman Wells, designed to detect differences in nest predator abundance immediately adjacent to the pipeline compared to areas away from the pipeline. A full study of the actual predation rate may not be necessary as it could be well designed and based on work published by Warren Fleming.

As discussed above, clearing and development of ROWs (especially in the boreal forest) increase edge habitat which can ultimately result in increased forest bird nest predation (typically by corvids and red squirrels), increased parasitism and changes to community composition (MVEIRB 2001). Nesting shorebirds are also susceptible to increased predator access as a result of ROWs (CWS pers. comm. 2003).

Berger (1977) concluded that while moose are not immediately sensitive to encroachment on its habitat, successive disturbances will cause moose to move farther away. Furbearers are also susceptible to successive development affecting their habitat and pushing them farther from the proposed pipeline corridor. Arctic foxes, red foxes and wolves all den in well-drained, gravely soil, areas that could provide borrow material for construction (Berger 1977). Winter construction will not likely coincide with spring denning, however, all three species re-use the same den sites year after year.

The following mitigation measures have been noted to reduce impacts due to habitat loss (Dennington and Johnson 1974; NEB 1977, MVEIRB 2000; CWS pers. comm. 2003; J. Nagy pers. comm. 2003):

- avoid productive habitat areas for wildlife species (e.g. riparian and wetland habitat for moose, wetland habitat for breeding birds, muskrat and beaver);
- maintain a buffer between developments and sensitive habitats;
- where construction is required, minimize habitat impacts and restore the function of the habitat;
- minimize areas of impact. Best practices for seismic lines, roads, well leases and pipelines to minimize impacts on wildlife could include utilizing existing corridors, narrower corridors, adding bends in lines (to minimize line of sight), minimize redundant clearing of habitat (due to overlapping seismic programs), maintain forested paths across ROWs and do not disturb topsoil;
- restore cleared areas with vegetation previously present to minimize long-term loss of habitat type; and
- monitor wildlife and habitat following development to determine habitat regeneration and effects of development on wildlife.

Studies in other parts of Canada (e.g., Alberta) suggest some wildlife species are particularly sensitive to habitat fragmentation. It was noted at the *Scientists' Workshop* that although some studies of this nature have been conducted in the Mackenzie Valley (as noted above), they are relatively few. Communities and the renewable resource boards also raised concerns about the lack of information and understanding about the effects of habitat fragmentation on wildlife. Additional research is required into the potential effects of habitat loss and fragmentation and evaluated for applicability to the Mackenzie Valley.

4.7.2.3 Barriers to Wildlife Movement

Barriers to wildlife movement may apply at the daily or migratory movement scale and can be physical or sensory in nature. Above ground structures such as pipelines can pose a major barrier to mammal movement. ROWs can be considered partial barriers for mammals and birds due to their avoidance of these areas. Long lines of sight, anthropogenic structures and noise may result in alterations in wildlife movement (MVEIRB 2001).

Altering movement or migration patterns can result in increased energy use for some species. Caribou are particularly sensitive to deflections of movement during calving. Woodland caribou barriers to movement (roads, fences and elevated pipelines) have been known to reduce the number of crossings and act in a synergistic manner when parallel (Applied Ecosystem Management Ltd. 2002a). There is currently no information to discriminate between natural and man-made changes in caribou migration with any degree of certainty (NWT CIMP 2002).

Migratory caribou herds use a wide range of habitat in their large-scale movements. The loss of any part of a herd's range could reduce the vitality of a herd (Berger 1977). Berger specified concern for the Bluenose herd's expansion west at that time and the potential for a pipeline development (and associated hydrocarbon development) to halt this.

The following mitigation measures have been noted to reduce the impacts of barriers:

- retain buffers of undisturbed land between cleared areas or developments and routes frequented by wildlife to prevent visual and auditory distraction;
- bury pipelines;
- create wildlife crossings across above-ground linear developments at key movement locations;
- leave forested crossings along cleared ROWs;
- leave large buffers along rivers to maintain riparian zones identified as important wintering or calving areas for ungulates; and
- use trenchless methods (e.g., horizontal directional drilling) of watercourse crossings for pipelines where riparian zones are used as important travel corridors.

During community visits and at the *Norman Wells Workshop*, communities raised concerns about how species behaviour and inter-species relationships (predator-prey) may change due to development activity (e.g., cutlines). Behavioural responses of wildlife to development activities have been studied in other areas, but confirmation is needed that similar responses can be predicted for hydrocarbon development in the Mackenzie Valley.

4.7.2.4 Wildlife Sensory Disturbance

Sensory disturbance to wildlife can result from visual, auditory, vibrational or olfactory stimuli.

Sensory disturbance of animals can result in a physiological response of stress that results in increased energy expenditure and reduced foraging efficiency. Ungulates are particularly sensitive to disturbance that results in energy use during the winter when reserves are low and during calving (NEB 1977). In addition, breeding birds are sensitive to sensory disturbance, especially during clearing or construction activities. A decrease or loss of shorebird breeding productivity could occur in the five development areas (CWS pers. comm. 2003). Species have been known to adapt to sensory disturbance from permanent facilities if disturbances are regular and predicable (Paramount and Golder 2001).

The distribution of moose in the vicinity of an oil drilling rig and its associated haul road in the Norman Wells development area was monitored from December 1989 to March 1990 by eight survey flights. The haul road traversed the lower Mountain River, a recognized wintering area for moose. The drilling rig was situated 7 km from the Hume River valley, also a recognized wintering area for moose. Moose abundance increased then stabilized during the study period in the haul road area and remained in the vicinity of the haul road all winter (i.e., within 0-2 km) despite regular, but variable, vehicular traffic on the road. Moose were absent within a 5 km radius of the oil rig itself, but this was most likely a result of the poor moose habitat there. Nearby, moose numbers remained low and constant (Latour 1992).

Visual disturbance may result from alterations of landscape and vegetative cover (seismic cuts through a forest) or the presence of anthropogenic structures (pipelines, buildings, machinery). Sensory disturbance of mammals (ultimately leading to changes in animal distribution, abundance and productivity) during construction of the proposed Mackenzie Valley pipeline was considered a moderate issue during a recent assessment (Kavik-Axys and LGL 2001). Of note were sensory impacts on denning bears, wolverines and wolves as well as migratory and calving ungulates.

Impacts of project-related toxins (gases or liquids) on wildlife have been noted as an issue. Depending on the type of toxin, location and amount, impacts can range from loss of forage opportunities from vegetation being killed (e.g., salt water spill) to mortality from ingestion (e.g., oil spill coating a frog or mink). There may be other long-term health impacts on wildlife that are not well understood such as long-term exposure to low levels of H_2S.

Auditory disturbance can result from active machinery and transportation (aircraft, vehicles), as well as operations of facilities. Although auditory disturbance on wildlife is not well documented, studies have been completed to determine effects of noise on boreal woodland caribou in Alberta (S. Boutin pers. comm. 2002). Noise from construction and operations (even compressor stations) could result in avoidance of nearby areas, which could be important travel corridors, feeding or breeding areas for wildlife (NEB 1977). Aircrafts (fixed wing and helicopter) are known to disturb wildlife, including migratory birds, Dall's sheep (J. Nagy pers. comm. 2003), caribou (Applied Ecosystem Management Ltd. 2002a) and bears.

Little information is available on the impacts of light on wildlife that may result from construction, drilling, service rigs, flaring and lit facilities. Light may attract or deter wildlife under various conditions. The potential for disturbance to birds that migrate by the stars has been raised (Paramount and Golder 2001).

Vibrational disturbance to wildlife can result from seismic surveys or blasting during construction. Seismic exploration is known to cause bears to abandon their dens (Sahtu Land and Water Board pers. comm. 2003). In-river seismic surveys can also disturb semi-aquatic fur-bearers.

Noise disturbance may potentially result from such structures and activities as compressor stations, noise from traffic/aircraft, general operations and construction. Studies of the impacts of compressor station noise on snow geese demonstrated that birds had disrupted movement patterns and as far as three miles away birds were displaced. A mitigation measure is to muffle sound from compressor stations. Further studies of the birds' movements and behaviour patterns are necessary to plan appropriate mitigation measures (DIAND PAAG 1974).

Raptors are prone to abandon their nests and/or young when disturbed by man or noise. Scheduling of operations that are close to raptor nesting areas, according to DIAND PAAG (1974), should be outside of February 1st to July 31st for gyrfalcons, and outside of April 15th and August 31st for other raptors.

The following mitigation measures have been noted to reduce the impacts of sensory disturbance on wildlife:

- conduct seismic and construction work outside of times when wildlife are in sensitive stages (no breeding birds or calving caribou). Winter construction will avoid the Porcupine caribou herd in the northern development areas and migratory bird breeding and movements;
- maintain distance from sensitive species. For example, blast at a distance from grizzly dens during the winter. Foothills proposed to avoid blasting within one mile of grizzly dens from Nov 15 to May 15 and blasting away from waterfowl breeding areas May 1 to June 15 (NEB 1977);
- prohibit harassment by aircraft or terrestrial vehicles (NEB 1977);
- confine machinery and vehicles to work areas (ROW, access roads, landing strips, borrow areas) (NEB 1977);
- maintain regular and predictable flight paths, avoid sensitive areas and maintain a minimum distance from the ground, where possible, particularly during sensitive times (NEB 1977);
- during in-river seismic surveys, utilize bubble curtain and/or ramping up methods to minimize auditory and vibrational impacts on semi-aquatic fur-bearers.
- keep facility noise levels at those considered acceptable for permanent facilities (Paramount and Golder 2001);
- flare to reduce gas emissions; and
- have an emergency response plan in place and conduct regular inspections and repairs to deal with accidental releases of liquid or gas toxicants.

4.7.2.5 Impact Knowledge Gaps

1. Need to study the potential effects of habitat fragmentation on different wildlife species.

2. Need to study the behavioural responses of wildlife to development activities, including inter-species behaviour changes, i.e. changes in prey vulnerability

3. Boreal Woodland Caribou - Need information on factors affecting caribou survival and responses to human activities.

4. Bison - Information is needed on how linear developments contribute to re-colonization of Bison.

5. Raptors - Information is needed on how specific development activities affect nesting success rates and nest site abandonment.

6. Moose - Need information on effects of increased access resulting from development.

7. Forest Birds - Information is required on effects of rights-of-way on predation rates on forest birds.

4.8 Biodiversity

Canada was the first industrialized nation to ratify the *United Nations Convention on Biological Diversity*, which entered into force on December 29, 1993. The concept of biodiversity, however, had been in existence for at least the previous three decades. Biodiversity, or biological diversity refers to "the variety of species and ecosystems on Earth and the ecological processes of which they are a part". The *Convention* recognizes three components of biodiversity:

- ecosystem;
- species; and
- genetic diversity.

The Canadian Biodiversity Strategy is Canada's response to the *Convention*. The NWT Biodiversity Action Plan is largely based on the Canadian Biodiversity Strategy, and it aims to review each goal of the Strategy from the context of the NWT and strategically implement them. The major products of the plan will be: a searchable list of NWT activities and initiatives related to biodiversity, a web page on biodiversity, Report 1 will list current activities related to biodiversity in the NWT, and Report 2 will provide a gap analysis, and future strategies and actions.

The goals of the NWT PAS works towards protecting biodiversity. The NWT PAS is a community-based tool initiated in 1999 by both the federal and territorial governments and supported by a comprehensive stakeholder group – the vision is to promote a balanced approach to land use decisions and develop a network of protected areas.

Understanding the biological diversity of the NWT is in its infancy. A great deal of information has been collected on the species of the Mackenzie Valley and much of this information has been recorded within the ASTIS database at the University of Calgary. Not unexpectedly, much of this information is a one-time snapshot of a species study in a particular area. On the other hand, there are several monitoring programs underway within the NWT that are designed to collected long-term species presence and abundance data (S. Carrière pers. comm. 2003). However, these programs will not capture all extant species in the NWT and are not specific to the oil and gas development areas or a potential pipeline route (see Table 10). Instead, the focus of these programs is to capture information on species of importance for reasons of subsistence, livelihood or rarity (e.g., mammals, waterfowl and fish).

TK conveys a wide range of information, and may include valuable information about biodiversity. In addition to governmental, university and industrial research programs, TK collected by communities and organizations has contributed to knowledge of species and ecosystem processes (MacDonald Environmental Sciences Ltd. 1995). For example, a pilot project in the Dogrib region looked at place names as an indication of information about the land, waterways and resources and how this contributes information necessary for caribou hunting. The results showed that place names made good indicators of hunting biogeographical knowledge. Further, patterns show that place names associated with flora and fish names are indicators of biodiversity, while place names with topographical or water flow information are descriptors of the landscape and water situations conveying information necessary to travel across the land (Dogrib Treaty 11 Council 1998).

Communities have expressed interest and raised concerns over the need to develop a better understanding of the balance of nature and how the biological and physical components are related and dependent on each other, and how these relate to biodiversity. TK that conveys information about diversity would provide invaluable input to understanding biodiversity in the Mackenzie Valley.

Few genetic diversity studies have been completed in the NWT and even fewer have been done specific to areas of potential oil and gas development or a potential pipeline corridor. Species studied include:

- woodland caribou in the Mackenzie Mountains (Benn 2000, MacDonald 2000);
- bison (Nishi 2000, 2001);
- cisco (Reist *et al*. 2002);
- char (Reist *et al*. 1997);
- wolves (Musiani *et al*. 2000); and
- selected aquatic invertebrates (Hebert *et al*. 1997).

Local genetic variation reflects local adaptation within a species, and is an important part of biodiversity. Identifying genetically distinct sub-populations would contribute to our knowledge of the local/regional ecosystem, and would also influence project planning. Such genetic information would be particularly useful for understanding the vulnerabilities of species at risk (S. Carrière pers. comm. 2003).

Selected ecological processes or ecosystem functions have been studied for northern boreal forests. Attention has been paid to the possible effects of climate change on particular species or specific ecosystems and on the relationship of fire and wildlife (Johnson 1992). Selected species specific studies have also taken place e.g., woodland caribou distribution and movement (Gullickson 1998; Quayle and Kershaw 1994) and andromous fish movement (Howland 1997).

Oil and gas exploration and development and pipeline construction has the potential to impact species, ecosystems and genetic diversity i.e., the three components of biodiversity. Understanding the impacts on biodiversity is an expansion of the impacts to wildlife and wildlife habitat and vegetation and forests. The possible impacts on biodiversity include:

- changing the status, distribution and vulnerability of individual species;
- changing the dynamics of ecosystems that support threatened or endangered species;
- changing the rate of extinction occurring and likely to occur;
- changing regional differences in extinction rates; and
- changing minimum sustainable gene pools and population size (IUCN 1993).

In an effort to better record the impact on biodiversity as a result of development proposals, the GNWT (2001), the Environmental Resources Management Ltd. (2000), the Canadian Environmental Assessment Agency and Biodiversity Convention Office (1996) and others have developed (or are developing) guidance material aimed at enhancing the ability to collect and exchange information specific to evaluating the impact on biodiversity and understanding how to mitigate for potential impacts. Some basic questions (not exhaustive) to be addressed in any assessment process include:

- what is the species?
- where and how may populations are there?
- what are the trends in their numbers and distribution?
- what are the threats to the populations or habitats?
- will there be an impact on an established protected area?
- will there be an impact on biological resources important for the conservation of biological diversity?
- will there be an impact on attempts to protect ecosystems or promote the recovery of threatened species?
- will there be a release living modified organisms resulting from biotechnology which may have adverse environmental impacts? and
- will there be an introduction of an alien species which threaten ecosystems, habitats, or species? (adapted from Bagri *et al* 1998).

In the absence of a single approach to measuring impact on biodiversity, a variety of approaches have been used to measure impacts. Potential changes to biodiversity at the landscape, community or species level can be looked at relative to the natural variability in the measurable parameters for biodiversity, such as uncommon landscape units (Kavik-Axys and LGL 2001). Another method is to use the indicators in the Limits of Acceptable Change approach to deal with biodiversity impacts and predictions (Macleod Institute 2002). In general, the probability of human impacts on biodiversity and ecosystem function can generally be related to distance to human infrastructure (Applied Ecosystem Management Ltd. 2002a). In an analysis of the general concepts relating to biodiversity (Biodiversity Science Assessment Team 1994), caution to adhering to any one approach was issued and it was stressed that it was important that the appropriate indicators be selected and that suitable spatial and temporal boundaries be selected. Methodologies for assessing impacts to biodiversity need to consider that adequate baseline information may be absent for some species and that there is limited information on ecological processes.

4.8.1 Baseline Knowledge Gaps

1. Need TK that conveys information about biodiversity.

2. Genetically distinct species sub-populations of 'species at risk' need to be identified

4.8.2 Impact Knowledge Gaps

1. Methodologies for assessing impacts to biodiversity need to be improved.

4.9 Air

The upstream oil and gas industry includes all activities that find, produce and process oil and natural gas including the treatment of liquid petroleum gas, condensates, crude oil, heavy oil and crude bitumen. Collectively, the upstream oil and gas sector is a significant source of criteria air contaminants in Canada. Criteria air contaminants are defined by Environment Canada under its reporting requirements for the National Pollutant Release Inventory (NPRI) (Canada Gazette, part I, January 4, 2003) as including the following substances:

- carbon monoxide;
- oxides of nitrogen;
- $PM_{2.5}$;
- PM_{10};
- sulphur dioxide;
- total particulate matter; and
- volatile organic compounds (VOCs).

There are a couple of other air contaminants that are important to consider for the oil and gas sector that are not included in the list of criteria air contaminants. These include ground-level ozone, hydrogen sulphide and benzene. Ground-level ozone generally results from the atmospheric transformation of oxides of nitrogen oxides and VOCs in the presence of ultraviolet light. Therefore, air quality issues associated with ground level ozone must address emission of its precursors. Hydrogen sulphide and benzene, on the other hand are natural constituents in petroleum reservoirs and can be produced with both natural gas and crude oil. Reservoirs containing hydrogen sulphide are classed as sour and additional processing is required to remove this contaminant at source. Benzene is a natural constituent of petroleum products and is included in the general category of VOCs. Both hydrogen sulphide and benzene are toxic substances listed under Group 1 substances in the NPRI reporting requirements.

Based on the most recent annual NPRI report (Environment Canada 2002), the Crude Petroleum and Natural Gas Industries were the largest industrial sector in terms of reporting on-site releases of NPRI substances. It should be noted that of the total emissions, 35 percent are emitted to air and the scope of the reporting includes many compounds in addition to the criteria air contaminants noted above. It should also be noted that several of the criteria air contaminants are considered greenhouse gases and their emission will contribute to climate change. The primary greenhouse gas compounds associated with the upstream oil and gas industry include carbon dioxide, methane and nitrous oxide.

There have been a number of emission inventories conducted regarding releases of these compounds from the upstream oil and gas sector. For example, the Canadian Association of Petroleum Producers has prepared emission estimates for methane and VOCs (CAPP 1999). This information is used for illustrative purposes to identify the relative contribution of emissions from oil and gas exploration, production, storage and transportation activities. Table 11 provides a summary of emissions and the percent contribution associated with each of these activities.

Table 11. Summary of Total Hydrocarbon Emissions in Tonnes from Canadian Upstream Oil and Gas Activities (1995) (Note: Percentage contributions are enclosed in brackets)

Activity	Equipment Leaks	Process Vents	Combustion Equipment	Storage Tanks	Accidents & Equipment Failures	Total
Drilling		3050 (79.2)	787 (20.4)	14 (3.7)		3,851
Well Servicing & Testing		8575 (98.8)	109 (1.2)			
Gas Production	484,686 (73.1)	127,507 (19.2)	50,692 (7.6)			662,886
Conventional Oil Production	100,515 (17.5)	57,701 (10.0)	42,770 (7.4)	373,465 (65.0)		574,451
Heavy Oil Production	43,785 (8.5)	459,810 (89.2)	7,087 (1.4)	4,695 (0.9)		515,376
Crude Bitumen Production	1,200 (8.4)	11,995 (83.8)	1,112 (7.8)			14,307
Gas Processing	54,146 (48.2)	19,610 (17.4)	35,784 (31.8)	2,869 (2.6)		112,410
Product Transportation	166,401 (58.6)	99,534 (35.1)	13,168 (4.6)	4,634 (1.6)		283,737
Accidents & Equipment Failures					99,908 (100)	99,908
Total Emissions	850,733 (37.4)	787,782 (34.6)	151,509 (6.7)	385,667 (16.9)	99,908 (4.4)	2,275,609

This information helps put the relative contribution of total hydrocarbon emissions into perspective for various upstream activities. Although differences in the percent contribution can be expected for other critical air contaminants, the total distribution is not expected to change significantly for the purpose of this investigation. Based on this, production activities are expected to be the largest contributor to emissions, followed by product transmission. The contribution from drilling and well servicing is expected to be relatively minor. Equipment leaks and process vents are expected to be the largest sources of VOCs. Emission of other critical air contaminants, notably carbon dioxide, oxides of nitrogen and sulphur dioxide, are likely to be more closely associated with combustion sources.
Potential sources of emissions include:

- flaring during well testing and oil production operations;
- glycol dehydrators (primary source of benzene emissions);
- gas flaring and sulphur recovery at gas processing plants;
- combustion gases from process heaters, processing equipment and compressors;
- fugitive emissions from storage and handling facilities;
- oil spills and waste management activities
- well blowouts; and
- pipeline failures.

It is also important to recognize the significant greenhouse gas emissions potential associated with upstream oil and gas activities. Not all greenhouse gases have the same potential to influence greenhouse effects or impacts. For example, a given quantity of methane has 21 times, and nitrous oxide has 310 times the potential of carbon dioxide to influence global warming. Therefore, control of process and fugitive sources of these compounds becomes critical in effectively managing the overall influence of oil and gas activities on climate change.

For the purpose of assessing potential impacts of oil and gas operations on the Mackenzie Valley it is important to have both the tools with which to predict emissions and background data to assess effects. For this purpose it is important to establish existing background conditions regarding air quality and provide the necessary meteorological data that will be necessary to run detailed air quality dispersion models. It is also important to investigate and identify potential gaps related to existing contaminant monitoring/baseline air quality data including meteorological parameters (wind speed, direction, temperature, solar radiation, turbulence, atmospheric stability, etc.).

4.9.1 Baseline

There are no known documented sources of TK about air along the potential pipeline corridor or in the oil and gas development areas of the Mackenzie Valley.

Air quality data have historically been collected at the following sites in the Mackenzie Valley: Yellowknife, Snare Rapids, Inuvik, Norman Wells and Fort Liard. The Yellowknife station has monitored:

- ground level ozone since 1998;

- total suspended particles (TSP) since 1974;
- sulphur dioxide since 1992;
- arsenic since 1985;
- lead since 1982;
- sulphate since 1985; and
- particulate matter since 1999.

Acid precipitation/deposition has been monitored at the Snare Rapids hydro site since 1989, but it currently does not monitor any other pollutants. The Fort Liard station has monitored hydrogen sulphide and sulphur dioxide since 2000. The addition of the Fort Liard station is in response to the significant oil and gas development in the region (2001/2002 NWT Annual Air Quality Report produced by RWED). The stations at Inuvik and Norman Wells monitor a number of gaseous and particulate pollutants (e.g., H_2S, SO_2), but not all that might be expected from oil and gas development. Emission producing equipment (e.g., compressors, dehydrators) will not necessarily be placed near the existing air quality monitoring stations, therefore some baseline information in such areas will be needed to predict future potential impacts in these areas.

In establishing appropriate baseline air quality data, the following pollutants associated with oil and gas development are typically measured: particulate matter, nitrogen oxides, VOCs, and ground level ozone, hydrogen sulphide, and sulphur dioxide. This information is also used for modelling air emissions.

Stations at Inuvik, Norman Wells, and Fort Liard monitor meteorological parameters, but provide site-specific information for these areas and are not necessarily useful for extrapolation to other locations. Snare Rapids does not monitor meteorological parameters. There is a need for meteorological data (wind speed and direction, air temperature, other parameters) sufficient enough to allow for a risk-based approach to point-source and multiple-source dispersion studies/modelling of air-dispersed contaminant releases from oil and gas exploration and development sites. This is usually done by the proponent at the time of development, but in advance of any permit application, as modelling requires a minimum of one full year of data.

The Meteorological Service of Canada has collected climate data at Fort Liard, Fort Simpson and Fort Nelson as well as some sporadic air quality data.

Under the *NWT Environmental Protection Act*, the GNWT has established ambient air quality standards for SO_2, TSP, $PM_{2.5}$ and ozone (Guideline for Ambient Air Quality Standards in the NWT, RWED 2002b). In addition, in response to the increase in hydrocarbon exploration and production in the Mackenzie Valley, the Environmental Protection Service of RWED published a consultation draft of the *Air Quality Code of Practice Upstream Oil and Gas Industry*, September 2002. This code provides air emission guidelines for flaring, fugitive emissions, pipeline emissions, venting and sulphur recovery. As well, it provides guidelines for noise emissions, measurement, reporting and modelling.

4.9.1.1 Baseline Knowledge Gaps

1. Air Quality Monitoring:
   a) Need to upgrade air quality monitoring stations at Inuvik, Norman Wells, and Fort Liard to measure for particulate matter (TSP, PM_{10} and $PM_{2.5}$), nitrogen oxides (NO_x), VOCs, and ground level ozone (O_3). The current acid precipitation station at Snare Rapids would provide true background concentrations (unaffected by any emission sources) but needs to be expanded such that it can measure TSP, PM_{10} and $PM_{2.5}$, NO_x, VOCs, O_3 as well as hydrogen sulphide (H_2S) and sulphur dioxide (SO_2).
   b) Baseline air quality monitoring for TSP, PM_{10} and $PM_{2.5}$, NO_x, VOCs, O_3, H_2S, and SO_2 needs to be established at other locations where emission producing equipment, such as compressor stations, are proposed.
   c) Using the above noted stations, need to establish baseline air quality conditions and to use these data for modelling air emissions.

2. Requirement for meteorological data sufficient to allow for point-source and multiple-source dispersion modelling studies of contaminant releases from oil and gas exploration and development sites.

4.9.2 Impact Assessment and Regulatory Processes

Air quality changes can result from flaring, generator use, compressor stations, vehicle use, and from other sources associated with oil and gas activities. Of primary concern to the residents of the Mackenzie Valley are changes due to flaring. There are no documented sources of TK concerning the impact of developments on air quality.

Air emissions resulting from oil and gas activities have the potential to impact the health of humans and the terrestrial and aquatic environment. H_2S is of most concern from a human health perspective. Acidifying emissions from oil and gas development have the potential to affect the terrestrial and aquatic environment, particularly oxides of sulphur and nitrogen. Regulatory agencies have established maximum acceptable ambient air concentration limits to protect against impacts to the environment. The NWT has ambient air quality limits for sulphur dioxide, ground-level ozone, TSP, and fine particulate matter. EIAs undertaken in the NWT have used air quality standards from other jurisdictions (e.g., Alberta) for other air emission substances/contaminants.

With the exception of project-specific EIAs, there is little, if any, work that has been or is currently being conducted on impacts of air emissions to human and environmental health, specific to the Mackenzie Valley. Some studies have been conducted on the effects of atmospheric emissions from the Royal Oak Giant Mine and Miramar Con Mine in Yellowknife (e.g., GNWT 1993).

There is research being conducted around the world on air emissions and human health impacts. Many studies of human health effects related to the oil and gas industry in Alberta have been conducted. The Canadian Council of Ministers of the Environment (CCME) continue to explore linkages between human health and the environment and promoting standards for key air pollutants affecting human health and the environment (CCME Business Plan 2003/04 to 2005/06).

Relatively little research has been conducted on air quality impacts to wildlife (G. Veale pers. comm. 2003). Concerns regarding wildlife impacts from air emissions include respiratory, reproductive, gastrointestinal and neurological problems (Clean Air Strategic Alliance 2003). Some research on wildlife impacts related to air contaminants has been conducted in Alberta related to the oil and gas industry, but with a focus on livestock (e.g., Alberta Environment Research Centre 1996; Waldner *et al.* 1998; Scott 1998). Under the Clean Air Strategic Alliance (CASA), an Animal Health Project Team was established in 1999 whose goal is to prevent short and long-term adverse impacts of air contaminants on animal health. CASA recently released its Animal Health Project Team Final Report and Recommendations in March 2003. Wildlife can also be indirectly affected if air emissions result in changes in the quality of available habitat (i.e., vegetation communities, water quality for amphibians).

Concentrations of NO_x and SO_2 can potentially affect vegetation health, depending on the dosage, plant sensitivity and environmental conditions. Direct effects to vegetation results when plants absorb gases or liquids containing harmful compounds through their leaves. Vegetation may be affected through long-term chronic exposures or short-term acute exposures to air emissions. Indirect effects are produced when acidifying emissions change the chemistry or biology of soil or water that, in turn, influences the amount and type of nutrients and toxic elements taken up by plants (e.g., reduction in soil pH). Lichens and mosses are more sensitive to air emissions than other plant groups as they absorb water and nutrients directly from the air.

When annual concentrations of SO_2 and NO_2 are sufficiently high, they have been linked to acid deposition, which can have an impact on waterbodies and the aquatic biota inhabiting these waterbodies.

4.9.2.1 Impact Knowledge Gaps

1. Biological Indicators of Air Quality:
   a) Need to research the sensitivity of wildlife and vegetation species to air quality changes, and determine which species would be good indicators of poor air quality.
   b) Need to research the appropriate ambient air quality standards for wildlife.

4.10 Climate Change and Climate Change Effects

4.10.1 Overview

There is a growing consensus among scientists, and a growing body of evidence to suggest that the earth’s climate is changing due in part to human activities that increase the amount of greenhouse gases in the atmosphere. The greenhouse effect, a normal part of the earth’s energy balance, is the absorption of long-wave radiation by the atmosphere. The absorption of long-wave radiation by the atmosphere causes additional heat energy to be added to the Earth's atmospheric system. Recent increases in concentrations of greenhouse gases in the atmosphere suggest that this effect may become enhanced. The Intergovernmental Panel on Climate Change (IPCC) has concluded that some global climate change has already occurred and that increased emissions of greenhouse gases due to human activity have contributed and will continue to contribute to this change (IPCC 1996).

Global climate change is difficult to predict accurately in both magnitude and rate, and varies considerably by region and type of impact. Local and regional variations in air and ocean circulation patterns (e.g., El Nino[26] and La Nina[27] events) and topographic features (e.g., the presence of water bodies and mountains) play an important part in influencing local weather. These events can make it difficult to distinguish climate change effects over the short-term. However, long-term temperature trends indicate the western Arctic has warmed by about 1.5°C over the past 100 years, with warming being most pronounced in the winter and spring (Etkin *et al.* 1998). Research further suggests increases in global annual mean temperatures by 1° to 3.5°C by 2100 are expected, and will be even more pronounced in the arctic (Etkin *et al.* 1998). More recently, the IPCC reported a range of warming, relative to 1990, of 1.4 to 5.8°C by 2100 using 40 scenarios (IPCC 2001). Arctic regions, including the Mackenzie Valley, will be particularly affected by these temperature and climate changes which will contribute to such effects as increased risk of forest fire, widespread thinning and disappearance of permafrost, and changes in snow pack and precipitation. These effects in turn will contribute to changes in vegetation, wildlife and other ecological patterns and functions.

4.10.2 Impact on Permafrost and Hydrology

Climate change can affect the distribution, extent and type of permafrost in a variety of ways through impacts on the ground temperature regime. Dyke and Brooks (2000) predicted that a 2°C increase in mean annual temperature would have very little effect in the Norman Wells area, but permafrost would almost completely disappear around Fort Simpson. Climate change could cause the melting of widespread ground ice which would result in down slope soil movement, loss of slope stability, ground subsidence, and massive terrain slumping, leading to increases in sediment loads to rivers and lakes (Shriner and Street 1997).

---

[26] El Nino is a disruption of the ocean-atmosphere system in the tropical Pacific, causing warming of the ocean temperature off the British Columbia coast, which in turn influences temperatures (warmer) and precipitation (dryer) weather patterns across Canada.

[27] La Nina is characterized by unusually cold ocean temperatures in the Equatorial Pacific, causing cooling of the ocean temperature off the British Columbia coast, which in turn influences temperatures (cooler) and precipitation (wetter) weather patterns across Canada.

The following is taken from Shiner and Street (1997) and is an excellent summary of the predicted impacts on permafrost in northern Canada as a result of climate change:

> "*The projected northward shift of the southern boundary of permafrost areas will alter ecosystem structure and functioning, with subsequent impacts on associated infrastructure and wildlife through terrain slumping, increased sediment loading in rivers and lakes, and dramatically altered hydrology*".

Eradication of permafrost is of long-term concern at sites where the frozen ground is less than 5 metres thick. At other sites, with deeper permafrost, the effects of climate warming are also likely to be evident in a deepening of the active layer. In the last 5 to 7 years numerous studies have begun to examine and report on the sensitivity of permafrost soils and processes to climate change in the Mackenzie Valley (M. Burgess pers. comm. 2003). For example, a network of active layer and ground temperature monitoring sites is being developed by the GSC to document recent changes (Nixon and Taylor 1994; Nixon *et al.* 1995; Nixon and Taylor 1998), but gaps in the network still exist, especially north of Norman Wells (also see Section 4.2.1). As well, predictive models of terrain sensitivity have been under development, (1D, 2D and deployed in GIS to generate maps at a variety of scales) but, the scale and resolution of these models need to be improved and applied to hydrocarbon development areas, in addition to the potential pipeline corridor (M. Burgess pers. comm. 2003).

As mentioned above, the GSC is monitoring active-layer thickness along the Mackenzie Valley. The critical impact of active layer thickening is on hill slopes, where thawing of near-surface ground ice may provide a failure plane for slope movement (Dyke and Brooks 2000). There is already considerable evidence for hill slope failure following forest fires as a result of changes in surface conditions i.e., ground warming and thawing of near-surface permafrost (Harry and MacInnes 1988; L. Dyke pers. comm. 2003). This deepening of the active layer has consequences for pipeline ROW siting making it essential to identify slopes where failure could occur.

In continuous permafrost areas of the Mackenzie Valley, a loss of permafrost would also affect foundations and the stability of structures. In these areas, permafrost has also been used as an impermeable containment barrier for sumps where used drilling fluids, drill cuttings and other wastes are disposed. Climate change could affect the stability of these sumps, which could result in ground subsidence, loss of sump containment, and contamination to surrounding land and water. The potential effects on permafrost due to sumps are further discussed in Section 4.2.2.

Runoff and stream flows are generally expected to increase in winter and decline in summer with climate change (Shriner and Street 1997). In arctic regions, permafrost maintains lakes and wetlands above the impermeable frost table and limits subsurface water storage. The thawing of permafrost would increase active-layer storage capacity and alter wetland hydrology. Shriner and Street (1997) note that although climatic warming could have a large effect on arctic hydrology, the changes are highly uncertain at this time and need further consideration.

Travelling over ice is an important part of life in the north, due to the dependence on traditional occupations, food gathering and hunting. Climate change could mean thinner ice on lakes and rivers, making winter travel more hazardous(C. Burn pers. comm. 2003). Likewise, as mentioned above, it is predicted that climate change could mean not only warmer temperatures in the north, but more snowfall (precipitation). Snow depth helps determine the thickness of ice, as snow acts to insulate ice from cold air. Ice thickness is related to the number of freezing degree-days (intensity) of a particular winter. The insulating effects of snow could compound problems with thinner ice. Models suggest that doubling the levels of greenhouse gases in the atmosphere would cause a 30 to 50 percent increase in Arctic snowfall (Skinner *et al.* 1995).

Ice cover duration on lakes and rivers may also be shorter as a result of climate change. This could mean longer open water seasons which could affect the water balance of a particular area, through changes in the hydrologic cycle such as increased evaporation (M. Lacroix pers. comm. 2003).

4.10.3 Impact on Vegetation

Climate change may result in increased fire frequency, air temperature changes, changes in precipitation levels, alterations in hydrology and melting permafrost in the NWT hydrocarbon development areas. These changes may directly affect the large-scale distribution of plant communities causing species migration, substitution or extinction. Indirectly, any change in vegetation may have an effect on the underlying ground structure, in particular, permafrost that in turn could again affect the distribution of vegetation. In reality, climate change must be considered as a cumulative effect on vegetation that introduces uncertainty in predicting future land cover (R. Case pers. comm. 2003). Approximately 50% of the wetlands in North America are found in Northern Canada and Alaska, and most of these wetlands rest on continuous or discontinuous permafrost (Shriner and Street 1997). Peatlands are projected to disappear from south of 60°N in the Mackenzie Basin (Cohen 1997). These types of impacts will undoubtedly have significant impacts on northern ecology including aquatic resources, wildlife and cultural values and lifestyles.

Fifteen years of monitoring along the Norman Wells pipeline, and several other studies in the Mackenzie Valley and western Arctic dealing with the effect of vegetation disturbance on ground thermal regime are available (Mackay 1970; Kerfoot 1973; Brown and Grave 1978; M. Burgess pers. comm. 2003). Also, measures to restrict thermal disturbance, in particular insulation with wood chip on slopes, have been undertaken and the effectiveness assessed. However, the effects on permafrost when climate change is considered on top of vegetation removal are not well understood.

4.10.4 Impact on Fish and Wildlife

Working on the assumption that climate change will mean gradual warming, preliminary work with respect to climate change impacts on fish and wildlife has focused on the potential for increased frequency and intensity of forest fires, extension of fish and wildlife northern ranges, and resulting effects from changes to ice conditions and precipitation. However, the impact on fish and wildlife may be even more pronounced. Research out of the University of Alberta, has shown that red squirrels are changing their genetic make-up to cope with global warming (Dey 2003).

Climate change research has identified the following potential impacts to fish and wildlife in the Mackenzie Basin (Cohen 1997). The impacts to fish and wildlife as noted previously largely stem from changes to the physical environment, such as thawing of permafrost, changes to hydrology and precipitation, and from the effects of increased forest fires:

- increased frequency of fire resulting in alterations of habitats, and therefore, species range alterations;
- changes in species ranges and open areas from fire may change their exposure to predators;
- warmer and wetter summers resulting in a northward shift of treeline and therefore species range alterations (i.e., shifts in locations of feeding, breeding/calving grounds);
- delayed expansion of the tundra regions and destabilization of permafrost and vegetation would also effect habitat;
- changes in species ranges and open areas from fire may change their exposure to predators;
- changes in water levels in northern lakes and rivers;
- melting permafrost resulting in landslides and sedimentation of watercourses that can effect waterfowl and fish habitat; and
- changes in hydrology and water temperatures resulting in shifts in fish populations.

There are currently no known mitigation measures for concerns related to synergistic effects of development and climate change on some animals, such as shorebird migration and breeding and fur-bearers (CWS pers. comm. 2003; SRRB and RWED 2002).

An example of how climate change can affect species ranges, and cause changes to community structure is drawn from research in the Thelon Wildlife Sanctuary. Included in information on the status of 50 bird species and five mammal species in the Thelon Wildlife Sanctuary are nine northward and three southward breeding range extensions for birds, along with 16 species not previously recorded in the Sanctuary. Thirty of the bird species, along with red squirrel, moose, porcupine, river otter, and beaver were not reported by either J.C. Critchell-Bullock (1930) or C.H.D. Clarke (1940) during reconnaissance of the area in the 1920s and 1930s. Although recent, increased search effort may explain many of these differences, it is likely that the common loon (*Gavia immer*), mallard (*Anas platyrhynchos*), american widgeon (*Anas americana*), surf scoter, gyrfalcon, yellow-rumped warbler (*Dendroica coronata*), rusty blackbird (*Euphagus carolinus*), moose and red squirrel have established breeding populations in the area since the 1930s. Several hypotheses may explain northward range expansions, including a recent warming trend at the northern treeline during the 1970s and 1980s. Although apparent changes in the mammalian and avian faunas are consistent with a hypothesis linked to climate change, correlation studies are probably inadequate to link climate change causally with changes in species distribution. The long-term implications of species and community structural changes on northern ecosystems is yet unknown.

Climate change scenarios for the Mackenzie Basin show mean annual temperature increases of up to 5°C by the mid-21st century. Related to this will be changes in the amount and timing of other climatic variables such as precipitation. These shifts in climate could have profound direct effects upon northern aquatic ecosystems. Changes in the aquatic habitats could, in turn, affect the fauna, in particular fishes of importance to humans. The major effects of climate change could be transmitted to fish populations either directly via changes in aquatic habitats, or indirectly through changes in the patterns and processes of other components of the aquatic ecosystem, such as hydrological changes and sediment transfer processes. The major effects of climate change could be:

- Shifts in Distribution - Southern species will likely colonize more northerly regions as physiological needs are optimized. Northern species may experience reduction of geographic range and/or extirpation from areas presently occupied.
- Shifts in Abundance and Growth - Growth rates will change as the range of physiological temperatures change. This, in turn, may result in earlier maturation and other factors affecting abundance. For example, locally increased abundance of fish favouring warmer temperatures can be expected. In a similar fashion, decreased abundance of fish not favouring warmer conditions will occur. As well, decreased availability of cool water refugia will result in decreased abundance of fish requiring such habitats.
- Shifts in Fisheries Yield - As a direct consequence of both of the above factors, the yields of important fisheries will change locally.
- Shifts in Ecosystem Structure and Function - Other components and processes of the aquatic ecosystem will change in ways similar to those described above for fish. In turn, these will affect factors such as productivity of lower trophic levels. Such shifts will have indirect effects on fish abundance, growth and productivity, and may also provide for the introduction of alien species
- Cumulative Effects - The direct effects on fish populations and the indirect effects stemming from coincident changes in the ecosystem may additively or multiplicatively cumulate to result in substantive effects on fish. The ability to predict the effects of simple and complex climate change events on northern fish populations is generally quite low.

4.10.5 Gap Analysis

As already stated, it is expected in northern Canada that the result of climate change will be “greater-than-average” warming trends in the summer and “much greater-than-average” warming trends in winter months with precipitation increases in both seasons (Weaver 2003). This will have major impacts to permafrost and overall terrain stability that includes melting, decreases in geotechnical strength characteristics and increases in frost heaving (also see Section 4.2, Permafrost). There will also be changes to vegetation as well as fish and wildlife abundance and distribution. From the perspective of hydrocarbon development in the Mackenzie Valley, pipeline design, construction and maintenance, especially in areas of discontinuous permafrost (Shriner and Street 1997) will need to account for changes in the biophysical environment for the lifespan of a project.

For example, the melting of ground ice may result in down slope soil movement, loss of slope stability, ground subsidence, and massive terrain slumping, leading to increases in sediment loads to rivers and lakes (Shriner and Street 1997). This has implications for the application of mitigation measures related to water quality and fish management. It directly has implications for pipeline integrity and other supporting infrastructures, such as transportation corridors that may be damaged due to slope failure. The speed and extent (i.e., variability) of any change in the permafrost regime will have implications to current project design, construction and maintenance. Likewise, climate change may influence thaw settlement and frost heave, frozen/thawing slope processes and stability, river processes and slope stability. These influences will also have implications of these changes could affect infrastructure integrity, including a potential pipeline in the Mackenzie Valley.

Climate change will also have implications on long-term mitigation measures proposed for impacts to vegetation, fish and wildlife. The external biological environment will not remain static for the duration of the project. Any monitoring and follow-up programs will need to be adaptive and responsive to changes brought on by climate change.

One means of advancing the understanding of the implications of climate change on hydrocarbon development is to develop a number of climate change scenarios for the Mackenzie Valley to properly assess environmental impacts from hydrocarbon development. As outlined above, ecological responses to climate change will vary along the length of the Mackenzie Valley. As a result, any climate change scenarios developed for the lower portions may not be valid for the upper portions of the valley and vice-versa (C. Burn pers comm. 2003). Likewise, the duration of hydrocarbon projects is such that there is a strong possibility that the effects of climate change will be felt on the project (C. Burn pers. comm. 2003). In the past, climate change assessments have only considered changes in a general manner with a limited number of climate changes scenarios. Considering the scope of hydrocarbon projects, there must be a comprehensive assessment carried out for a number of climate change scenarios in combination with changing environmental baseline conditions. Ultimately, climate change assessment and impacts on the environmental conditions in the Mackenzie Valley is a risk assessment evaluation based on the data available and the scenarios that are being assessed.

The following subsections outline areas that should be considered for future work in regards to climate change. The focus of most of the gaps identified below is on understanding the potential impacts on the physical environment as a result of climate change. Such an understanding is critical to understanding the effects on infrastructure development and integrity and to understanding the effects on the biological environment.

4.10.5.1 Baseline Knowledge Gaps

1. Need to develop an understanding of the range and type of climate change scenarios along the entire Mackenzie Valley, including hydrocarbon development areas such that the impact on the physical environment (land/vegetation, water and permafrost) can be evaluated for environmental assessment predictions

4.10.5.2 Impact Knowledge Gaps

1. Climate Change Effects on the Physical Environment:
   a) Along the Mackenzie Valley pipeline ROW, the impact of climate change on shallow ground temperatures (upper 5 metres of the ground) requires assessment, especially in widespread and sporadic discontinuous permafrost zones.
   b) The impact of climate changes on forest fire frequency along the entire length of the Mackenzie Valley and the risk to infrastructure development needs to be assessed.
   c) The impact of climate change on ice thickness in rivers and lakes for ice bridges and winter roads along the entire length of the Mackenzie Valley.
   d) The impact of climate change on snow conditions and associated winter trafficability associated with hydrocarbon developments including drilling and pipeline development.
   e) The impact of climate change on regional hydrology.

2. Permafrost Response to Climate Change / Pipeline Integrity:
   a) Need to document spatial and temporal variability in permafrost response to climate change.
   b) Need to continue development of predictive models of permafrost thermal changes, distribution changes and terrain sensitivity, with focus on improving the scale/resolution, as well as moving from the pipeline corridor to the development areas.
   c) Need to understand impacts to pipeline integrity as a result of changes to permafrost from climate change.

Section 4.2 provides further background information to support gap 2a-c, above.

3. Need to continue analyses on the effects of vegetation removal (e.g., rights-of-way) on permafrost conditions in the context of climate change.

4. Require research on the potential impact of climate change scenarios on the terrestrial and aquatic ecology in the Mackenzie Valley and the linkage of these predicted changes with the environmental conditions that will be assessed for any hydrocarbon development.

4.11 Land and Resource Use/ Harvesting/Protected Areas

Land and resource use information and research on harvesting is inextricably linked with the protected area initiatives in the NWT, including land use plans, interim measures agreements and the NWT PAS.

Section 4.11.1 describes information available on land and resource use and harvesting and potential impacts to these resources due to oil and gas development and activities. Section 4.11.2 describes the various forms of protected areas for the Mackenzie Valley, and discusses ecoregion representativeness in the context of the NWT PAS.

Land and resource use and protected areas information provides important data to assist decision makers to avoid potential conflict.

4.11.1 Land and Resource Use, and Harvesting

Land and resource use is a broad concept which includes not only traditional or subsistence harvesting activities by Aboriginal people, but also outfitting camps, exploration camps, mines, oil and gas development and so forth. These are all activities that take place on the land and have an effect on renewable and non-renewable resources.

The major communities potentially affected by proposed developments are Inuvik, Norman Wells, Hay River, Fort Smith and Fort Simpson. The primary activities in these areas include hunting, trapping, fishing, mining, oil and gas extraction, some forestry and tourism.

Oil and gas activities have the potential to impact on land and resource use and harvesting activities important to northerners. Often the concerns regarding land and resource use and harvesting and development can be addressed by limiting timing, adjusting route alignment and limiting area of extent. The potential impacts may include:

- temporary disruption and loss of, or in some cases, increased access to traditional use and harvesting areas;
- removal of food bearing plants;
- temporary and some permanent displacement of harvested wildlife species;
- potential encroachment on culturally and/or environmentally significant areas; and,
- aesthetic impacts from industrial development

Land and resource use, and harvesting data have been noted and documented in a variety of sources and are frequently available electronically. The GNWT has collected harvesting records for at least two decades. This information has been collected to determine the annual allowable harvest. The GNWT uses licenses and non-resident harvest records to estimate the numbers of animals harvested and where they may have been harvested (http://www.nwtwildlife.rwed.gov.nt.ca). Harvest data are important as they highlight significant species and areas important for hunting and trapping, assisting decision makers to avoid potential impacts. The GNWT has also collaborated on or collected information on a host of species in the Mackenzie Valley (see Table 10).

Land and resource use, and harvesting information has also been collected by the Gwich'in Land Use Planning Board, the Sahtu Land Use Planning Board, the GRRB (www.grrb.nt.ca), the Sahtu Renewable Resources Board (SRRB) (www.srrb.nt.ca), and the Deh Cho First Nation. The information collected features harvesting information related to animals of economic or dietary importance. Traditional land use and occupancy information has also been collected by First Nations. While some of this information is available, much of it is held as confidential, by the First Nations groups.

Many other human activities have been recorded and mapped for the Mackenzie Valley. Through DIAND and the various land and water boards, land use permit, water licence, and surface disposition information is available. Similarly, DIAND also holds current and abandoned well-site information and oil and gas rights information, as well as, mineral showings and mineral rights. Easy public access to this can be found on an interactive website (http://ism-sid.inac.gc.ca). The active layers that may be manipulated are:

- 1:50,000 NTS Grid
- 1:250,000 NTS Grid
- Hydrometric Stations
- Water Quality Stations
- Snow Survey Stations
- Oil and Gas Wells
- Oil and Gas Rights
- Surface Dispositions
- Land Use Permits
- Linear Land Use Permits (Winter Roads)
- Mineral Leases
- Mineral Claims
- Prospecting Permits
- Geological Provinces
- National Wildlife Areas
- Wildlife Sanctuaries
- Migratory Bird Sanctuaries
- National Parks
- North Baffin Land Claim Parcels
- Kitikmeot Land Claim Parcels
- Keewatin Land Claim Parcels
- Inuvialuit Land Claim Parcels
- Gwich'in Land Claim Parcels
- Sahtu Land Claim Parcels
- Dogrib Land Claim
- Land Claim Areas
- DIAND Districts
- Roads
- Rivers
- Lakes
- Land

The data behind the interactive database is derived from the Land Information Management System (LIMS) and LIMS Miners and is less than 24 hours old. This information is maintained in Yellowknife.

4.11.2 Protected Areas in the Mackenzie Valley

The NWT PAS, land use plans and interim measures agreements are examples of conservation mechanisms used to protect the special natural and cultural areas in the NWT. These conservation mechanisms assist in safeguarding special natural and cultural areas, while recognizing the need to keep resource development options open for the future.

Protected areas are an important component of sustainable development and act to:

- safeguard culturally important areas;
- represent the diversity of habitats and landscapes;
- maintain the ecological integrity of NWT ecoregions;
- ensure the viability of wide-ranging species such as caribou, bears, wolves, wolverine and migratory birds;
- maintain a well-connected natural landscape;
- maintain areas for high-quality wilderness experience; and,
- provide benchmark reference sites.

Should permanent protection of protected areas identified in the land use plans and land withdrawals be required, the NWT PAS is an option that could be used to identify areas for long term protection.

4.11.2.1 Land Use Plans and Interim Measures Agreements

Land and resource use and harvesting activities are fundamental to Gwich'in, Sahtu and Deh Cho land use planning, all in various stages of preparation or approval. The Gwich'in and Sahtu draft land use plans identify lands for "protection" whether under the NWT PAS or outside this strategy (e.g., conservation areas) and each recognizes that pipeline development in the Mackenzie Valley is likely to occur and have planned for it accordingly. Within the Deh Cho, there have been interim land withdrawals from disposal and mineral staking under the *Territorial Lands Act.* The parties of the Deh Cho Process have agreed to a defined pipeline study corridor, therefore the land withdrawals will not interfere with a potential pipeline (DIAND website http://www.ainc-inac.gc.ca/nr/prs/j-a2003/02287bbk_e.html April 17, 2003). A Deh Cho land use plan is under development.

Sahtu Land Use Plan

The Sahtu preliminary draft Land Use Plan (SLUP) designates three types of land use: Conservation Areas, Special Management Areas and Multiple Use Areas.

All development activities are permitted on lands within Multiple Use Areas provided their impacts on other resource users and values are minimized, and that necessary regulatory approvals are obtained.

The SLUP also identifies 12 Special Management Areas. Special Management Areas include intensive traditional use locations, Great Bear Lake, and the Mackenzie River corridor. These areas are to be primarily managed to maintain traditional activities; however there is opportunity for surface and/or subsurface developments in some areas. Some sites within these areas may prohibit all forms of development, while in other locations terms and conditions may be placed on the appropriate land use permits, water licenses or other authorizations to conduct work.

The SLUP identifies 21 Conservation Areas, of which four areas currently have both surface and subsurface lands withdrawn from development for the purposes of creating National or Territorial parks or other legislated protected areas (e.g., NWT PAS). Conservation Areas include sites and places with a combination of high traditional, cultural, historical and/or biological significance. The primary goal of the Conservation Areas is to ensure that traditional, cultural, heritage and biophysical values are maintained – all surface and subsurface development activities, except for low impact recreation and tourism, are prohibited on Conservation Areas.

The SLUP recognizes that the potential pipeline may be routed through one or more Conservation Areas, and states that the Sahtu Land Use Planning Board will grant either an amendment or exception to allow for the passage of the pipeline (with conditions).

Gwich'in Land Use Plan

The Gwich'in Land Use Plan (GLUP), draft November 2002 identifies three zones which describe what is allowed and not allowed in specific areas: Gwich'in Conservation Zones, Gwich'in Special Management Zones and Gwich'in General Use Zones.

For Gwich'in General Use Zones, the GLUP does not impose conditions for proposed use and activities, provided that necessary regulatory approvals are obtained.

Sixteen Gwich'in Special Management Zones are outlined in the GLUP. Special Management Zones are areas where all land uses are possible provided that conditions outlined in the land use plan are met. The conditions are designed to protect valued resources identified by communities or other organizations. The appropriate approvals through the regulatory system must also be obtained.

The GLUP outlines specific new uses and associated activities that are not permitted in Gwich'in Conservation Zones, such as oil and gas exploration and development and power development. The land use plan does not allow regulatory agencies to issue a licence, permit or authorization for these uses and activities. The GLUP designates four Conservation Zones and 13 Heritage Conservation Zones

The GLUP recognizes that the potential pipeline route may extend through some Conservation Zones, and states that the Planning Board feels that with proper planning the negative impacts within these zones can minimized with the potential for positive economic impacts.

Deh Cho Interim Land Withdrawals

Within the Deh Cho, there have been interim land withdrawals from disposal and mineral staking under the *Territorial Lands Act*, that will protect some areas of the Deh Cho territory from new development activities. The interim land withdrawals process flows from the Interim Measures Agreement signed by the Deh Cho First Nations, Canada and the GNWT in May, 2001. The following criteria were used to identify lands to be withdrawn:

- lands harvested for food and medicinal purposes;
- culturally and spiritually significant areas;
- lands which are ecologically sensitive; and,
- watershed protection.

The lands will be temporarily set aside by a federal Order in Council for five years. Once that happens, no new mining claims can be registered or land leases issued on withdrawn lands. In addition, the terms of the Interim Measures Agreement and all current environmental protection and land use legislation will continue to apply.

Other key aspects of the interim land withdrawals include:

- Some lands will be withdrawn from surface and sub-surface development, which means no development will be allowed. Other lands will be withdrawn from only sub-surface development, which means surface activities, like forestry, could be allowed. Restrictions will apply to seismic activity on some withdrawn lands. Existing interests such as registered mineral claims, cottages, business licences and leases will not be affected by the land withdrawals.
- Withdrawn land is not "off limits". Access to and across withdrawn lands shall not be affected. http://www.ainc-inac.gc.ca/nr/prs/j-a2003/02287bbk_e.html

Portions of these areas may be protected under the NWT PAS (Deh Cho First Nation *et al*. 2001).

4.11.2.2 NWT Protected Areas Strategy

Overview

The NWT PAS was developed pursuant to commitments made in 1996 during the environmental assessment of the Ekati Diamond Mine and is based on a number of earlier national and international policy documents/commitments. It was approved by the GNWT and DIAND in 1999. The PAS Secretariat, at the direction of the Protected Areas Strategy Implementation Committee, has drafted the *NWT-PAS Five-year Action Plan for the Mackenzie Valley: Conservation Planning for Pipeline Preparedness* (Action Plan). The Action Plan places emphasis on enhancing conservation planning in the ecoregions faced with accelerated oil and gas development activity in the Mackenzie Valley.

The goals of the NWT PAS works towards protecting biodiversity. The NWT PAS is a community-based tool initiated in 1999 by both the federal and territorial governments and supported by a comprehensive stakeholder group – the vision is to promote a balanced approach to land use decisions and develop a network of protected areas through two main goals.

The NWT PAS Advisory Committee (1999) sets out two goals for protected areas in the NWT, which are aligned with protecting biodiversity. The first goal is to protect special natural and cultural areas important to local residents, who are well positioned to identify areas important for cultural and recreational purposes or for harvesting wildlife habitat. The second goal is to protect representative core areas within each of the NWT's ecoregions. Resource-based development in these representative core areas is not permitted. Under goal 1, development will be permitted when compatible with values being protected.

To achieve the goals identified in the NWT PAS, the PAS applies a generic eight step protected areas planning model to the NWT and assigns roles and responsibilities under each step to: communities, regional organizations and land claim bodies; stakeholders such as environmental groups and industry; and government institutions.

Traditional and scientific knowledge contribute to the significant documentation and evaluations required for protected area proposals. For example, information required when considering the area for protection includes, but is not limited to: significant features and location, ecoregion representation, NWT landscape unit representation, bedrock geology, surficial geology, elevation and physiography, climate (annual mean temperature, annual mean precipitation, annual mean snowfall), watersheds, soils, vegetation and landcover, fire history, wildlife habitat, TK - mammals, fish habitat, TK - fish, archaeological sites, Slavey Place Names, TK of trails and cultural sites, values at risk, land use permits and dispositions, mineral activities, oil and gas activities, and timber productive forest.

Within the Mackenzie Valley, there are currently only two officially legislated protected areas: Wood Buffalo National Park and Nahanni National Park Reserve (Figure 12). Edéhzhie, Sahyoue, and Edacho Candidate Protected Areas are under interim withdrawal (Figure 12). These are time-limited withdrawals of the surface and/or subsurface to ensure that detailed evaluations of the values (ecological, non-renewable, renewable and cultural) can be completed without compromise. There are also several areas of interest including Pehdzeh Ki Deh, Mowhi Trail, Hook Lake/ Slave River Delta, Waters of Desnedhé Che, and the Ramparts. Areas of interest have no definitive boundaries and have no restrictions on land access. To date, the candidate protected areas and areas of interest fall under Goal 1 of the PAS, to protect special and natural areas. There have been no areas advanced under Goal 2, protect core representative areas in each ecoregion.

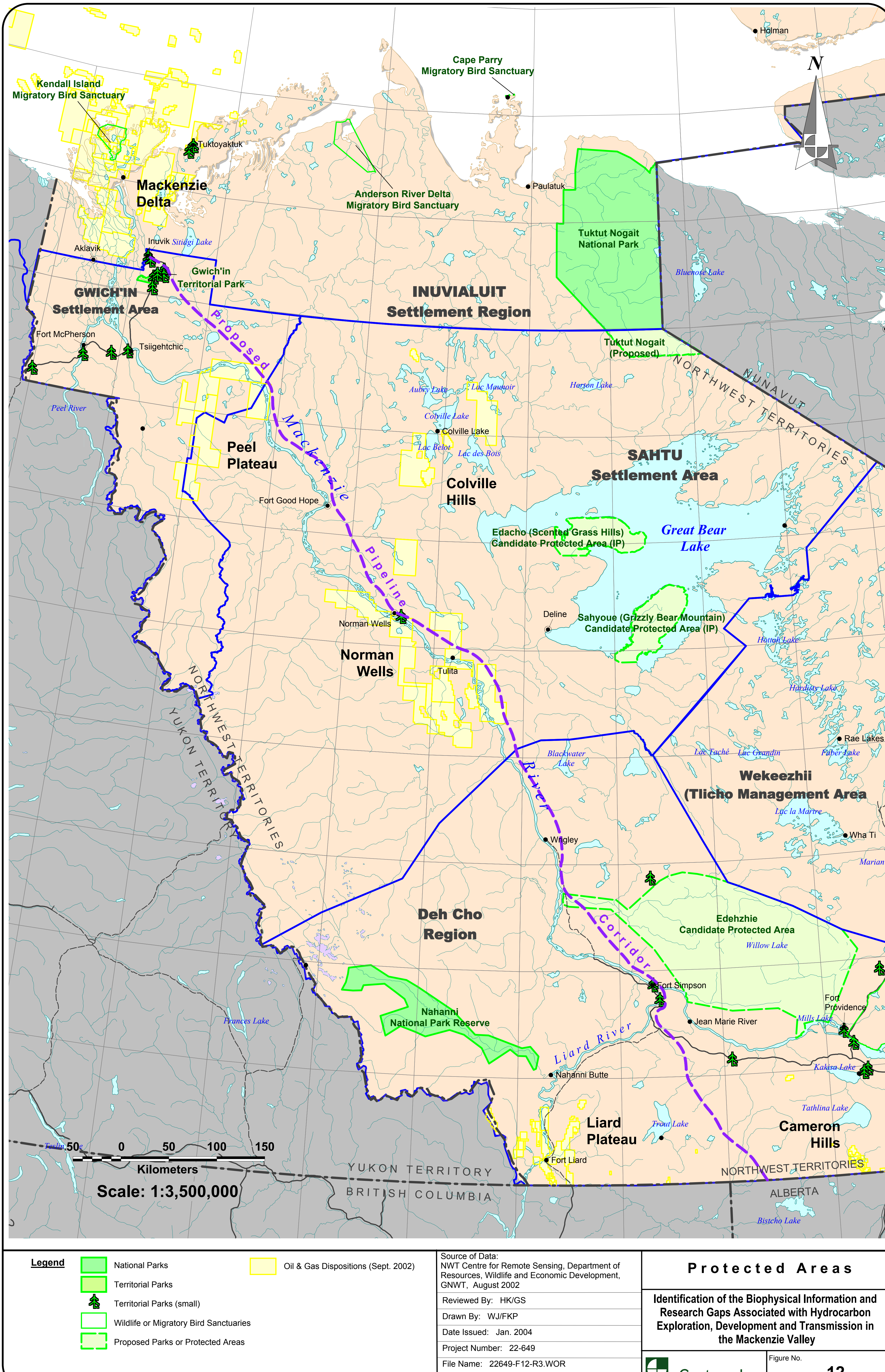
Potential for Ecoregion Representativeness

The Mackenzie Valley is comprised of six ecozones, one of which is the Taiga Plains ecozone. Each of the potential hydrocarbon areas and potential pipeline is located in the Taiga Plains ecozone, which is made up of 18 ecoregions (Figure 13) (http://www.ec.gc.ca/soer-ree/English/Framework/arDesc/taipln_e.cfm).

As stated above, the second goal of the NWT PAS is to protect core representative areas within each ecoregion. The goal is intended to address the following elements and issues (NWT PAS Advisory Committee 1999):

- Each of the NWT’s ecoregions is made up of a unique combination of landscape features, plants and animals.
- Some ecoregions are under-represented in existing protected areas. Establishing core representative protected areas in these ecoregions will contribute to the conservation of the entire diversity of life forms and their habitats in the NWT.
- The federal and territorial governments have made numerous commitments to this goal through their endorsement of such agreements as the Convention on Biodiversity, the Whitehorse Mining Initiative, and the GNWT Sustainable Development Policy which recognize local, national and international commitments.

Resource based development such as mining, logging, hydroelectric projects, agriculture, oil and gas surface work and associated infrastructure will not be permitted in core representative areas.



Source of Data:
NWT Centre for Remote Sensing, Department of Resources, Wildlife and Economic Development, GNWT, August 2002

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2004

Project Number: 22-649

File Name: 22649-F12-R3.WOR

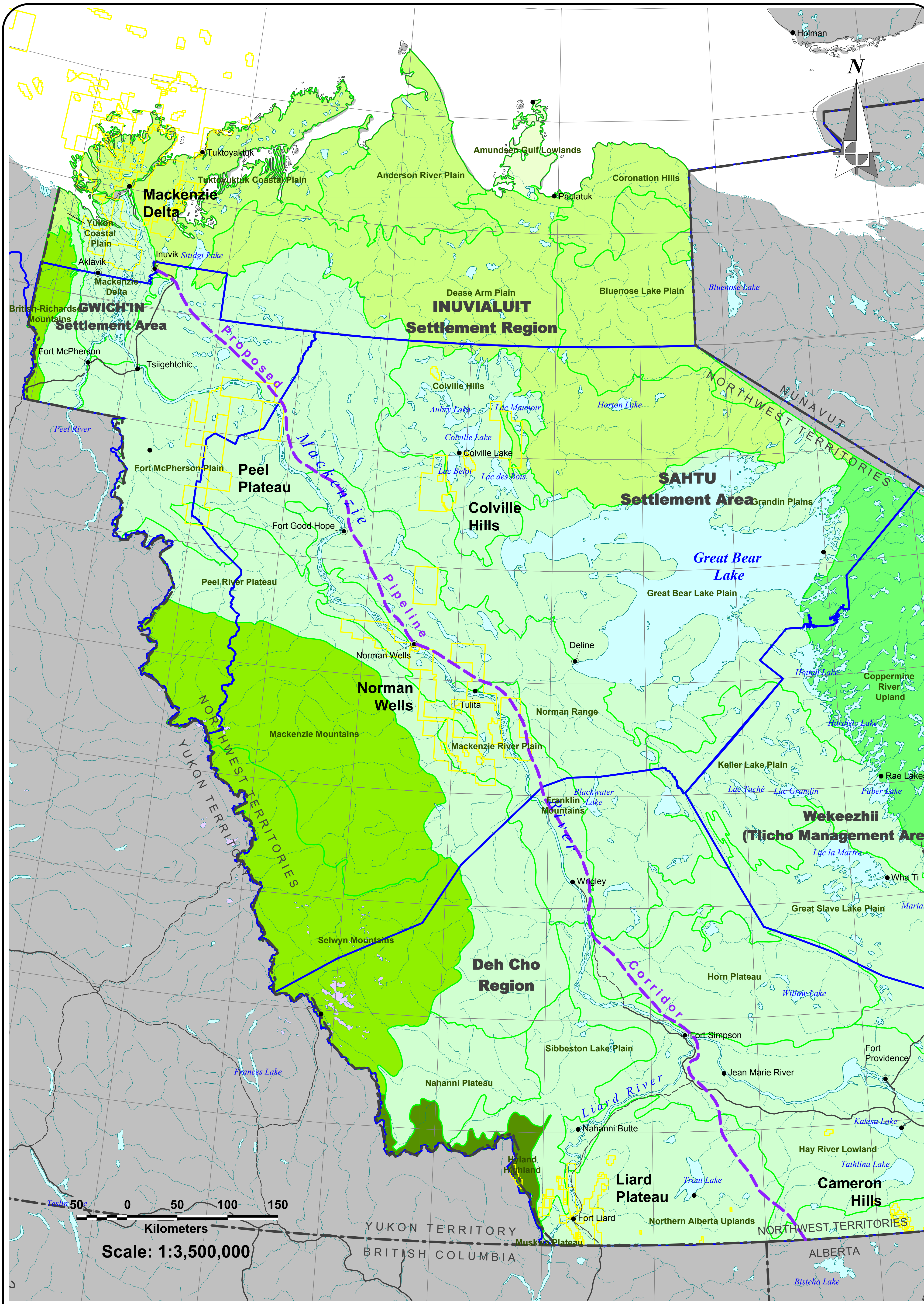
Revision: 3

Protected Areas

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No. 12



Legend

- Approximate Location of Proposed Pipeline Corridor
- Oil & Gas Dispositions (Sept. 2002)
- Ecoregion Boundaries

Ecozones

- Northern Arctic
- Southern Arctic
- Taiga Plains
- Taiga Shield
- Taiga Cordillera
- Boreal Cordillera

Source of Data:
A National Ecological Framework for Canada, GIS Dataset
Agriculture and Agri-Foods Canada, 2003

Reviewed By: HK/GS

Drawn By: WJ/FKP

Date Issued: Jan. 2003

Project Number: 22-649

File Name: 22649-F13-R3.WOR

Revision: 3

Ecoregions of Western NWT

Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley

Gartner Lee

Figure No.

13

Through the various conservation mechanisms described above, there are currently only two legislated protected areas, and the level of core representation is yet to be determined. However, there are potential areas identified under the NWT PAS, land use plans and interim measures agreements located in the ecoregions which may potentially be intersected by the potential pipeline, and are also located in ecoregions potentially impacted by hydrocarbon development areas. Table 12 shows established and proposed protected areas in relation to development areas/potential pipeline, ecoregion, and land claims.

A potential pipeline will cross eight ecoregions: Fort McPherson Plain, Great Bear Lake Plain, Norman Range, Mackenzie River Plain, Franklin Mountains, Horn Plateau, Hay River Lowland, and Northern Alberta Uplands. The oil and gas development areas are found in the same ecoregions (except Horn Plateau), but are also found in an addition four ecoregions: Colville Hills, Peel River Plateau, Sibbetson Lake Plain, and Hyland Plain (Table 12). These ecoregions are also in the vicinity of the potential pipeline corridor except for Colville Hills. The Colville Hills development area lies away from the pipeline corridor in the Colville Hills ecoregion.

The opportunity to establish a representative network of core protected areas in the ecoregions facing hydrocarbon development has not commenced. There are no sites specifically identified for ecoregion representation though the NWT PAS and the NWT PAS Five-Year Action Plan provide a process for doing so. Given that establishing protected areas has generally taken considerable time and that detailed biophysical data is often poor, there is a need to prioritize action in the Mackenzie Valley.

Gaps identified in the NWT PAS Action Plan

The NWT PAS Action Plan focuses on the following key gaps:

1. *enhancing the implementation process*, which focuses on strengthening goal 2 objectives and looking at ways to streamline / improve the strategy with respect to co-ordination with multiple processes;
2. *building capacity*, to ensure community-based and government/non-government agencies have necessary resources to participate adequately;
3. *ensuring information requirements* for advancing candidate sites, including non-renewable, ecological and cultural resource assessments; and,
4. *increasing communications*, to ensure all partners and the public are aware of the NWT-PAS, it’s goals and objectives, and most importantly how it works in relation to other processes that reserve lands for protection.

Most germane to the objective of this biophysical information and research gap analysis is the identification of gap 3 (above), ensuring information requirements including resource assessments. The information and research gaps identified throughout this report, if filled, will assist in addressing this gap, by providing background information on which non-renewable, ecological and cultural resource assessments can be conducted. This information would be made available to communities, Aboriginal organizations and other NWT PAS partners, and will in turn facilitate the realization of the NWT PAS goals.

Table 12. Protected Areas (established, candidate, areas of interest and proposed) in Relation to Land Claim Areas, Hydrocarbon Development Areas, and Ecoregion

Land Claim Area	Development Area/Pipeline (parcel no.)*	Ecoregion (No.)	Protected Area/Proposed Protected Area
Gwich'in	Peel Plateau (EL415, 374, 386, 373, 413)	Fort McPherson Plain (53)	**Travaillant Lake, Mackenzie-Tree River** (Gwich'in proposed protected area – small area overlapped by EL386)
			Arctic Red River (Gwich'in proposed protected area – not directly affected by hydrocarbon development but is located in ecoregion 53)
	EL373, 413	Great Bear Lake Plain (52)	**Travaillant Lake, Mackenzie-Tree River** (Gwich'in proposed protected area – partially overlapped by EL373)
	Pipeline	Fort McPherson Plain (53) Great Bear Lake Plain (52)	**Travaillant Lake, Mackenzie-Tree River** (Gwich'in proposed protected area – intersected by the pipeline proposal)
Sahtu	Colville Hills SDL006, 042, 023, 024, EL400, 399	Colville Hills (54)	N/A
	SDL023, EL400	Great Bear Lake Plain (52)	**Sahyoue/Edacho** (NWT-PAS Candidate Protected Area with Interim Protection – not directly affected by hydrocarbon development but is in ecoregion 52)
	Central Mackenzie EL401, 412, 421, 416, 391	Peel River Plateau (51)	**Ramparts** (NWT-PAS Area of Interest – not directly affected by hydrocarbon development but is partially in ecoregion 51)
	EL398 EL414, 402	Franklin Mountains (58); Norman Range (55)	**Pehdzeh Ki Deh** (NWT-PAS Area of Interest - not directly affected by hydrocarbon development. Most of the area is in ecoregion 55)
	EL401, 412, 421, 416, 391, 392, 398, 402, Norman Wells Proven Area	Mackenzie River Plain (56)	**Ramparts** (NWT-PAS Area of Interest – not directly affected by hydrocarbon development but partially includes ecoregion 56)
	Pipeline	Franklin Mountains (58); Norman Range	**Pehdzeh Ki Deh** (NWT-PAS Area of Interest)

Land Claim Area	Development Area/Pipeline (parcel no.)*	Ecoregion (No.)	Protected Area/Proposed Protected Area
		Mackenzie River Plain (56)	**Ramparts** (NWT-PAS Area of Interest – not directly affected by the pipeline but partially includes ecoregion 56)
		Great Bear Lake Plain (52)	**Sahyoue/Edacho** (NWT-PAS Candidate Protected Area with Interim Protection – not directly affected by the pipeline but is in ecoregion 52)
Deh Cho	Liard Plateau SDL119, 120, 099, EL363, PL10, 09, 705-70, 710-R-70, 709-R-70, 704-70, 708-R-70, 707-R-70, 703-70, 529-R-69, 838-70	Sibbetson Lake Plain (62)	Nahanni National Park Reserve
	SDL001, 002, 003 (all closer to Trout Lake), 013, 121, 098, 122, 090, EL380, 381, 382, 383, 365, 363, PL07, 08, 12, 838-70	Northern Alberta Uplands (65)	N/A
	SDL012, 442-R-68	Hyland Highland (182)	**Nahanni National Park Reserve** (not directly affected by hydrocarbon development but a small portion is within ecoregion 182)
	Cameron Hills SDL004, 008, SDL011 (not really Cameron Hills but closer to Kakisa)	Hay River Lowland (64)	**Wood Buffalo National Park; Edéhzhie** (NWT-PAS Candidate Protected Area with Interim Protection – not directly affected by hydrocarbon development but is within ecoregion 64)
	SDL007, 008, 010, 101, 102, 103, 104, 105, 106, 107, 108, 109, PL 03, 04, 05, 13, 14, 15, 16, 17, 18	Northern Alberta Uplands (65)	N/A
	Pipeline	Franklin Mountains (58)	**Pehdzeh Ki Deh** (NWT-PAS Area of Interest - intersected by proposed pipeline)

Land Claim Area	Development Area/Pipeline (parcel no.)*	Ecoregion (No.)	Protected Area/Proposed Protected Area
		Mackenzie River Plain (56) (pipeline appears to go into this ecoregion just along the border of ecoregion 58	**Pehdzeh Ki Deh** (NWT-PAS Area of Interest)
		Norman Range (55) (very southeastern point)	**Pehdzeh Ki Deh** (NWT-PAS Area of Interest - very southeastern point)
		Horn Plateau (63)	**Edéhzhie** (NWT-PAS Candidate Protected Area with Interim Protection - northwestern part intersected by proposed pipeline)
		Hay River Lowland (64)	**Wood Buffalo National Park; Edéhzhie** (NWT-PAS Candidate Protected Area with Interim Protection)
		Northern Alberta Uplands (65)	N/A

**EL = Exploration Licence; SDL = Significant Discovery Licence; PL = Production Licence*

Gap Analysis

There is an opportunity to ensure that the Mackenzie Valley is developed sustainably and meets both ecological and resource development goals. Table 12 lists several areas identified for protection under the NWT-PAS, as well as through interim measures agreements and land use plans in the Mackenzie Valley. There are only two legislatively protected areas and no areas have been advanced under the second goal of the NWT PAS, protect core representative areas in the ecoregions. As stated in various sections of this report, impacts are poorly understood, and there are a number of knowledge gaps requiring the need for further research and analysis, including the protection of biodiversity.

The other information and research gaps identified throughout this report, if filled, will assist in addressing this gap, by providing background information on which assessments can be conducted. This will in turn facilitate the realization of the NWT PAS goals.

Baseline Knowledge Gaps

1. A specific study to document and analyze baseline biophysical data along a proposed pipeline corridor and in the hydrocarbon regions south of the ISR[28] to identify unique landscapes, unusual features, rare, threatened or endangered species and associated habitat, areas of high biodiversity or

[28] This work also needs to be undertaken in the ISR as described in the NWT-PAS *Mackenzie Valley Five-Year Action Plan*. The ISR is not included in the study area identified for this biophysical gap analysis project.

other important biological and cultural resource use areas that will contribute to identifying potential protected areas which would contribute to ecoregion representation goals.

2. Detailed non-renewable, ecological and cultural resource assessments i.e., specific studies for each site, will then be needed for each potential candidate protected area.

4.12 Cumulative Effects Analysis

The discussion in this section is focussed on the regional aspect of cumulative effects. The requirement for cumulative effects assessments at the project-specific level was considered in developing the research and information gaps outlined in the remainder of Section 4.

The concept of cumulative environmental effects recognises that the environmental effects of individual human activities can combine and interact with each other to cause combined effects that may be different in nature or extent from the effects of the individual activities. Ecosystems cannot always cope with the combined effects of human activities without fundamental functional or structural changes to an ecosystem. (Canadian Environmental Assessment Agency 1994)

The Canadian Environmental Assessment Agency defines cumulative effects as:

> *the effect on the environment which results from effects of a project when combined with those of other past, existing and imminent projects and activities. These may occur over a certain period of time and distance* (Canadian Environmental Assessment Agency 1994).

Cumulative effects analysis (CEA) is approached on different levels in the Mackenzie Valley. First and foremost, CEA is approached on a project-by-project basis for those projects referred for environmental assessment under the *MVRMA*. It is also possible to achieve CEA on a regional basis through the land use planning processes available in the Mackenzie Valley. To date, however, no planning board has developed a land use plan that is explicitly addresses potential cumulative impacts and the carrying capacity of a local resource. However, the SLUP and GLUP have addressed aspects of cumulative effects in their land use plans (e.g., withdrawal of lands from development activities, recognition of present and future interactions and processes of humans and the environment as a whole).

The MVRMA sets out an integrated resource management regime with the following components: land use planning, land and water regulation, environmental assessment, cumulative impact monitoring and auditing. Although this system is not yet fully implemented in the Mackenzie Valley, it provides a series of mechanisms through which cumulative effects can be assessed, monitored and managed at project-specific and regional levels.

Project-level CEA has been undertaken for hydrocarbon projects in the Fort Liard, Nahanni Butte and Cameron Hills areas. Applications for seismic activities, field development and pipelines have been referred to environmental assessment for reasons of potentially significant adverse cumulative impacts.

In each of these cases, it was determined after the environmental assessment was completed that there was not as of yet any potentially significantly adverse cumulative environmental effects.

4.12.1 Possible Potential Cumulative Effects

Studies conducted in NWT areas that are directly affected by hydrocarbon development have found that as of yet, there are no cumulative impacts. While cumulative effects may not yet be present in the Mackenzie Valley, elsewhere (Rohner and Demarchi 2000) in areas where hydrocarbon and other industrial development is more advanced, cumulative effects have been identified. In particular, a recent retrospective review of oil and gas activity on the North Slope of Alaska (Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope, National Research Council 2003) found present or potential cumulative effects in the following areas:

- damage to tundra from off-road travel;
- effects on animal populations including reduced reproduction, changes in behaviour, and direct mortality;
- climate change related impacts and the effectiveness of current mitigation for oil and gas field development; and
- interference with First Nation subsistence activities as a result of changes to the environment.

Similarly, in northern Alberta, where three woodland caribou herds have been studied the cumulative impacts of industrial development have been marked with contributing to their decline. Predation and conflicts with land use practices are factors for the decline of caribou. Caribou are part of a complex predator-prey system. It is theorized that human activity has disrupted the balance of this system placing caribou at a higher risk of predation. The presence of human activity and infrastructure may also negatively impact caribou by altering their behaviour. The loss of old-growth habitat due to industrial expansion is another contributing factor. Caribou are dependent upon the lichens of old-growth forests for winter forage. A decline in the availability of lichens may compromise the health and viability of a caribou herd. There are several land use practices within the ranges of the three woodland caribou herds. These include timber harvesting, extensive oil and gas exploration and production, coal mining, roads, recreational off-road vehicle use, recreational hunting, and commercial trapping (http://www.rr.ualberta.ca/research/caribou/caribou.htm).

Like their Alaska and Alberta counterparts, concern is growing in the Mackenzie Valley for potential cumulative impacts on animal populations. The GNWT has been considering indirect habitat loss such as edge and buffer zones where hydrocarbon development is taking place and the implications to woodland caribou populations (MVEIRB 2001). They have noted, however, that there is currently insufficient baseline information to make recommendations about impact thresholds. As noted earlier, the CWS has similar concerns for migratory bird species and has been studying the impacts.

Impacts to wildlife and wildlife habitat are not the only potential cumulative impacts. Any of the impacts that can result from hydrocarbon development have the potential to accumulate.

The petroleum industry in Canada has recognized the environmental impacts resulting from their activities and the need to alter practices to reduce the potential impacts (Bott 1999). For example, the Cumulative Environmental Management Association (CEMA) was established to manage the cumulative environmental impacts of industrial development in the oil sands region and make recommendations on how to best manage these impacts and protect the environment in the region. Despite measures to reduce impacts, cumulative changes continue to take place through a series of small, environmentally insignificant actions.

4.12.2 Recommendations for NWT CEAM Strategy and Framework and the NWT CIMP

Cumulative effects can, and frequently do, occur as a result of series of minor actions when considered together over a period of time or within a confined area. With the growing recognition that small, incremental changes have the potential for significant changes, CEA has recently become part of the legislated requirements of environmental assessment practice, and with it, the practice of CEA has been improving. The primary problems that remain with evaluating cumulative impacts are:

- how to distinguish the human activities from natural variation;
- how to manage for cumulative impacts in a regulatory process aimed at dealing with one project at a time;
- the need for adequate baseline information; and
- determining significance and acceptability of cumulative effects (Gunn *et al.* 2001).

Two initiatives to address cumulative effects in the NWT currently exist. NWT Cumulative Impact Monitoring Program (CIMP) and Cumulative Effects Assessment and Management (CEAM) Strategy and Framework are separate initiatives, but have an aim of working co-operatively. NWT CIMP are requirements of the Gwich'in and Sahtu land claim agreements, the Tlicho [Dogrib] Agreement, and Part 6 of the MVRMA. It monitors cumulative impacts of land and water uses and waste deposits in the NWT. Under a stand alone audit program, at least once every 5 years an independent audit is conducted to look at the effectiveness of the CIMP, the health of the environment, effectiveness of environmental management processes and response to audit recommendations. CEAM Strategy and Framework was a ministerial commitment from DIAND and Environment Canada following the environmental assessment of the Diavik Diamonds Project in 1999. It provides advice to decision-makers to improve environmental management and stewardship in the NWT.

The CEAM Steering Committee set out *A Blueprint for Implementing the CEAM Strategy & Framework in the NWT and its Regions, April 2003.* In the Blueprint, the Steering Committee made a recommendation:

> *to establish a comprehensive information management system to support CEAM throughout the NWT* (Recommendation 15, NWT CEAM Steering Committee 2003)

The following are recommendations with respect to cumulative effects assessment in the context of NWT CIMP and CEAM Strategy and Framework

1. Need to undertake preliminary cumulative effects analysis of each development area to establish a baseline which can be used to determine significance and impact thresholds

In the Mackenzie Valley, a series of minor actions have taken place (e.g., road access, gravel extraction, seismic lines). Many of these actions have been recorded in the LIMS database held by the DIAND. It is possible to use this information supplemented by information from other departments and agencies to undertake preliminary cumulative effects analysis using an approach such as UNEP's Global Methodology for Mapping Human Impacts on the Biosphere (GLOBIO) (http://www.lobio.info/methodology/) or A Landscape Cumulative Effects Simulator (ALCES) developed by Dr. Brad Stelfox for integrated resource management purposes (http://www3.gov.ab.ca/env/irm/alces.html). GLOBIO and ALCES are examples of tools that can be used to undertake a preliminary cumulative effects analysis to establish a baseline.

It is possible with existing data to get an overview of the current level of impact and establish some criteria for avoiding potential cumulative impacts especially for sensitive species like caribou. There is currently little evidence of cumulative effects in the development areas. Undertaking a preliminary CEA allows for a forward-looking approach, in which good baseline data could be collected now before development pressures exist. At the *Scientists' Workshop*, the GRRB expressed that there is a need to determine thresholds for development that will protect wildlife species and their habitats from cumulative effects.

GLOBIO estimates the impact of human pressure on ecosystems, and has been used worldwide. It offers a high-level view of cumulative impacts as they may already exist. It is also possible to use the tool to project future development and related impact. However, given the sporadic nature of development in the Mackenzie Valley, the tool or something similar may be more appropriately used to gauge the changes that have already taken place and develop information needed to determine significance and acceptability of cumulative effects. This could be done for each of the development areas.

ALCES, like GLOBIO, can be used to study how the landscape might change in the future, including cumulative effects of land uses and resource outputs. It is possible to manipulate outcomes of various land use options under a range of future scenarios for the region, and the trade-offs that might be made between competing uses. ALCES has been considered in the Mackenzie Delta to model cumulative effects associated with hydrocarbon activity. Several studies have used ALCES in Alberta (e.g., The Forestry Corp. 2002; CyberCervus International 2002; van Laake 2002).

The caribou modelling undertaken by Don Russell (CWS) for the Porcupine Caribou Herd and the transfer of this model to the Bathurst Herd and other herds is another way of assessing cumulative effects, at least on a single species.

2. Need to gather regional baseline information for the purposes of cumulative effects assessment

Obtaining adequate baseline information for undertaking cumulative effects assessment is a continual challenge. As already noted earlier in this report, a considerable number of baseline knowledge gaps exist in the Mackenzie Valley. From an environmental assessment perspective, proponents are generally required to collect baseline information specific to the project under consideration. Generally, in areas where little development has already taken place, it is necessary to collect a substantial amount of information because the data may not be available. For the project specific area, this collection is generally intensive.

However, a more regional perspective is necessary for cumulative effects analysis. As sampling spreads from the local study area to the regional study area, the baseline collection may be broader and coarser. This is generally the work of government departments and agencies, university researchers and land use managers i.e., population studies, habitat requirements, state of the environment.

Establishing solid baseline information is also necessary to distinguish between the human activities and impacts on the environment and from natural variation in the environment. This will be necessary for understanding impact significance.

5. References

Addison, E.M. and B. Boles. 1978. Helminth parasites of wolverine, *Gulo gulo*, from the District of Mackenzie, Northwest Territories. Canadian Journal of Zoology, 56: 2241-2242.

Agra Earth and Environmental Ltd. and Nixon Geotech Ltd. 1999. Monograph on Norman Wells Pipeline geotechnical design and performance. Final report to Department of Natural Resources, March 1999. Geological Survey of Canada, Open File 3773, 120 pp.

Alberta Environmental Research Centre. 1996. Cattle and the Oil and Gas Industry in Alberta: A Literature Review with Recommendations for Environmental Management.

Anderson, D.G. 1998. Local Caribou Ethologies in the Circumpolar Arctic. ASTIS - Research Project.

Applied Ecosystem Management Ltd. 2002a. Development of a Threshold Approach for Assessing Industrial Impacts on Woodland Caribou in Yukon. Draft report (v2.1) prepared by Anderson, R.B, Dyer, S.D., Francis, S.R., and Anderson, E.M. for Environment Directorate, Indian and Northern Affairs Canada, Whitehorse, Yukon, November 2002.

Applied Ecosystem Management Ltd. 2002b. Alberta: Handbook for Planning and Implementing Works in and Around a Waterbody. 68 pp.

Aquatic Environments Limited. 1973. Data report: Late Winter Surveys of Lakes and Streams in Canada and Alaska along the Gas Pipeline Routes under Consideration by Canadian Arctic Gas Study Limited.

Aquatic Environments Limited. 1974. Fisheries research associated with proposed gas pipeline routes in Alaska, Yukon and Northwest Territories. McCart, P.J. (ed.).

Aquatic Environments Limited. 1982. An assessment of the fisheries resources of the Great Bear and Mackenzie Rivers in the Vicinity of Proposed IPL Pipeline Crossings. Prepared for Interprovincial Pipe Line (NW) Ltd.

ArctiGas. undated. Preliminary Information Package for the Northern Gas Pipeline Project: Volume I. Document prepared for/by ArctiGas Resources Limited Partnership, 67 p. + appendices.

ArctiGas. 2001. NRGPC Northern Gas Pipeline Project Corridor Atlas Rev. 4: Volume II. Prepared by Cimarron Project Engineers and GeoAnalytic Mapping and GIS for ArctiGas Resources Limited Partnership, December 20, 2001 41 p.

Aylsworth, J.M. 1992. Landslides, distribution and classification, 60^{o} to 64^{o} N, Mackenzie Valley, N.W.T. Geological Survey of Canada, Open File 2554, scale 1:1,000,000.

Aylsworth, J.M. and J.A. Traynor. 2001. Landslide inventory, Mackenzie corridor (southern part). Geological Survey of Canada, Open File 3915.

Aylsworth, J.M., J.A. Traynor, and G. Krusynski. 2001. Landslide inventory, Mackenzie Delta and adjacent Beaufort Coast. Geological Survey of Canada, Open File 3917.

Aylsworth, J.M., M.M. Burgess, D.T. Desrochers, A. Duk-Rodkin, T. Robertson, J.A. Traynor. 2000. Surficial geology, subsurface materials, and thaw sensitivity of sediments. In: The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (ed.). Geological Survey of Canada, Bulletin 547.

Bagri, A., J. McNeely and F. Vorhies. 1998. Biodiversity and Impact Assessment. Paper Presented at a Workshop on Biodiversity and Impact Assessment, Christchurch, New Zealand, 21-22 April 1998.

Barichello, N., J. Carey, and K. Jingford. 1987. Population Ecology, Range use and Movement Patterns of Dall Sheep in the Northern Richardson Mountains. Unpublished. Yukon Territory Department of Renewable Resources, Whitehorse, Y.T.

Barnaby, J. and A. Emery. 2002. Traditional Knowledge and the Cumulative Effects Assessment and Management Strategy and Framework: Summary of Findings and Recommendations. Prepared by the SCI-TEK Partnership for presentation at the January 29-30, 2002 Workshop to Review the 'Working Draft' NWT Cumulative Effects Assessment and Management Strategy and Framework

Benn, B. 2000. Woodland caribou in the Arctic River headwaters region of the Gwich'in Settlement Area. ASTIS - Research Project.

Berger, T.R. 1977. Northern Frontier, Northern Homeland: the Report of the Mackenzie Valley Pipeline Inquiry. Volumes 1 and 2. Mackenzie Valley Pipeline Inquiry, Canada.

BGC Engineering Inc. Standards of Practice Water Course Crossings. Submitted to Indian and Northern Affairs Canada, Water Resources Division, June 2003. BGC Project No. 0131-008.

Biodiversity Science Assessment Team. 1994. Biodiversity in Canada: A Science Assessment for Environment Canada. Prepared for Environment Canada.

Bird, C.D., J.W. Thomson, A.H. Marsh, G.W. Scotter, P.Y. Wong. 1981. Lichens from the area drained by the Peel and Mackenzie Rivers, Yukon and Northwest Territories, Canada. II. Microlichens. Canadian Journal of Botany, 59(7): 1231-1252.

Boothroyd, P. 1987. Preliminary Assessment of the Effects of the Proposed Polar Gas Pipeline and Other Hydrocarbon Development Projects on Waterfowl of the Northern Mackenzie Valley. Technical report series - Canadian Wildlife Service, no. 22. 112 pp.

Bott, R. 1999. Our Petroleum Challenge: Exploring Canada's Oil and Gas Industry. 6th Edition Petroleum Communication Foundation. 101 pp.

Boutin, S. 2002. Personal Communication, December 17, 2002. University of Alberta

Branigan, M. 1999. Grizzly Bear Reproductive Rates and Cub Survival in the Richardson Mountains, NWT and YT. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Brown, J., and N.A. Graves. 1978. Physical and thermal disturbance and protection of permafrost. Third International Conference on Permafrost, Edmonton, Canada, vol. 2. p. 51-91. Ottawa. N.R.C.C.

Burgess, M. 2003. Personal Communication. Natural Resources Canada.

Burgess, M.M. and D.E. Lawrence. 2000. Permafrost and surficial materials along a north-south transect: observations from the Norman Wells pipeline. In: The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change. L. D. Dyke, and G. R. Brooks (eds.). Geological Survey of Canada, Bulletin 547, p. 127-141.

Burgess, M.M., and S.L. Smith. 2000. Shallow ground temperatures. In: The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (ed.). Geological Survey of Canada, Bulletin 547, p. 89-103.

Burgess, M.M., and C. Tarnocai. 1997. Peatlands in discontinuous permafrost zone along the Norman Wells pipeline, Canada: their characteristics and response to pipeline related environmental changes. In: Proceedings, International Symposium on Physics, Chemistry and Ecology of Seasonally Frozen Soils. CCREL Special Report 97-10, Alaska, p. 417-424.

Burgess, M.M., D. T. Desrochers and R. Saunders. 2000. Potential changes in thaw depth and thaw settlement for three locations in the Mackenzie Valley. In: The physical Environment of the Mackenzie Valley, Northwest Territories: A Baseline for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (eds.). Geological Survey of Canada Bulletin 547, p. 187-195.

Burgess, M.M., S.E. Grechischev, P.J. Kurfurst, E.S. Melnikov, and N.G. Mostalenko. 1993. Comparison of engineering-geological processes along pipeline routes in permafrost terrain in Mackenzie River Valley, Canada and Nadym area, Russia. In: Proceedings of the Sixth International Conference on Permafrost, Beijing, South China University of Technology Press, China, p. 54-59.

Burgess, M.M., J.F. Nixon, and D. E. Lawrence. 1998. Seasonal pipe movement in permafrost terrain, kp2 study site, Norman Wells Pipeline. In: Proceedings, Seventh international Conference on Permafrost, Yellowknife, June 1998, Université Laval, Quebec, Collection Nordicana, no. 57, pp. 95-100.

Burn, C.R. 2003. Personal Communication. Professor, Carleton University.

Burn, C.R. 1982. Investigation of Thermokarst Development and Climate Change in Central Yukon Territory. M.A. thesis. Carleton University, Ottawa, 142 pp.

Burn, C.R., and C.S.A. Smith. 1988. Observations of the “Thermal Offset” in near-surface mean annual ground temperatures at several sites near Mayo, Yukon Territory, Canada. Arctic, 41(2):99-104.

Burn, C.R., and C.S.A. Smith. 1990. Development of thermokarst lakes during the Holocene at sites near Mayo, Yukon Territory. Permafrost and Periglacial Processes, 1: 161-176.

Canada-France Pipeline-Ground Freezing Experiment: Frozen Transition Experiment. Experimental Design, Planning and Start-up Phase. 1991. Report to Permafrost Section, Terrain Sciences Division. Geological Survey of Canada, EMR, July, 1991.

Canada-France Pipeline-Ground Freezing Experiment: Frozen Transition Experiment First Freeze Period. 1992. Report to Terrain Sciences Division. Geological Survey of Canada, EMR May, 1992.

Canada-France Pipeline-Ground Freezing Experiment: Frozen Transition Experiment Second Freeze Period and Pipe Relaxation Period. 1993. Report to Permafrost Section, Terrain Sciences Division. Geological Survey of Canada, EMR and seven companies, May, 1993.

Canada-France Pipeline-Ground Freezing Experiment: Phase IX. Fourth Thaw. 1988a. Report to Permafrost Section, Terrain Sciences Division. Geological Survey of Canada, EMR, June, 1991.

Canada-France Pipeline-Ground Freezing Experiment: Phase VIII. Fourth freeze cycle. 1988b. Report to Permafrost Section, Terrain Sciences Division. Geological Survey of Canada, EMR, July, 1988.

Canada-France Pipeline-Ground Freezing Experiment: Uplift Resistance Tests. 1994. Final Report to Terrain Sciences Division. Geological Survey of Canada, Natural Resources Canada and to National Energy Board of Canada, March, 1994.

Canadian Arctic Gas Pipeline Limited. 1974. Mackenzie Valley Pipeline Assessment: Environmental and Socio-economic Effects of the Proposed Canadian Arctic Gas Pipeline on the Northwest Territories and Yukon. Ottawa, Canada. Prepared for Government of Canada, Pipeline Application Assessment Group.

Canadian Association of Petroleum Producers (CAPP). 1999. CH and VOC Emissions from the Canadian Upstream Oil and Gas Industry Volume I, Organic and Common-Pollutant Emissions by the Canadian Upstream Oil and Gas Industry. CAPP Pub. # 1999-0009.

Canadian Environmental Assessment Agency. 1994. Responsible Authority's Guide. November 1994.

Canadian Environmental Assessment Agency and Biodiversity Convention Office. 1996. A Guide on Biological Diversity and Environmental Assessment. April 1996.

Canadian Pipeline Water Crossing Committee. 1999. Water Course Crossings. 2nd Edition.

Canadian Wildlife Service (CWS). 2003. Personal Communication response to questionnaire from Paul Latour, Craig Machtans, Vicky Johnson and Jim Hines. January 16, 2003.

Carbyn, L.N. 1968. Overwintering birds observed along the Mackenzie-Great Slave Lake highways. Arctic, 21: 294-297.

Carey, J.H., E.D. Ongley and E. Nagy. 1989. Hydrocarbon Transport in the Mackenzie River, Canada. NWRI Contribution No. 89-32. Lakes Research Branch.

Carrière, S. 2000. Peregrin Falcon Survey. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Carrière, S. 2003. Personal Communication, January 16 and September 23, 2003. GNWT , Department of Resources, Wildlife and Economic Development.

Case, R. 1989. Distribution and Abundance of Dall's sheep in the southern Mackenzie Mountains, NWT. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT. 39 pp.

Case, R. 2003. Personal Communication. Manager of Technical Support, GNWT , Department of Resources, Wildlife and Economic Development.

Case, R.L. and K.G. Poole. 1985. Distribution, Abundance and Composition of Muskoxen North of Great Bear Lake, March 1983. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT. 48 pp.

Chudobiak, D.H., M.V. Abrahams, and R.E. Tallman. 1994. Life history variation in broad whitefish (*Coregonus nasus*). Paper presented at the Conference of the Canadian Society of Zoologists, Winnipeg Manitoba, May 1994.

Cihlar, J. and J. Beaubien. 1998. Land Cover of Canada Version 1.1. Special Publication, NBIOME Project. Produced by the Canada Centre for Remote Sensing and the Canadian Forest Service, Natural Resources Canada. Available on CD ROM from the Canada Centre for Remote Sensing, Ottawa, Ontario.

Cizek, P. 2003. Personal Communication, January 13, 2003. Cizek Environmental Services

Clarke, C.H.D. 1940. A biological investigation of the Thelon Game Sanctuary. Natl. Mus. Canada Bull., Ottawa.

Clean Air Strategic Alliance (CASA). 2003. Animal Health Project Team Final Report and Recommendations. March 2003.

Cluff, H.D., L.R. Walton, and P.C. Paquet. 2001. Movements and Habitat Use of Wolves Denning in the Central Arctic, Northwest Territories and Nunavut. (1996-1999) Final Report to the West Kitikmeot Slave Study Society, Yellowknife, NT.

Cody, W.J.; K.L. MacInnes; J. Cayouette and S. Darbyshire. 2000. Alien and invasive native vascular plants along the Norman Wells Pipeline, District of Mackenzie, Northwest Territories. Canadian Field-Naturalist Canadian field-naturalist, v.114, no. 1, Jan.-Mar. 2000, p. 126-137.

Cohen, S.J. 1997. Mackenzie Basin Impact Study, Final Report. Proceedings of the MBIS Final Workshop: May 5-8, 1996, Yellowknife. Environment Canada. 372 pp.

Colt Engineering Corporation. 2001. Mackenzie Delta Onshore Gas Feasibility Study: Alignment Map Sheets. Prepared for Mackenzie Delta Producers Group, March 2001.

Committee on the Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope, National Research Council. 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. The National Academies Press. 250+ pp.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2002. Canadian Species at Risk, May 2002. 34 pp.

Critchell-Bullock, J.C. 1930. An expedition to sub arctic Canada, 1924-1925. Canadian Field Naturalist, 44 (9): 210.

CyberCervus International. 2002. An Evaluation of ALCES, A Landscape Cumulative Effects Simulator for use in Integrated Resource Management in Alberta. Discussion paper circulated for review by the ALCES Review Team, July 31, 2002.

Cypser, D.A. and S.D. Davis. 1994. The state of corporate knowledge on injection induced earthquakes: an informal survey. EOS, Trans. Amer. Geophys. Union Abstracts 472.

Dallimore, S.R. and T.S. Collett. undated. Gas Hydrates Associated with Deep Permafrost in the Mackenzie Delta, N.W.T., Canada: Regional Overview. Published by Geological Survey of Canada, 9 p. (publication date likely around 1997). Found at: http://sts.gsc.nrcan.gc.ca/page1/hydrat/art/DC.pdf

Dames and Moore. 1974. Report on Containment and Disposal of Drilling Fluids in the Northwest Territories. Prepared for the Arctic Petroleum Operators Association, and Canada. Dept. of Indian Affairs and Northern Development.

DeGrosbois, T. and G.P. Kershaw. 1987. The effects of canopy removal on the vigor of *Salix arbusculoides* (Anderss) in a decadent sub arctic black forest, Fort Norman, N.W.T. Paper presented by T. deGrosbois, 16th Arctic Workshop, Edmonton, Alberta.

Deh Cho First Nations, Government of Canada, and Government of the Northwest Territories. 2001. The Deh Cho First Nations Interim Measures Agreement.

Dene/Metis Negotiations Secretariat. 1986. Special Places in Denendah: A Preliminary List. Prepared for Parks Development in Relation to Claims workshop, February 29, 1986, Yellowknife.

Dennington, M. and B. Johnson [Task Force on Northern Oil Development (Canada)] . 1974. Studies of Beaver Habitat in the Mackenzie Valley and Northern Yukon. Environmental-Social Committee, Northern Pipelines, Task Force on Northern Oil Development, Report No. 74-39.

Department of Indian Affairs and Northern Development (DIAND). 1988. Geophysical Assessment of Waste Drilling Fluid Containment Sites in the Mackenzie River Valley Region, NWT. 54 pp.

Department of Indian Affairs and Northern Development (DIAND). 2002a. Oil and Gas Dispositions: Cameron Hills. Prepared by Northern Oil and Gas Directorate, Indian and Northern Affairs Canada, Ottawa, ON, May 2002. Updated regularly and found at: http://www.ainc-inac.gc.ca/oil/act/Lan/mps/snt_e.html

Department of Indian Affairs and Northern Development (DIAND). 2002b. Oil and Gas Dispositions: Fort Liard. Prepared by Northern Oil and Gas Directorate, Indian and Northern Affairs Canada, Ottawa, ON, May 2002. Updated regularly and found at: http://www.ainc-inac.gc.ca/oil/act/Lan/mps/snt_e.html

Department of Indian Affairs and Northern Development (DIAND). 2002c. Oil and Gas Dispositions: Mackenzie Valley – Central Region. Prepared by Northern Oil and Gas Directorate, Indian and Northern Affairs Canada, Ottawa, ON, July 2002. Updated regularly and found at: http://www.ainc-inac.gc.ca/oil/act/Lan/mps/cmv_e.html

Department of Indian Affairs and Northern Development (DIAND). 1975. Bibliography of reports presenting data and results obtained through investigations carried out in the Mackenzie Valley and Northern Yukon under the Environmental-Social Program Northern Pipelines of the Government of Canada.

Dey, P. 2003. Researchers find genetic response to global warming: Changing climate prompts genetic change in squirrels. Folio., 40(12). University of Alberta.

DiLabio, R. 2003. Personal Communication, October 2003. Natural Resources Canada

Dillinger, R.E., T.P. Birt, and J.M. Green. 1992. Arctic cisco, *Coreginus autumnalis*, distribution, migration and spawning in the Mackenzie River. Canadian Field-Naturalist 106: 175-180.

Dogrib Treaty 11 Council. 1998. Habitat of Dogrib Traditional Territory: Place Names as Indicators of Bio-Geographical Knowledge. Project conducted under West Kitikmeot/ Slave Study.

Dogrib Treaty 11 Council. 2002. Dogrib Knowledge of Place Names, Caribou and Habitat, Final Report. Submitted to West Kitikmeot Slave Study Society. July 2002.

Douglas, R.L., L.G. Fisher, and M. Mair. 1983. Habitat selection and food habits of marten, *Martes americana*, in the Northwest Territories. Canadian Field-Naturalist 97: 71-74.

Dryden, R. L. 1973. An Evaluation of the Fish Resources of the Mackenzie River Valley as Related to Pipeline Development: Volume II. Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development report, no. 73- 2.

Duk-Rodkin, A. 1993a. Surficial geology mapping of the Mackenzie Transportation Corridor. In: Granular Resource Requirements for Proposed Mackenzie Valley Pipelines : technical papers and workshop proceedings. Prepared by R.J. Mahnic and T.J. Fujino. - [S.l.] : Stanley Associates Engineering, 1993, p. 7-9.

Duk-Rodkin, A. 1993b. Landslides in the central Mackenzie River region and adjacent mountainous areas, 64 ^{o} to 68 ^{o} N, Yukon - N.W.T. Geological Survey of Canada, Open File 2611, scale 1:1,000,000.

Duk-Rodkin, A. and O.L. Hughes. 1992a. Surficial geology, Arctic Red River, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1746A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992b. Surficial geology, Canot Lake, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1748A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992c. Surficial geology, Fort Good Hope, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1741A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992d. Surficial geology, Fort McPherson, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1745A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992e. Surficial geology, Martin House, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1743A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992f. Surficial geology, Ontaratue, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1742A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992g. Surficial geology, Trail River, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1744A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1992h. Surficial geology, Travaillant Lake, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1747A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1993a. Surficial geology, Sans Sault Rapids, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1784A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 1993b. Surficial geology, Upper Ramparts River, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1783A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 2002a. Surficial geology, Carcajou Canyon, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1988A, scale 1:250,000.

Duk-Rodkin, A. and O.L. Hughes. 2002b. Surficial geology, Norman Wells, District of Mackenzie, Northwest Territories. Geological Survey of Canada, map 1989A, scale 1:250,000.

Duk-Rodkin, A. and T. Robertson. 2001. Landslide inventory, Mackenzie corridor (central part). Geological Survey of Canada, Open File 3916.

Dyke, L.D. 2000. Stability of permafrost slopes in the Mackenzie Valley. In: The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (ed.). Geological Survey of Canada, Bulletin 547.

Dyke, L.D. 2001. Contaminant migration through the permafrost active layer, Mackenzie Delta area, Northwest Territories, Canada. Polar Record, 37(202): 251-228.

Dyke, L.D. 2003. Personal Communication. Natural Resources Canada

Dyke, L.D and G.R. Brooks. 2000. The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change. Geological Survey of Canada, Bulletin 547.

Dyke, L., J. Hunter, M. Douma, C. Hyde. 1997. Using drilling mud sumps to determine how well permafrost contains contaminants. Geological Survey of Canada.

EBA Engineering Consultants Ltd. 1987. An Evaluation of the Feasibility of Developing Granular Borrow from the Bed of the Mackenzie River. Department of Indian Affairs and Northern Development.

EBA Engineering Consultants Ltd. 2003. Project Final Report: Ecosystem Land Classification for the Northwest Territories. Prepared for Government of the Northwest Territories, Department of Resources, Wildlife and Economic Development. Project No. 5825155. September 29, 2003.

Envirocon Limited. 1980. Survey of Benthic Macro Invertebrate and Fish Populations in the Mackenzie River at Norman Wells, N.W.T., Beaufort E.I.S. reference work, no. RWB13; Calgary, Alta. Esso Resources Canada and Interprovincial Pipe Line (NW) Ltd (corporate authors).

Environment Canada. 2002. Informing Canadians on Pollution 2002: Highlights of the 2000 National Pollutant Release Inventory (NPRI).

Environmental Resources Management Ltd. 2000. Biodiversity and Environmental Assessment Toolkit. Prepared for the World Bank. March 2000.

EPA Region 5 and Agricultural & Biological Engineering, Purdue University. 1998. Groundwater Primer. http://www.epa.gov/seahome/groundwater/src/ground.htm

ESL Environmental Sciences Limited, LGL Limited, Environmental Research Associates, Environmental and Social Systems Analysts Ltd., Arctic Laboratories Limited, and Arctic Sciences Limited. 1985. Beaufort Environmental Monitoring Project 1984-1985: Final Report. Environmental Studies - Department of Indian Affairs and Northern Development, no. 39, NOGAP project no. A.07. 162 pp.

Etkin, D., G. Paoli and D. Riseborough. 1998. Climate Change Impacts on Permafrost Engineering Design. Funding provided by Panel on Energy Research and Development (PERD).

Evans, S.G., J.D. Aitken, R.J. Wetmiller, and R.B. Horner. 1987. A rock avalanche triggered by the October 1985 North Nahanni earthquake, District of Mackenzie, N.W.T. Canadian Journal of Earth Sciences, 24: 176-184.

EVS Consultants Ltd. 1985. Assessment of Freshwater Impacts from the Norman Wells Oilfield Development : Part I : Chemical Characterization of Norman Wells Crude Oil Refinery Effluent and Cooling water, Literature Review of Fate and Effects, Research Program Design. Environment Canada. (NOGAP project no. C.02 : Criteria for the control and monitoring of petroleum development impacts on the Mackenzie River).

EVS Consultants Ltd. 1986. Assessment of Freshwater Impacts from the Norman Wells Oilfield Development. North Vancouver: E.V.S. Consultants Ltd, 1985-86; 3v., ill.; 28 cm.

F.F. Slaney & Company. 1974. Base Data Volume 3: Fish Study 1972-73, Mackenzie Highway, mile 300 to 550. Vancouver, B.C.

Falk, M.R. 1972. Unusual occurrence of the brook stickleback in the Mackenzie River, NWT. Journal of Fisheries Research Board of Canada, 29: 1655.

Faria, D.A. 2002. Overview of the Hydrology in the Deh Cho Region – NWT. Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NWT. August 2002.

Federal Environmental Assessment and Review Office. 1978. Federal Environmental Assessment And Review Process: Guide for Environmental Screening. Federal Activities Branch, Environmental Protection Service and Federal Environmental Assessment Review Office, Government of Canada, 75 pp. plus appendices.

Ferguson, R.S., K.D. Davidge and R.S. Douglas. 1985. Distribution and Abundance of Dall's sheep Near Jackfish River, Northwest Territories in June 1984. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT. 20 pp.

Fernet, D.A. 1986. Aquatic Monitoring Survey Norman Wells to Zama Pipeline July, 1986. Prepared by Environmental Management Associates for Interprovincial Pipe Line (NW) Ltd.

Fetter, C.W. 1994. Applied Hydrogeology. Prentice-Hall Inc., Englewood Cliffs, New Jersey, 691 pp.

Fisheries and Oceans Canada. 1995. Freshwater Intake End-of-Pipe Fish Screen Guideline. Minister of Supply and Services, Ottawa, Ontario.

Foothills Pipe Lines Ltd. 1976. A Preliminary Study into the Use of Insulation to Alleviate Frost Heave Problems Relevant to the Operation of a Cold Gas Pipeline. 38 pp.

Forestry Corp, The. 2002. ALCES Timber Supply Validation, Comparison of ALCES and Woodstock/Stanley. Prepared for NWS ALCES Core Team, Alberta Environment and AFPA. Final Report August 1, 2002.

Fournier, B. and A. Gunn. 1997. Muskox Numbers and Distribution in the Northwest Territories, 1997. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT. 55 pp.

Fournier, M.A. and R.G. Bromley. 1996. Status of the Harlequin duck, *Histrionicus histrionicus*, in the western Northwest Territories. Canadian Field-Naturalist, 110: 638-641.

French, H.M. 1980. Terrain, land use and waste drilling fluid disposal problems, Arctic Canada. Journal of Arctic Institute of North America, 33(4): 794-806.

French, H.M. and O. Slaymaker. 1993. Canada's Cold Environments. McGill-Queen's University Press, Montreal.

French, H.M. and I.E. Egorov. 1998. 20th century variations in the southern limit of permafrost near Thompson, northern Manitoba, Canada. In: Proceedings of the Seventh International Conference on Permafrost, A.G. Lewkowica and M. Allard (eds.). Centre d' Études Nordiques, Université Laval, Quebec. p. 297-304.

Freshwater Institute. 1975. Species List of Aquatic Plants and Animals Collected from the Mackenzie and Porcupine River watersheds from 1971 to 1973. Technical Report - Freshwater Institute (Canada), no. 557.

Fulton, R.J. 1970. Surficial deposits and landform maps along the Mackenzie Valley, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Open File 21 scale 1:125,000.

Gates, C.C. and N.C. Larter. 1990. Growth and dispersal of an erupting large herbivore population in northern Canada: The Mackenzie wood bison population (*Bison bison athabascae*). Arctic, 43: 231-238.

GeoNorth Northern Environmental Consulting. 2001. An aquatic effects study for the ferry crossings near Tsiigehtchic and Fort McPherson, NT. ASTIS Research Project.

GeoWest Environmental Consultants Ltd. 1997. Ecosystem Classification and Mapping with Wildlife Interpretation for the MO4 Forest Management Unit, NWT. August 1997.

Gibson, J.J., T.W. Edwards, and T D. Prowse. 1992. Runoff Pathways and Flow-Contributing Areas in a High-Boreal Wetland, Upper Mackenzie Valley, N.W.T.

Gillet, J., B.M. Scherzinger, and E. Lithopoulos. 2000. Inertial/GPS System for Seismic Survey. Applanix Corporation, Richmond Hill, Ontario, Canada, 8 pp.

Godfrey, R.N., and R.A. Eaton. 1986. Movement Study of the Trans-Alaska Pipeline at Selected Sites. U.S. Army. Cold Regions Research and Engineering Lab (CRREL), Special Report 86-28.

Government of the Northwest Territories (GNWT). 1993. An Investigation of Atmospheric Emissions from the Royal Oak Giant Mine. June 1993.

Grasso, J.R. and G. Wittlinger. 1990. Ten years of seismic monitoring over a gas field. Bulletin of the Seismological Society of America, 80: 450.

Grey, B. 2003. Personal Communication. Natural Resources Canada.

Gullickson, D. 1998. Beyond Boundaries: South Nahanni Woodland Caribou. In: Research Links: A Forum for Natural, Cultural and Social Studies, Volume 6, No. 2.

Gunn, W. H. and C.E. Tull. 1976. Recommendations for a Program of Environmental Surveillance and a Program of Ornithological Monitoring in Regard to the Proposed Arctic Gas Pipeline.

Gunn, A., B. Griffith, G. Kofinas, and D. Russell. 2001. Cumulative Impacts and the Bathurst Caribou Herd: Proposed Tools for Assessing the Effects. Report for the Department of Indian Affairs and Northern Development, Yellowknife, Northwest Territories. February 2001.

Gwich’in Renewable Resource Board (GRRB). 2003. GRRB 2003 Summary of Studies. 29 pp. Found at: www.grrb.nt.ca

Hall, E. 1989. People and Caribou in the Northwest Territories. Department of Renewable Resources, Government of the Northwest Territories. 190 pp.

Halliwell, D. 2003. Personal Communication through response to questionnaire and phone conversation (October 3, 2003). Environment Canada.

Hanley, P.T. 1973. Surficial geology and geomorphology maps of Fort Norman, Carcajou Canyon, Norman Wells, and Sans Sault Rapids, Mackenzie Valley, Northwest Territories. Geological Survey of Canada, Open File 155 scale 1:125,000.

Hanley, P.T., S.C. Chatwin, O.L. Hughes, and J. Pilon. 1975. Surficial geology and geomorphology of Norman Wells, Mahoney Lake, and Canot Lake, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Open File 294 scale 1:125,000.

Hanna, A.J. and E.C. McRoberts. 1988. Permafrost slope design for a buried oil pipeline. In: Proceedings, Fifth International Permafrost Conference, 2: 1247-1252.

Hardy Associates (1978) Limited. 1980. Revegetation and Impact Assessment Studies in the Mackenzie River Region. Beaufort E.I.S. reference work, no. RWE18. ESSO Resources Canada.

Hardy Associates (1978) Limited. 1994. Land Use Guidelines: Access Roads and Trails. Northern Affairs Program (Canada).

Hardy BBT Limited. 1987. Reclamation Guidelines for Northern Canada. Northern Affairs Program (Canada).

Hardy BBT Limited. 1988a. Geophysical Assessment of Waste Drilling Fluid Containment Sites in the Mackenzie River Valley Region, N.W.T. NOGAP project no. A.05. 30 pp. Department of Indian Affairs and Northern Development.

Hardy BBT Limited. 1988b. 1987 Revegetation Monitoring of the Interprovincial Pipe Line (NW) Ltd. Norman Wells to Zama pipeline. Interprovincial Pipe Line (NW) Ltd.

Hardy BBT Limited. 1990. Environmental Operating Guidelines: Northern Seismic Operations. Prepared for Indian and Northern Affairs Canada.

Harlan, R.L. 1974. Hydrogeological Considerations in Northern Pipeline Development. Prepared for the Environmental-Social Program Northern Pipeline Studies. November 1974. Report No. 72-26.

Harper, K.A., and G.P. Kershaw. 1996. Natural revegetation on borrow pits and vehicle tracks in shrub tundra, 48 years following construction of the CANOL No. 1 Pipeline, N.W.T., Canada. Arctic, Antarctic, and Alpine Research, 28(2): 163-171.

Harper, K.A., and G.P. Kershaw. 1997. Soil characteristics of 48-year old borrow pits and vehicle tracks in shrub tundra along the CANOL No. 1 Pipeline corridor, N.W.T., Canada. Arctic, Antarctic, and Alpine Research, 29(1): 105-111.

Harry, D.G. and K.L. MacInnes. 1988. The effect of forest fires on permafrost terrain stability, Little Chicago-Travaillant Lake area, Mackenzie Valley, N.W.T. Geological Survey of Canada Paper 88-1D: 91-94.

Hasegawa, H.S. 1974. A theoretical evaluation of design ground seismic motions for pipelines in the Yukon Territory and Mackenzie Valley. Publ. Earth Physics Br., D.E.M.R., v. 44, no. 12.

Hatfield, C.T., J.N. Stein, M.R. Falk and C.S. Jessop. 1972. Fish Resources of the Mackenzie River Valley, Interim Report I. Winnipeg: Fisheries Service, Environment Canada.

Heard, D.C. 1981. Historical and present status of wolves in the Northwest Territories. In: Wolves in Canada and Alaska: Their Status, Biology, and Management: Proceedings of the Wolf Symposium. Edmonton, Alberta, 12-14 May, 1981. Carbyn, L.N. (ed.). Canadian Wildlife Service Report Series, No. 45. p. 44-47.

Heard, D.C. and T.M. Williams. 1992. Distribution of wolf dens on migratory caribou ranges in the Northwest Territories, Canada. Canadian Journal of Zoology, 70: 1504-1510.

Hebert, P.D.N., K. Schwenk, J. Witt, A. Cox, C. Rowe, and J. Rhydderch. 1997. To study the levels and patterns of genetic diversity in arctic freshwater organisms. ASTIS - Research Project.

Heginbottom, A. 2000. Permafrost distribution and ground ice in surficial materials, In: The Physical Environment of the Mackenzie Valley, Northwest Territories: a Base Line for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (ed.). Geological Survey of Canada, Bulletin 547, p. 31-39.

Hines, J. 2003. Personal Communication, October 27, 2003 (through V. Charlwood). Canadian Wildlife Service.

Hobson, K. and E. Bayne. 2000. Effects of forest fragmentation by agriculture on avian communities in the southern boreal mixed woods of Western Canada. Wilson Bull., 112(3), p. 373–387.

Hovey, F.W., L.L. Kremsater, R.G. White, D.E. Russell, F.L. Bunnell. 1989. Computer Simulation Models of the Porcupine Caribou Herd: II. Growth. Technical Report Series - Canadian Wildlife Service, no. 54. 34 pp.

Howland, K.L. 1997. Migration Patterns of Freshwater and Anadromous Inconnu, in the Mackenzie River. M.Sc. Thesis. University of Alberta, Edmonton, AB.

Howland, K.L., J.A. Babaluk and W.M. Tonn. 2001. Identification of freshwater and anadromous inconnu in the Mackenzie River system by analysis of otolith strontium. Transactions of the American Fisheries Society, 130: 725-741.

Howland, K.L., R.F. Tallman and W.M. Tonn. 2000. Migration patterns of freshwater and anadromous inconnu, *Stenodus leucichthys*, in the Mackenzie River system. Transactions of the American Fisheries Society, 129: 41-59.

Hughes, O.L. 1970. Five surficial maps of Mackenzie District, Northwest Territories. Geological Survey of Canada, Open File 26 scale 1:125,000.

Hutchinson, T. C. 1984. Recovery of Arctic and Sub-arctic Vegetation Nine Summers after Crude and Diesel Oil Spills. 39 pp Ministry of Indian Affairs and Northern Development.

Hutchinson, T.C. and J.A. Hellebust. 1978. Vegetational Recovery in the Canadian Arctic after Crude and Diesel Oil Spills. Northern Natural Resources and Environment Branch. Environment Division. North of 60; Ottawa, vi, 62 pp.

Intergovernmental Panel on Climate Change (IPCC). 1996. Climate Change 1995 – The Science of Climate Change: Contribution of Working Group I to the Second Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge, England, Cambridge University Press.

Intergovernmental Panel on Climate Change (IPCC). 2001. Climate Change 2001, The Scientific Basis. Contribution of Working Group I to the Third Scientific Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, England, Cambridge University Press.

International Union for Conservation of Nature and Natural Resources (IUCN) - The World Conservation Union E&P Forum. 1993. Oil and Gas Exploration and Production in Arctic and Subarctic Onshore Regions: Guidelines for Environmental Protection. Published by IUCN.

Interprovincial Pipe Line (NW) Ltd. 1982. Norman Wells Pipeline Project: Geotechnical Report on Thaw Settlement Design Approach, March 1982. Report submitted to National Energy Board, prepared for IPL by Hardy Associates (1978) Ltd. 75 p. & appendices.

Interprovincial Pipe Line (NW) Ltd. 1984 to 2002. Norman Wells Pipeline, Project Report on Monitoring of Construction and Operation, 17 Annual Reports to National Energy Board.

Interprovincial Pipe Line (NW) Ltd. 1987. Norman Wells Pipeline Project: 1987 Report on Monitoring of Construction and Operation.

Interprovincial Pipe Line (NW) Ltd. 1988a. Norman Wells Pipeline Organic Terrain Revegetation Trials, 1987 Report. Edmonton, Alta.

Interprovincial Pipe Line (NW) Ltd. 1988b. Norman Wells Pipeline Project: 1988 Report on Monitoring of Construction and Operation.

Interprovincial Pipe Line (NW) Ltd. 1989. Norman Wells Pipeline Project: 1989 Report on Monitoring of Construction and Operation.

Interprovincial Pipe Line (NW) Ltd. 1991. Norman Wells Pipeline Project: 1991 Report on Monitoring of Construction and Operation.

Interprovincial Pipe Line (NW) Ltd. 1993. Norman Wells Pipeline Project: 1993 Report on Monitoring of Construction and Operation.

Ion, P.G. and G.P. Kershaw. 1989. The Selection of Snowpatches as Relief Habitat by Woodland Caribou (*Rangifer tarandus caribou*), Macmillan Pass, Selwyn/Mackenzie Mountains, N.W.T. Canada. Arctic, 21: 203-211.

Jasper, J.N. and J.A. Kerr. 1994. Routing: Mackenzie River and Delta. In: Mackenzie Basin Impact Study (MBIS), interim report #2 : Proceedings of the Sixth Biennial AES/DIAND Meeting on Northern Climate & Mid Study Workshop of the Mackenzie Basin Impact Study, Yellowknife, Northwest Territories, April 10-14, 1994 p. 254-271.

Jessop, C.S. 1974. A further evaluation of the fish resources of the Mackenzie River valley as related to pipeline development. Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development report, no. 74-7.

Jingfors, K. 1984. To Determine Early Winter Distribution and Abundance, Population Characteristics and Habitat Use of Moose, Mackenzie River Valley west of Norman Wells. Unpublished. Northwest Territories Department of Renewable Resources, Yellowknife, NWT.

Johnson, E.A. 1992. Fire and Vegetation Dynamics: Studies from the North American boreal forest. Cambridge University Press. 129 pp.

Jones, D.R., O.S. Bamford and J.W. Kiceniuk. 1971. An Evaluation of the Swimming Performance of Several Fish Species from the Mackenzie River. University of British Columbia. Dept. of Zoology., and Canada. Fisheries and Marine Service. Winnipeg, Man: Dept. of the Environment, Fisheries and Marine Service, Central Region.

Kavik-Axys Inc. and LGL Ltd. Environmental Research Associates. 2001. Overview of Key Issues and Data Gaps Related to Development and Transportation of Gas from the Western Canadian Arctic and Alaska. Prepared for the Department of Indian and Northern Affairs. 131 pp.

Kerfoot, D.E. 1973. Thermokarst features produced by man-made disturbances to tundra terrain. In: Research in Polar and Alpine Geomorphology. In: Proceedings of 3rd Guelph Symposium on Geomorphology, B.D. Fahey and R D. Thompson (eds.).

Kershaw, G.P. 1983. Some abiotic consequences of the Canol crude oil pipeline project, 35 years after abandonment. In: Permafrost: Fourth International Conference, Proceedings, July 17-22, 1983.

Kershaw, G.P. 2001. Snowpack characteristics following wildfire on a simulated transport corridor and adjacent subarctic forest, Tulita, NWT, Canada. Arctic and Alpine Research, 33(2): 131-139.

Kokelj, S.A. 2001. Hydrologic Overview of the Gwich'in and Sahtu Settlement Areas. Water Resources Division, Indian and Northern Affairs Canada, Yellowknife, NWT. December 2001.

Kokelj, S.V. and GeoNorth Ltd. 2002. Drilling Mud Sumps in the Mackenzie Delta Region: Construction, Abandonment and Past Performance. A report submitted to Department of Indian Affairs and Northern Development, NWT Region.

Kovach, R.L. 1974. Source mechanisms for Wilmington Oil Field, California, Subsidence Earthquakes. Bulletin of the Seismological Society of America, 64: 699.

Krebs, C.J., S. Boutin and R. Boonstra. 2001. Ecosystem Dynamics of the Boreal Forest: The Kluane Project. University of Oxford Press, New York. 511 pp.

Kutz, S. 2002. Personal Communication in response to questionnaire. Research Group for Arctic Parasitology, Western College of Veterinary Medicine, University of Saskatchewan.

Kwong, Y.T.J., and T.Y. Gan. 1994. Northward migration of permafrost along the Mackenzie Highway and climatic warming. Climatic Change, 26(4): 399-419.

Lacroix, M. 2003. Personal Communication. National Water Research Institute.

Ladanyi, B. and M. Shen. 1993. Freezing pressure development on a buried chilled pipeline. In: Frost in Geotechnical Engineering, Phukan (ed.). Balkema, Rotterdam.

Laperriere, F. 1985. High Pressure Waterjet Barrier Trial in Norman Wells. Spill Technology Newsletter, v. 10, no. 1-3, Jan.-June 1985, p. 5-10.

Larsen, K. 2003. Personal Communication, March 7, 2003. Wildlife Ecology and Management, University College of the Caribou, Kamloops, British Columbia

Larsen, K.W. and P.T. Gregory. 1988. Amphibians and reptiles in the Northwest Territories. In: The Natural History of Canada's North: Current Research. Kobelka, C. and C. Stephens (eds.). Occasional Papers of the Prince of Wales Northern Heritage Centre. No. 3. Prince of Wales Northern Heritage Centre, Yellowknife, NWT. p. 31-52.

Latour, P. 1992. Moose Distribution Along the Lower Mountain and Hume Rivers during Oil Drilling, Winter 1989/90. 18 pp.

Latour, P. and N. MacLean. 1994. An analysis of data returned by outfitted hunters from the Mackenzie Mountains, NWT, 1979-1990. 41pp.

Lawrence, D.E. 2003a. Northern Pipelines Survey of Expert Opinion on Permafrost and Geotechnical Issues and the use of GSC Products and Services. Prepared for M.M. Burgess Terrain Sciences Division Geological Survey of Canada, Contract No. NRCAN-02-0367, 26 February 2003, 22 pp. Geological Survey of Canada, Open File in preparation.

Lawrence, D.E. 2003b. Northern Pipelines, Critical Issues Related to Permafrost and Terrain. An unpublished presentation based on Issues for Northern Pipelines a Review of Environmental Assessments and Pipeline Monitoring: Geological Survey of Canada, Open File in preparation.

LeBlanc, G. and H.S. Hasegawa. 1974. Earthquake data and design ground motions for the Yukon Territory and the Mackenzie Valley. Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development report, no. 74- 15

LeBlanc, G., and R.J. Wetmiller. 1974. An evaluation of seismological data available for the Yukon Territory and Mackenzie Valley. Canadian Journal of Earth Sciences, 11: 1435-1454.

Lockhart, W.L., D.A. Duncan, B.N. Billeck, R.A. Danell and M.J. Ryan. 1997. Chronic toxicity of the 'water-soluble fraction' of Norman Wells crude oil to juvenile fish. In: Proceedings of the 20th Arctic and Marine Oilspill Program Technical Seminar, Vancouver, June 11-13, 575-580.

Lockhart, W.L., D.A. Metner, D.A.J. Murray, R.W. Danell, B.N. Billeck, C.L. Baron, D.C.G. Muir and K. Chang-Kue. 1989. Studies to determine whether the condition of fish from the lower Mackenzie river is related to hydrocarbon exposure. Environmental Studies 61, Department of Indian Affairs and Northern Development, Ottawa. 84 pp.

Lockhart, W.L., D.A. Metner, D.A.J. Murray and D.C.G. Muir. 1987. Hydrocarbons and complaints about fish quality in the Mackenzie River, Northwest Territories, Canada. Water Poll. Res. J. Canada, 22(4): 661-628.

Lockhart, W.L., R. Wagemann, B. Tracey, D.J. Sutherland, and D. J. Thomas. 1992. Presence and implications of chemical contaminants in the freshwaters of the Canadian Arctic. The Science of the Total Environment Science, 122(1/2): 165-243.

Lornel Consultants. 2002. Northern Rivers Surveys Ltd. Liard River Geophysical Survey - Environmental Assessment. 115 pp.

Low, G. 2003. Personal Communication in response to questionnaire. Department of Fisheries and Oceans.

MacDonald Environmental Sciences Ltd. 1993. An Assessment of Ambient Environmental Conditions in the Liard River Basin, Northwest Territories. Activity Reports 1992-93: Arctic Environmental Strategy NWT Water Component / Northern Affairs Program (Canada). Water Resources Division. - Yellowknife, N.W.T. 89 pp.

MacDonald Environmental Sciences Ltd. 1995. Expert's Workshop on the Development of Ecosystem Maintenance Indicators for the Ttransboundary River Systems within the Mackenzie Basin. Prepared for Department of Indian Affairs and Northern Development, Ottawa. 41 pp + appendices.

MacDonald, B. 2000. Woodland Caribou in the Mackenzie Mountains, Northwest Territories - Initial studies. Affiliated with Sahtu Renewable Resources Board. Sponsored by Sahtu Renewable Resources Board, Northwest Territories Department of Resources, Wildlife and Economic Development, Fort Good Hope Renewable Resource Council, Norman Wells Renewable Resource Council, Tulita Renewable Resource Council. Northwest Territories Wildlife Research Permit, no. 2074)

MacDonald, B. 2002. Personal Communication in response to questionnaire. Ducks Unlimited.

Machtans, C.S. 2000. Extra-limital observations of Broad-winged Hawk, *Buteo platypterus*, Connecticut Warbler, *Oporornis agilis*, and other bird observations from the Liard Valley, Northwest Territories. Canadian Field-Naturalist, 114: 671-679.

Machtans, C.S. and P.B. Latour. 2003. Boreal forest songbird communities of the Liard Valley, Northwest Territories, Canada. The Condor, 105(1).

MacInnes, K. L., M.M. Burgess, D.G. Harry, and T.H.W. Baker. 1989. Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline, v. I. Environmental and Engineering Considerations. Department of Indian and Northern Affairs Canada, Northern Affairs Program, Environmental Studies Report no. 64. 132 pp.

MacInnes, K. L., M.M. Burgess, D.G. Harry, and T.H.W. Baker. 1990. Permafrost and Terrain Research and Monitoring: Norman Wells Pipeline, v. II. Research and Monitoring Results: 1983-1988. Department of Indian and Northern Affairs Canada, Northern Affairs Program. 204 pp.

Mackay, J.R. 1970. Disturbances to tundra and forest tundra environment of the western Arctic. Canadian Geotechnical Journal, 7: 420-432.

Mackay, J.R. 1992. Lake stability in an ice-rich permafrost environment: examples from the western Arctic coast. In: Aquatic Ecosystems in Semi-Arid Regions: Implications for Resource Management, R.D. Robarts and M.L. Bothwell (eds.). NHRI Symposium Series 7. Environment Canada: Saskatoon, Saskatchewan, p. 1-26.

Mackenzie Gas Pipeline Producers. 2002a. Mackenzie Gas Project: Next Steps Toward a Mackenzie Valley Natural Gas Pipeline. Presentation made June 2002, 10 p.

Mackenzie Gas Pipeline Producers. 2002b. Mackenzie Gas Project. Background Document on Proposed Mackenzie Gas Pipeline Project, May 2002, 8 p. plus overhead slides.

Mackezie Global Energy and Water Cycle Experiment Study (MAGS). 2003. Specific Study for MAGS. Interim Review. Submitted to International Advisory Panel. October 2003.

Mackenzie Highway Granular Materials Working Group. 1975. Granular Materials Inventory, Mackenzie River Valley, NWT. Department of Indian Affairs and Northern Development.

Mackenzie Valley Environmental Impact Review Board (MVEIRB). 2000. Decision, Reasons for Decision and Report on the Environmental Assessment of the EXPLOR Data Limited Land Use Permit N1998B0861 - Seismic Program, Nahanni Butte, NT. 41 pp.

Mackenzie Valley Environmental Impact Review Board (MVEIRB). 2001. Report on the Paramount Resources Limited Cameron Hills Gathering System and Pipeline Development. December 3, 2001. 59 pp.

Mackenzie Valley Pipe Line Research Limited. 1971. Feasibility Study: 1971: Back-up Data: Volume II – Pipe Line Construction.

Macleod Institute of Environmental Analysis at the University of Calgary. 2002. Carrying Capacity and Thresholds: Theory and Practice in Environmental Management. Prepared for the Canadian Arctic Resource Committee. 77 pp.

Mahnic R.J. and T.J. Fujino. 1993. Typical northern community borrow requirements. In: Granular Resource Requirements for Proposed Mackenzie Valley Pipelines: technical papers and workshop proceedings, prepared by Stanley Associates Engineering, p. 78.

Marsh, P. 2003. Personal Communication, September 23, 2003. National Water Research Institute, Environment Canada.

Marsh, P. and N.N. Neumann. 2001. Processes controlling the rapid drainage of two ice-rich permafrost-dammed lakes in NW Canada. Hydrol. Process. 15, 3433–3446.

Marshall, R. 2003. Personal Communication in response to questionnaire. GNWT, Department of Resources, Wildlife and Economic Development.

Maslen, L. and G.P. Kershaw. 1987. The Use of Native Shrub Species in Northern Revegetation Programs: Fort Norman, N.W.T. 1987.

Maxim, L.D., and R.W. Niebo. 2001. Water Spills on the Alaska North Slope. Prepared by Everest Consulting Associates, Cranbury, NJ for Alaska Oil and Gas Association, Anchorage, AK, October 2001.

McKenzie, A. 1989. Oil wells cause earthquakes. Science News, 136: 279.

McLean, B.D. 1992. An Aerial Survey of Muskoxen North of Great Bear Lake, August 1987. Unpublished. Northwest Territories Department of Renewable Resources, Yellowknife, NWT. 19 pp.

McLeod, C.L. and J.P. O'Neil. 1983. Major range extension of anadromous salmonids and first record of chinook salmon in the Mackenzie River drainage. Canadian Journal of Zoology, 61: 2183-2184.

McLoughlin, P.D., R.L. Case, R.J. Gau, S.F. Ferguson and F. Messier. 1999. Annual and seasonal movement patterns of barren-ground grizzly bears in the central Northwest Territories. Ursus, Vol. 11.

Milburn, D. 2003. Personal Communication, November 6, 2003. Department of Indian Affairs and Northern Development.

Milne, W.G. and M.J. Berry. 1976. Induced seismicity in Canada. 10 Engin. Geol. 219.
Waldner, C.L., C.S. Ribble, and E.D. Janzen. 1998. Evaluation of the impact of a natural gas leak from pipeline on productivity of beef cattle. Journal of Veterinary Medicine Today, 212(1).

Morgan, J.D., G.A. Vigers, P.G. Nix, EVS. Consultants Ltd. 1986. Assessment of Freshwater Impacts from the Norman Wells Oilfield development: Part II: Field and Laboratory Studies. NOGAP project no. C.02.

Morrell, G. 1995. Petroleum Exploration in Northern Canada: A Guide to Oil and Gas Exploration and Potential. Northern Oil and Gas Directorate, Indian and Northern Affairs Canada, Ottawa. 110 pp.

Mulders, R. 2001. Lynx Ecology, Health and Harvest Monitoring at Fort Providence. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Muller, S.W. 1947. Permafrost of Permanently Frozen Ground and Related Engineering Problems. J.W. Edwards, Ann Arbor, Michigan.

Murphy, J.E. 1990. The 1985 – 1986 Canadian Peregrine Falcon, *Falco peregrinus*, Survey. Canadian Field-naturalist, 104: 182-192.

Musiani, M., D. Cluff, R. Mulders, B.N. White and P. Wilson. 2000. Genetics, Movements and the Management of Wolves in Northern Canada. Sponsors: University of Calgary, World Wildlife Fund, Circumpolar/Boreal Alberta Research Program, University of Alberta, Italian National Research Council, University of Rome, BHP Diamonds, Diavik Diamond Mines Inc., West Kitikmeot Slave Study Society, Mountain Equipment Coop.

Nagy, E., E.D. Ongley and J.H. Carey. 1988. Final Report on Hydrocarbon Pathways in the Mackenzie River, N.W.T. NOGAP project no. C.02 : Criteria for the control and monitoring of petroleum development impacts on the Mackenzie River; Burlington, Ont. Environment Canada, National Water Research Institute, 1988. 12 pp.

Nagy, J. 2001. Richardson Mountain Dall's Sheep Population and Lungworm Infection Survey. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Nagy, J. 2003. Personal Communication with Brenda Parlee. GNWT, Department of Resources, Wildlife and Economic Development.

Nagy, J., T. Creighton, W. Wright, T. Slack, M. Branigan and D. Auriat. 2002. Wildlife Research and Information Gaps. Workshop Nov 19-21, 2002 (Gwich'in). Sponsored by Western NWT Biophysical Study and RWED. 64 pp.

National Energy Board (NEB). 1977. Reasons for Decision - Northern Pipelines. Volume III selected sections.

National Science Foundation. 2000. Workshop to Develop a Strategic Plan for Cold Regions Engineering Research in the New Millennium. Sponsored by National Science Foundation, Alaska Science and Technology Foundation and American Society of Civil Engineers. University of Alaska, Anchorage (UAA), Campus, Anchorage, Alaska, June 19-21, 2000.

Nishi, J. 2000. Comparative Evaluation of Genetic Diversity and Baseline Health of Free-ranging Bison in the Slave River Lowlands, Northwest Territories. Resources, Wildlife and Economic Development.

Nishi, J. 2001. Mackenzie Wood Bison Population Monitoring Project. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Nixon J.F., and M. M. Burgess. 1999. Norman Wells Pipeline settlement and uplift movement. Canadian Geotechnical Journal, 36: 119-135.

Nixon, F.M. 2000. Thaw-depth monitoring. In: The physical environment of the Mackenzie Valley, Northwest Territories: a baseline for the assessment of environmental change, L.D. Dyke and G.R. Brooks (eds.). Geological Survey of Canada Bulletin 547: 119-126.

Nixon, F.M. and A.E. Taylor. 1994. Active layer monitoring in natural environments, Mackenzie Valley, Northwest Territories. In: Current Research 1994-B, Geological Survey of Canada, p. 27-34.

Nixon, F.M. and A.E. Taylor. 1998. Regional active layer monitoring across the sporadic, discontinuous and continuous permafrost zones, Mackenzie Valley, Northwestern Canada. In: Proceedings of 7th International Conference on Permafrost, Yellowknife.

Nixon, J.F., K.A. Sortland, and D.A. James. 1990. Geotechnical aspects of northern gas pipeline design. In: Proceedings, Fifth Canadian Permafrost Conference: University Laval, Quebec, Collection Nordicana, no. 54, p. 299-308.

Nixon, F.M., A.E. Taylor, V.S. Allen, and F. Wright. 1995. Active layer monitoring in natural environments, lower Mackenzie Valley, Northwest Territories. In: Current Research 1995-B, Geological Survey of Canada, p. 99-108.

Nolan, J.W. and J.P. Kelsall. 1977. Dall's Sheep and their Habitat in Relation to Pipeline Proposals in Northwestern Canada. Mackenzie Valley Pipeline Investigations. Canadian Wildlife Service, Ottawa. 64 pp.

Northern Engineering Services Company Limited. 1976. Response to Dr. P.J. Williams' Report on Possible Frost Heave of Chilled Gas Pipeline. Prepared for Canadian Arctic Gas Study Limited by Northern Engineering Services Company Limited, 38, 15 pp.

Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee. 2002. Consolidated Information Requirements for the Environmental Assessment and Regulatory Review of a Northern Gas Pipeline Project through the Northwest Territories. September 2002. 35 pp.

NWT Biodiversity Team. 2001. A Planning Document for the NWT Biodiversity Action Plan, First Steps. May 2001.

NWT Biodiversity Team. 2003. Unpublished table of wildlife-related monitoring studies in the NWT. Compiled by the NWT Biodiversity Team and provided by S. Carrière March 20, 2003.

NWT Cumulative Effects Assessment Management (CEAM) Steering Committee. 2003. A Blueprint for Implementing the CEAM Strategy & Framework in the NWT and its Region. April 2003.

NWT Cumulative Impact Monitoring Program (CIMP) Working Group. 2002. A Preliminary State of Knowledge of Valued Ecosystem Components for the Cumulative Impact Monitoring Program and Audit. Final Draft report. February 2002. 95 pp.

NWT Protected Areas Strategy Advisory Committee. 1999. NWT Protected Areas Strategy: A Balanced Approach to Establishing Protected Areas in the Northwest Territories. 102 pp.

Oestreich, A. 1998. Demography and Seasonal Distribution of Dall's Sheep in the Liard Range, Mackenzie Mountains, NT. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Osterkamp, T.E., L. Viereck., Y. Shur, M. T. Jorgenson, C. Racine, A. Doyle, and R. D. Boone. 2000. Observations of thermokarst and its impact on boreal forests n Alaska, U.S.A. Arctic, Antarctic, and Alpine Research, 32(3): 303-315.

Paget, T. 2003. Personal Communication, October 24, 2003. Environment Canada.

Paramount Resources Limited and Golder Associates Limited. 2001. Environmental Impact Assessment in Response to the Terms of Reference for the Paramount Resources Limited Cameron Hills Drilling Project. June, 2001. 110 pp.

Parker, S.P. 1997. McGraw-Hill Dictionary of Earth Sciences. McGraw-Hill, New York, New York, 468 pp.

Pathfinder Geoservices Inc. 2002. POS/LS Product and Technical Information. Calgary, Alberta 2 p.

Petroleum Communication Foundation. 1999. Our Petroleum Challenge, 6th edition. Published by The Petroleum Communication Foundation, Calgary, AB, 101 pp.

Pidwirny, M.J. 1991-2001. Hydrologic Cycle. In: Introduction to Environmental Issues, Chapter 8: Introduction to Hydrology, Department of Geography, Okanagan University College, http://www.geog.ouc.bc.ca/conted/onlinecourses/geog_210/210_8_2.html

Pilon, J. 1990. Retracing an Archaeological Expedition. 1998 Field Report (part 4), NOGAP Archaeologist, Canadian Museum of Civilization.

Pilon, J.A., M.M. Burgess, A.S. Judge, V.S. Allen, K.L. MacInnes, D.G. Harry, C. Tarnocai, and H. Baker. 1989. Norman Wells to Zama pipeline permafrost and terrain research and monitoring program: site establishment report. Geological Survey of Canada, Open File 20044, 332 pp.

Piteau Engineering Ltd. 1990. Report to Indian and Northern Affairs Canada on Yukon and NWT Groundwater Databases. Indian and Northern Affairs Canada.

Pivnicka, K. 1970. Morphological variation in the burbot (*Lota lota*) and recognition of the subspecies, a review. Canada Fisheries Research Board Journal, 27(10).

Poole, K.G. 1992. Lynx Research in the Northwest Territories, 1991-92. 43 pp.

Poole, K.G. and B. Croft. 1990. Beaver Surveys in the Western NWT, September - October 1989. 15 pp.

Poole, K.G. and B. Elkin. 1992. Environmental Contaminants, Population Structure and Biological Condition of Harvested Mink in the Western Northwest Territories, 1991-92. 20 pp.

Popko, R. 2001. Determining the Number of Active Beaver Lodges in the Sahtu Settlement Area. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Quayle, J. and J.P. Kershaw. 1994. Summer habitat use by woodland caribou in the western Mackenzie Mountains, NWT, Canada. Poster presented at the Proceedings of the 6th North American Caribou Workshop, Prince George, BC, March 1-4, 1994.

Quon, S. 1999. Data Collection Summary as of October 1999. Prepared for the Sahtu Land Use Planning Board. 18 pp.

Rampton, V.N. 1973. The influence of ground ice and thermokarst upon the geomorphology the Mackenzie-Beaufort region. In: Research in Polar and Alpine Geomorphology. B.D. Fahey and R.D. Thompson (eds.). In: Proceedings of 3rd Guelph Symposium on Geomorphology, p. 43-59.

Rampton, V.N. 1981a. Surficial geology, Aklavik, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Map 31-1979.

Rampton, V.N. 1981b. Surficial geology, Mackenzie Delta, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Map 32-1979.

Reid, B. 2003. Personal Communication. Department of Indian Affairs and Northern Development

Reist, J. 2002. Personal Communication in response to questionnaire January 9, 2002. Department of Fisheries and Oceans.

Reist, J.D. R.A. Bodaly, R.J.P. Fudge, K.J. Cash and T.V. Stevens. 1987. External scarring of whitefish, *Coregonus nasus* and *C. clupeaformis* complex, from the western Northwest Territories, Canada. Canadian Journal of Zoology, 65: 1230-1239.

Reist, J.D., J.D. Johnson and T.J. Carmichael. 1997. Variation and specific identity of char from northwestern Arctic Canada and Alaska. American Fisheries Society Symposium, 19: 250-261.

Reist, J.D., G. Low, J.D. Johnson and D. McDowell. 2002. Range extension of bull trout, *Salvelinus confluentus*, to the central Northwest Territories, with notes on identification and distribution of Dolly Varden, *Salvelinus malma*, in the western Canadian Arctic. Arctic, 55: 70-76.

Resources, Wildlife and Economic Development (RWED). 2002a. Western NWT Biophysical Study - Deh Cho Wildlife Research Needs Workshop, September 23 to 25, 2002, Fort Simpson. 7 pp + appendices

Resources, Wildlife and Economic Development (RWED). 2002b. Guideline for Ambient Air Quality Standards in the Northwest Territories: Sulpur Dioxide, Ground Level Ozone, Total Suspended Particulate, Fine Particulate Matter. December 2002.

Ritter, D.F. 1986. Process Geomorphology. WM.C. Brown Publishers, Dubuque, Iowa. 579 pp.

Robinson, S.D. 2000. Thaw-slump-derived thermokarst near Hot Weather Creek, Ellesmere Island, Nunavut. In: Environmental Response to Climate Change in the Canadian High Arctic, M. Garneau and B.T. Alt (eds.). Geological Survey of Canada Bulletin 529, p. 335-345.

Rohner, C. and D.A. Demarchi. 2000. Cumulative Effects And Mountain Caribou In West-Central Alberta: An Individual-Based And Spatially Explicit Population Model For Conservation Planning. Prepared for West-Central Alberta Caribou Standing Committee (WCACSC), July 28, 2000.

Roots, F. 1997. Inclusion of Different Knowledge Systems in Research. Presentation for the Institute for Environmental Monitoring and Research: Traditional Ecological Knowledge and Western Scientific Knowledge Workshop, West Island, Labrador, September 10-11, 1997.Ruttan, R.A. and D.R.. Wooley [Renewable Resources Consulting Services]. 1974. A Study of Furbearers Associated with Proposed Pipeline Routes in the Yukon Territory and Mackenzie River Valley, 1971.

Rutter, N.W. and A.N. Boydell. 1979. Surficial geology and geomorphology, Kakisa River, District of Mackenzie, Northwest Territories. Geological Survey of Canada, Map 14-1978.

Rutter, N.W. and A.N. Boydell. 1980a. Surficial geology and geomorphology, Bulmer Lake, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 10-1978, scale 1:125,000.

Rutter, N.W. and A.N. Boydell. 1980b. Surficial geology and geomorphology, Root River, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 12-1979, scale 1:125,000.

Rutter, N. W. and A. N. Boydell. 1980c. Surficial geology and geomorphology, Wrigley lake, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 13-1978, scale 1:125,000.

Rutter, N.W. and A.N. Boydell. 1981. Surficial geology and geomorphology, Sibbetson Lake, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 10-1979, scale 1:125,000.

Rutter, N.W., A.N. Boydell, K.W. Savigny, and R.O. Van Everdingen. 1973. Terrain Evaluation with Respect to Pipeline Construction, Mackenzie Transportation Corridor, Southern Part, Latitude 60 to 64N. Environmental Social Program, Northern pipelines, Task Force on Northern Oil Development, Report No. 73-36. 135 pp.

Rutter, N.W., R.J. Hawes and N.R. Catto. 1993. Surficial geology, southern Mackenzie River valley, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 1693A, scale 1:500,000.

Rutter, N.W., G.V. Minning and J.A. Netterville. 1980a. Surficial geology and geomorphology, Camsell Bend, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 9-1979, scale 1:125,000.

Rutter, N.W., G.V. Minning, J.A. Netterville. 1980b. Surficial Geology and Geomorphology, Dahadinni River, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Preliminary Map , 18-1979.

Rutter, N.W., G.V. Minning and J.A. Netterville. 1980c. Surficial geology and geomorphology, Fort Simpson, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 3-1978, scale 1:125,000.

Rutter, N.W., G.V. Minning and J.A. Netterville. 1980d. Surficial geology and geomorphology, Mills Lake, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 15-1978, scale 1:125,000.

Rutter, N.W., G.V. Minning and J.A. Netterville. 1980e. Surficial geology and geomorphology, Trout Lake, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 16-1978, scale 1:125,000.

Rutter, N.W., G.V. Minning, J.A. Netterville. and A.N. Boydell. 1980f. Surficial geology and geomorphology, Fort Liard, District of Mackenzie, Northwest Territories, Geological Survey of Canada, Map 11-1979, scale 1:125,000.

Sahtu Land and Water Board. 2003. Personal Communication.

Sahtu Renewable Resources Board (SRRB) and Resource, Wildlife and Economic Development (RWED). 2002. Renewable research and monitoring in the Sahtu settlement area - October 29-30, 2002 workshop report. 18 pp.

Savigny, K.W. and N.R. Morgenstern, 1986. Geotechncial conditions of slopes at a proposed pipeline crossing, Great Bear River valley, Northwest Territories. Canadian Geotechnical Journal., 23, pp. 490-503.

Schwarz, S. 2002. 1st Draft - Index of Selected Map-Based References on Mackenzie Valley Pipeline Corridor. Prepared by S. Schwarz, NWT Centre for Remote Sensing, RWED, GNWT. 70 pp.

Scott, I. 2003. Personal Communication, via email, December 8, 2003.

Scott, M. 1998. Effects of air emissions from sour gas plants on health and productivity on beef and dairy herds in Alberta, Canada. Executive Summary, July 1998.

Segal, P. 1985. Stress and subsidence from subsurface fluid withdrawal in the epicentral region of the 1983 Coalinga Earthquake. Journal of Geophysical Research, 90: 6801.

Shank, C. 1990. Initial Investigations of the Movement of Muskox Groups Below Treeline. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Shank, C.C. 1997. The Northwest Territories Small Mammal Survey: 1990-1996. 25 pp.

Shank, C. and K.G. Poole. 1994. Status of Gyrfalcon, *Falco rusticolus*, populations in the Northwest Territories, Canada. In: Raptor Conservation Today, B.U. Meyburg, and R.D. Chancellor (eds.). Pica Press. p. 421-436.

Shen, M. and B. Ladanyi. 1991. Soil-pipe interaction during frost heaving around a buried chilled pipeline. In: Proceedings of the Sixth International Speciality Conference, West Lebanon, NH, p. 11-21.

Shriner, D.S., and R.B. Street. 1997. North America (Chapter 8). In: The Regional Impacts of Climate Change, An Assessment of Vulnerability. A Special Report of IPCC Working Group II, R.T. Watson, M.C. Zinyowera, and R.H. Moss (eds.), Cambridge University Press, UK. 517pp.

Simmons, C.L., K.R. Everett, D.A. Walker, A.E. Linkins and P.J. Webber. 1983. Sensitivities of plant communities and soil flora to saltwater spill, Prudhoe Bay, Alaska. CRREL 83-24. Hannover, NH. U.S Army Corps of Engineers, Cold Regions Research and Engineering Laboratory.

Simmons, N.M. 1982. Seasonal ranges of Dall's sheep, Mackenzie Mountains, Northwest Territories. Arctic, 35: 512-518.

Skinner, W. *et.al.*, 1995. The State of Canada's Climate: Monitoring Variability and Change, SOE Report No. 95-1, Atmospheric Environment Service, Environment Canada.

Smith, M.W. 1976. Permafrost in the Mackenzie Delta, Northwest Territories. Geological Survey of Canada, Paper 75-28.

Smith, S.L. and M.M. Burgess. 2000. Ground temperature database for northern Canada. Geological Survey of Canada Open File Report 3954.

Smith, S.L. and M.M. Burgess. 2002. Permafrost thickness database for northern Canada. Geological Survey of Canada Open File Report 4173.

Smith, S.L. and P.J. Williams. 1990. Ice lens orientation around a chilled buried pipe. In: Fifth Canadian Permafrost Conference, 1990,Centre d'etudes nordiques, Université Laval, Collection Nordicana 54. N.R.C. Canada, p. 83-87.

Smith, S.L., M.M. Burgess, and J.A. Heginbottom. 2001. Permafrost in Canada, a challenge to northern development. In: A Synthesis of Geological hazards in Canada, G.R. Brooks(ed.). Geological Survey of Canada Bulletin 548, p. 241-264.

Spencer Environmental Management Services Ltd. 1986. Environmental Operating Guidelines: Hydrocarbon Well-sites in Northern Canada. Prepared for Indian and Northern Affairs Canada.

Stein, J.N. 1973. An Evaluation of the Fish Resources of the Mackenzie River Valley as Related to Pipeline Development: Volume I. Environmental-Social Committee Northern Pipelines, Task Force on Northern Oil Development report, no. 73- 1

Stenhouse, G.B., P.B. Latour, L. Kutny, N. MacLean, and G. Glover. 1995. Productivity, survival, and movements of female moose in a low-density population, Northwest Territories, Canada. Arctic, 48: 57-62.

Stenseth, N.C., K.S. Chan, H. Tong, R. Boonstra, S. Boutin, C.J. Krebs, E. Post, M. O'Donoghue, N.G. Yoccoz, M.C. Forchhammer and J.W. Hurrel. 1999. Common dynamic structure of Canada lynx populations within three climatic regions. Science, 285: 1071-1073.

Stevens, A.E. and W.G. Milne. 1974. A study of seismic risk near pipeline corridors in Northwestern Canada and Eastern Alaska. Canadian Journal of Earth Sciences, 11:147-164.

Stewart, D.B. 1996. A review of the status and harvests of fish stocks in the Sahtu Dene and Metis Settlement area, including Great Bear Lake. Can. Manuscript. Fish Aquatic Sci., 2337: 64 pp.

Stewart, D.B. 2001. Possible Impacts on Overwintering Fish of Trucking Granular Materials Over Lake and River Ice in the Mackenzie Delta Area. Prepared by Arctic Biological Consultants for Fisheries Joint Management Committee, Inuvik, NT. 10 pp.

Stewart, D.B. and G. Low. 2000. A review of information on fish stocks and harvests in the Deh Cho area, Northwest Territories. Can. Manuscript. Fish Aquatic Sci., 2549: 73 pp.

Strange, N.E. 1985. Migration, Reproduction and Feeding of Lake Whitefish, Broad Whitefish and Arctic Cisco in the Mackenzie River-Beaufort Sea Region: a Review of Literature. North/South Consultants Inc. NOGAP Project No. B.03: Critical Western Arctic Freshwater Habitats.

Tallman, R. 2003. Personal communication in response to questionnaire January 17, 2003. Fisheries and Oceans Canada.

Tallman, R. and J. Reist. 1997. The Proceedings of the Broad Whitefish Workshop: The Biology, Traditional Knowledge and Scientific Management of Broad Whitefish (*Coregonus nasus* (Pallas)) in the lower Mackenzie River. Prepared by the Department of Fisheries and Oceans.

Tarnocai, C., I.M. Kettles and B. Lacelle. 2003. Peatlands of the Mackenzie River Valley Database and Map. Geological Survey of Canada, Open File 4413.

Taylor, A.E. and A.S. Judge. 1974. Canadian Geothermal Data Collection - Northern Wells 1955 to February 1974; Geothermal Series #1, Geothermal Service Canada, Earth Physics Branch, E.M.R.

Taylor, A.E., M.M. Burgess, A. Judge. and V. Allen. 2000. Deep ground temperatures. In: The physical environment of the Mackenzie Valley, Northwest Territories: a baseline for the assessment of environmental change, L.D. Dyke and G.R. Brooks (eds.). Geological Survey of Canada Bulletin 547, p. 105-109.

Thompson, C. 2001. Archaeological Survey of Mackenzie Valley Pipeline Route. Alaska Gas Producers Pipeline Team.

Treble, M. 1994. Lower Mackenzie River road whitefish (*Coregonus nasus*): central Delta biological characteristics (1984-1990), commercial and subsistence harvest trends and local management issues. Paper presented at the Inuvik Broad Whitefish Workshop, March 14-16, 1994.

U.S. Army Cold Regions Research and Engineering Lab (CRREL). 1981. Movement Study of the Trans-Alaska Pipeline at Selected Sites. U.S. Army. Cold Regions Research and Engineering Lab (CRREL), CRREL Report 81-4.

Van Everdingen, R. 1979. Potential Interactions Between Pipelines and Terrain in a Northern Environment, Ottawa, Ontario, National Hydrology Research Institute, Inland Waters Directorate.

Van Laake, P.E. 2002. ALCES Review, Final Report. Commissioned by Canadian Association of Petroleum Producers and Department of Energy, Government of Alberta. Edmonton, May 2002.

Veale, G. 2003. Personal Communication, October 20 and 29, 2003. GNWT, Department of Resources, Wildlife and Economic Development.

Veitch, A. 1997a. Population Size, Composition of Moose in Fort Good Hope Area, November 1997. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Veitch, A. 1997b. An Aerial Survey for Muskoxen in the Northern Sahtu Settlement Area, March 1997. 42 pp.

Veitch, A. 1998a. Population Size, Composition and Harvest of Moose in the Tulita Area, NT, November 1998. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Veitch, A. 1998b. Juvenile Dispersal of Martens in the Boreal Forest of the Northwest Territories. Northwest Territories Wildlife Research Permit, no. 1572.

Veitch, A. 2001. Moose Population Size and Composition in the Norman Wells Area. Unpublished. Northwest Territories Department of Resources, Wildlife and Economic Development, Yellowknife, NWT.

Walker, D.A. 1996. Disturbance and recovery of arctic Alaska vegetation. In: Landscape Function and Disturbance in Arctic Tundra, J.F. Reynolds and J.D. Tenhunen (eds.). Ecological Studies, vol. 120, p. 35-71.

Walton, L.R., H.D. Cluff, P.C. Paquet and M.A. Ramsay. 2001. Movement patterns of barren-ground wolves in the central Canadian arctic. Journal of Mammalogy, 82(3).

Walton-Rankin, L. 1977. An Inventory of Moose Habitat of the Mackenzie Valley and Northern Yukon. Unpublished. Canadian Wildlife Service, Ottawa. 39 pp.

Washburn. A.L. 1979. Geocryology. Edward Arnold, 406 pp.

Weaver, A.J. 2003. The science of climate change. GeoScience Canada, 30(3): 91-109.

Weichert, D.H. and R.B. Horner. 1987. The Nahanni earthquakes. In: Symposium Proceedings, National Committee on Earthquake Engineering Research, State University of N.Y., Buffalo, Technical Report NCEER87-0025, October 1987, Sterling Forest, N.Y., p. 318-328.

Wein, R.W., S.M. Landhausser, M.J. Salomons, B. Sander, J. Schoplick and J. Truscott. 2001. Sustainable Forestry in the Gwich'in Area - A Biological Perspective. Sustainable Forest Management Network, 46 pp.

Wetmiller, R.J. 1986. Earthquakes near Rocky Mountain House, Alberta, and their relationship to gas production facilities. Canadian Journal of Earth Science, 23: 172.

Wetmiller, R.J., P.W. Basham, D.H. Weichert and S.G. Evans. 1987. The 1985 Nahanni earthquakes: problems of seismic hazard estimates in the northeast Cordillera. In: Proceedings of the 5th Canadian Conference on Earthquake Engineering, Ottawa, p. 695-704.

White, C.M., R.W. Fyfe, and D.B. Lemon. 1990. The 1980 North American peregrine falcon, *Flacon peregrinus*, survey. Canadian Field-Naturalist, 104: 174-181.

White, T.L. 1998. Field Report on Environmental Conditions of Abandoned Oil and Gas Drilling Pads and Sumps Situated in Sporadic and Continuous Permafrost. Geotechnical Science Laboratories, Carleton University. 34 pp.

White, T.L., and P.J. Williams. 1993. Microstructural alternation of a frost heave susceptible soil adjacent to a buried chilled pipeline. In: Proceedings 6th International Conference on Permafrost, Beijing, China, 5-9 July 1993, Vol. I, p. 700-705.

Williams, P.J. 1993. Gas pipelines, oil pipelines and civil engineering in Arctic climates. In: Proceedings of a Seminar, Caen and Paris, France, Centre National de la Recherche Scientifique; Laboratoire Central des Ponts et Chaussees. 181 pp.

Williams, P.J. 1986. Pipelines & Permafrost: Science in a Cold Climate. Carleton University Press Inc. Carleton. Canada, 129 pp.

Williams, P.J. 1992. Gas pipelines and the challenge of the cold regions: experimental study. In: Proceedings of the International Conference on Pipeline Reliability, Calgary, v. 1, II 2-2-12.

Williams, P.J., and M.W. Smith. 1989. The Frozen Earth : Fundamental of Geocryology. Cambridge University Press, Cambridge, England. 306 pp.

Wolfe, S.A. 1998. Living with frozen ground – A field guide to permafrost in Yellowknife. Geological Survey of Canada, Miscellaneous Report no. 64. 71 pp.

Wright, J.F., C. Duchesne and M.M. Côté. 2003. Digital compilation of vegetation types of the Mackenzie Valley Transportation Corridor. Geological Survey of Canada, Open File 1614, 1 CD-ROM.

Wright, J.F., M.W. Smith and A.E. Taylor. 2000. Potential changes in permafrost distribution in the Fort Simpson and Norman Wells regions. In: The Physical Environment of the Mackenzie Valley, Northwest Territories: A Baseline for the Assessment of Environmental Change, L.D. Dyke and G.R. Brooks (eds.). Geological Survey of Canada Bulletin 547, p. 197-207.

Yarrow Holdings Limited. 1985. Assessment of Compliance with R&D Recommendations of Selected EARP Panels.

Young, S. and A.S. Judge. 1985. A Ground Temperature Data Collection for Northern Canada. McGill University Workshop on Climate and Thermal Regimes in Northern Canada. Unpublished Report.

Young, S. and A.S. Judge. 1986. Canadian permafrost distribution and thickness data collection: a discussion. In: Proceedings of National Student Conference on Northern Studies. W.P Adams and P.G. Johnson (eds.), p. 223-228.

Yunker, M.B. and R.W. Macdonald. 1995. Composition and origins of polycyclic aromatic hydrocarbons in the Mackenzie River and on the Beaufort Sea shelf. Arctic, 48: 118-129

Yunker, M.B., R.W. Macdonald, W.J. Cretney, B.R. Fowler, F.A. McLaughlin. 1993. Alkane, terpene, and polycyclic aromatic hydrocarbon geochemistry of the Mackenzie River and Mackenzie shelf: riverine contributions to Beaufort Sea coastal sediment. Geochimica et Cosmochimica Acta NOGAP project no. B.06 :Beaufort Sea oceanography; v. 57 p.3041-3061, ill., 1 map.

Yunker, M.B., R.W. MacDonald, B.R. Fowler, W.J. Cretney, S.R. Dallimore and F.A. McLaughlin. 1991. Geochemistry and fluxes of hydrocarbons to the Beaufort Sea shelf: A multivariate comparison of fluvial inputs and coastal erosion of peat using principal components analysis. Geochim Cosmochim. Acta., 55: 255-273.

Yunker, M.G., R.W. MacDonald, D.J. Veltkamp and W.J. Cretney. 1995. Terrestrial and marine biomarkers in a seasonally ice-covered Arctic estuary – Integration of multivariate and biomarker approaches. Mar. Chem., 49: 1-50.

Yunker, M.B., R.W. MacDonald, and B.G. Whitehouse. 1994. Phase associations and lipid distributions in the seasonally ice-covered Arctic estuary of the Mackenzie Shelf. In: Advances in Organic Geochemistry 1993. Org Geochem, 17: 651-699.

Yunker, M.B., L.R. Snowdon, R.W. MacDonald, J.N. Smith, M.G. Fowler, D.N. Skibo, F.A. McLaughlin, A.I. Danyushevskaya, V.I. Petrova, and G.I. Ivanov. 1996. Polycyclic aromatic hydrocarbon composition and potential sources for sediment samples from the Beaufort and Barents Seas. Environ. Sci. Technol., 30: 1310-1320.

Appendices

Appendix A

Traditional Knowledge: Types of Knowledge

Appendix A
Traditional Knowledge: Types of Knowledge

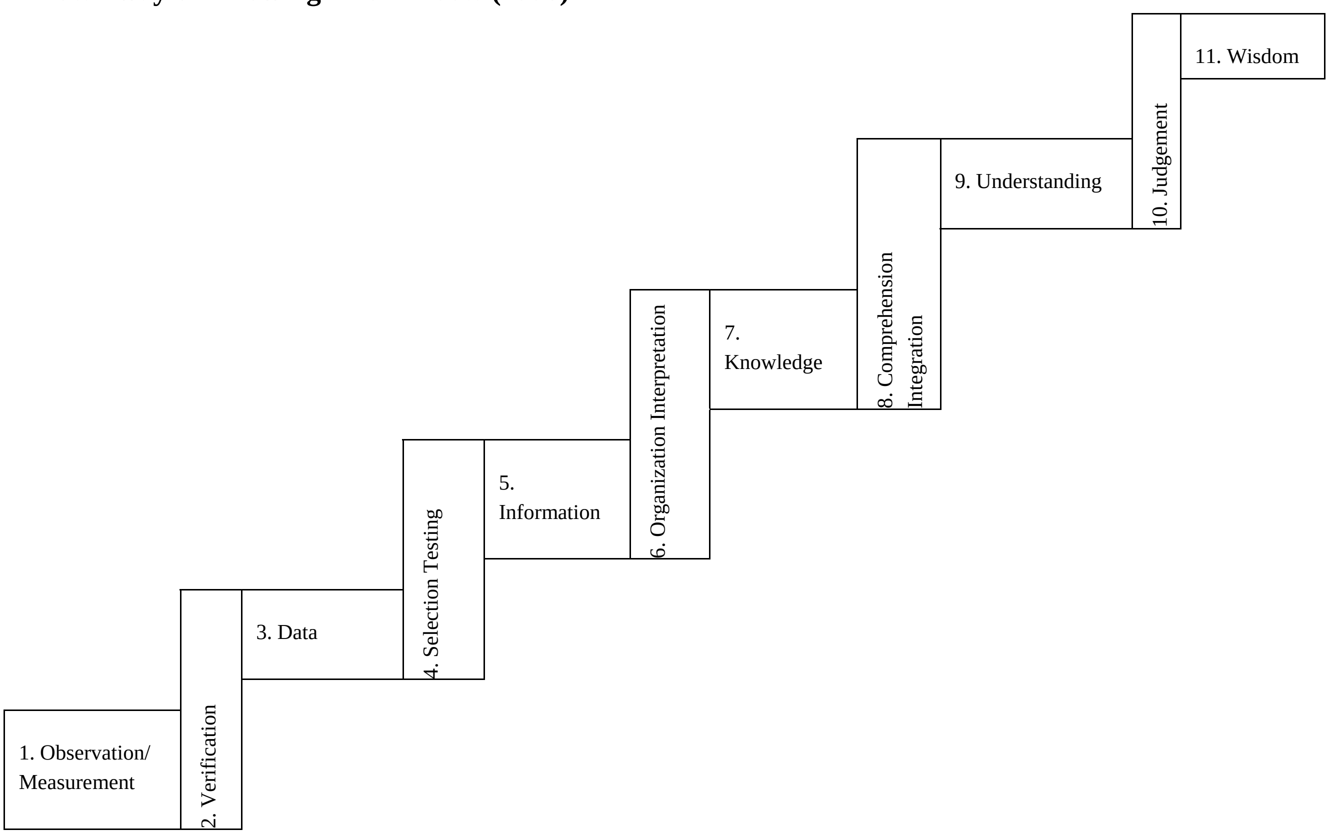
The use of traditional knowledge (TK) in environmental assessment and regulatory processes has frequently been limited to noting presence or absence of species, archaeological sites, etc. rather than considering TK as a crucial piece of the puzzle. The reason for this has to do with the ease with which TK can be accessed, understanding the information TK can impart, and the time available for collecting TK.

Traditional knowledge is not, however, limited to "data lists". Instead, like scientific knowledge, TK is made up of the following types of information:

- Data and Information: baseline information
- Interpretative Knowledge: effects analysis
- Ecosystem Management: planning and management
- (Worldview) Values-based Decision-Making: regional planning

The following figure exemplifies the ways of knowing.

"Stairway of Knowing" from Roots (1998)



Appendix B

Tables of Exploration and Development Potentials

Appendix B
Tables of Exploration and Development Potentials

Exploration and Development Potential Tables

These exploration and development potential tables were prepared based on knowledge of existing and potential hydrocarbon reserves in the development areas of the Mackenzie Valley, and on exploration and development scenarios of typical activities to assist in the identification and analysis of information gaps. To assist in achieving the goals and objectives of this project, a "What if" planning approach was followed to help ascertain the important research and biophysical information gaps. These estimates will assist us in prioritizing the research needs over the next five years to conduct research and to gather knowledge to fill the identified gaps.

Seismic Exploration

Summary of Predicted Seismic Exploration Programs in the Mackenzie Valley (from Oil and Gas Development Scenarios found in Section 3 of this report)

Oil & Gas Development Area	Number of Seismic Exploration Programs (2-D & 3-D) per annum	Total Number of Potential Seismic Exploration Programs for next 5 to 15 years
Cameron Hills *	5	25 to 75
Liard Plateau *	5	25 to 75
Norman Wells	3	15 to 45
Colville Hills	3	15 to 45
Peel Plateau	1	5 to 15

** Interim land withdrawal while the Deh Cho Process is underway would reduce the number of seismic exploration programs in these oil and gas development areas.*

Cameron Hills Oil and Gas Development Area

Summary of Exploration Potential With and Without Interim Land Withdrawal for a 5 to 15 year Timeframe, Cameron Hills

Activity*	No Restrictions
Seismic Exploration (2-D and 3-D)	5 programs per annum
Exploration Wells	4 wells per annum
Total number of seismic programs	25 to 75 seismic programs
Total number of exploration wells	20 to 60 exploration wells

** These activities would not occur on withdrawn lands, but on those lands not included in the withdrawal areas.*

Summary of Oil and Gas Development Potential for 5 to 15 year Timeframe, Cameron Hills

Source	Number of Wells
Existing reserves	17
Potential reserves	3 to 6
Total	20 to 23

Liard Plateau Oil and Gas Development Area

Summary of Exploration Potential With and Without Interim Land Withdrawal for 5 to 15 year Timeframe, Liard Plateau

Activity*	No Restrictions
Seismic Exploration (2-D and 3-D)	5 programs per annum
Exploration Wells	4 wells per annum
Total number of seismic programs	25 to 75 seismic programs
Total number of exploration wells	20 to 60 exploration wells

** These activities would not occur on withdrawn lands, but on those lands not included in the withdrawal areas.*

Summary of Oil and Gas Development Potential for a 5 to 15 year Timeframe, Liard Plateau

Source	Number of Wells
Existing reserves	2
Potential reserves	3 to 6
Total	5 to 8

Norman Wells Oil and Gas Development Area

Summary of Exploration Potential for a 5 to 15 year timeframe, Norman Wells

Activity	Program
Seismic Exploration (2-D and 3-D)	3 programs per annum.
Exploration Wells	2 wells per annum to 2010
Total Number of Seismic Programs	15 to 45
Total Number of Exploration Wells	16

Summary of Development Potential for a 5 to 15 year Timeframe, Norman Wells

Source	Number of wells
Existing reserves	4
Potential reserves	2
Total	6

Colville Hills Oil and Gas Development Area

Summary of Exploration Potential for a 5 to 15 year Timeframe, Colville Hills

Activity	Program
Seismic Exploration (2-D and 3-D)	3 programs per annum
Exploration Wells	2 wells per annum to 2010
Total Number of Seismic Programs	15 to 45
Total Number of Exploration Wells	16

Summary of Development Potential for 5 to 15 year Timeframe, Colville Hills

Source	Number of wells
Existing reserves	3
Potential reserves	7
Total	10

Peel Plateau Oil and Gas Development Area

Summary of Exploration Potential Peel Plateau

Activity	Program
Seismic Exploration (2-D and 3-D)	1 program per annum
Exploration Wells	1 well per annum
Total Number of Seismic Programs	5 to 15
Total Number of Exploration Wells	5 to 15

Appendix C

Environmental Impact Matrices

MACKENZIE VALLEY OIL AND GAS DEVELOPMENT AREAS

ACTIVITIES IN VARIOUS STAGES OF OIL AND GAS DEVELOPMENT IN THE MACKENZIE VALLEY

PHYSICAL-CHEMICAL EFFECTS

		WATER									NOISE			SURFICIAL GEOLOGY					LAND						GEOTECHNICAL						ATMOSPHERE					
STAGE	ACTIVITY	SURFACE WATER FLOW	WATER TABLE ALTERATION	INTERACTION WITH SURFACE DRAINAGE	SURFACE AND GROUNDWATER QUALITY	SURFACE AND GROUNDWATER QUANTITY	SHORELINE AND BOTTOM ALTERATIONS	WETLANDS	DRAINAGE/FLOOD CHARACTERISTICS	ICE	INTENSITY	DURATION	REPETITION	LANDFORM PHYSICAL CHARACTERISTICS	LANDFORM DELINEATION	PERMAFROST DISTRIBUTION	DRAINAGE CONDITIONS	TERRAIN HAZARDS	SOIL EROSION	SOIL STABILITY	SOIL COMPACTION AND SETTLING	FIRE SUSCEPTIBILITY	FLOOD PLAIN USAGE	BUFFER ZONES	SLOPE STABILITY (SLIDES & SLUMPS)	STRESS AND STRAIN (EARTHQUAKES)	FROST SUSCEPTIBILITY	IMPACTED SOIL	ALTERATION OF PERMAFROST REGIME	ACTIVE ZONE DISTURBANCE	AIR CHARACTERISTICS (QUALITY)	PARTICULATES	GREENHOUSE GAS EMISSIONS	WIND	INVERSION	ICE FOG
SEISMIC/DRILLING	ACCESS ROADS	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT	X		X	X	X					X		X																		X		X	X		X
	BLASTING				X						X		X						X	X	X							X				X				
	BURNING				X			X											X	X					X				X	X	X	X			X	X
	CAMPS/ACCOMMODATION	X	X	X	X	X		X						X	X	X	X	X			X								X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X	X						
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X					X	X	X	X		X	X					X				X	X						
	DRILLING		X	X	X	X					X	X	X	X	X	X	X												X	X						
	ENVIRONMENTAL SURVEY/MONITORING													X	X				X		X								X							
	EQUIPMENT/VEHICLES				X														X		X							X	X	X	X	X	X	X	X	X
	EXCAVATION	X			X	X	X	X						X	X	X	X		X	X					X				X	X						
	FLARING										X	X	X																		X	X	X	X		X
	HYDROLOGICAL TESTING	X	X	X	X	X																														
	POWER																												X	X	X		X		X	X
	PRODUCT				X														X									X	X	X						
	RELOCATION				X														X										X							
	SEISMIC SURVEY			X	X			X			X		X	X	X	X	X	X	X										X	X						
	SITE/ROUTE CLEARING	X		X	X			X						X	X	X	X	X	X	X	X				X				X	X						
	SITE SURVEY																																			
	SOIL TESTING													X	X	X	X		X																	
	SPILLS AND LEAKS				X									X	X	X	X		X								X	X	X	X	X		X	X	X	
	STREAM CROSSING	X		X	X		X	X	X					X	X	X	X		X	X									X						X	
	WASTE				X														X	X								X	X	X	X	X			X	
	WATER	X	X	X	X	X		X																			X		X							
	WELL TESTING				X																															
	WILDLIFE/PEST MANAGEMENT				X																															
CONSTRUCTION	ACCESS ROADS	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT	X		X	X	X					X		X																		X		X	X	X	X
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X		X	X			X		X				X	X	X	X	X	X	X					X			X	X	X						
	BARGING				X		X			X									X																	
	BLASTING			X	X						X		X						X	X	X							X				X				
	BORROW RESOURCES		X	X	X		X							X	X	X	X		X	X									X	X						
	BURNING				X														X	X					X				X	X	X	X			X	X
	CAMPS/ACCOMMODATION	X		X	X	X								X	X	X	X	X			X								X	X						
	CONSTRUCTION	X		X	X	X	X	X		X				X	X	X	X	X	X	X	X				X			X	X	X		X				
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X	X						
	DEMOBILIZATION/DECONSTRUCTION				X									X	X	X	X	X																		
	DRAINAGE/EROSION CONTROL	X		X	X									X	X	X	X		X	X					X				X	X						
	DREDGING				X		X	X						X	X				X	X																
	DRILLING		X	X	X						X	X		X	X	X	X												X	X						
	DUST CONTROL				X									X	X	X	X										X					X		X		
	ENVIRONMENTAL SURVEY/MONITORING													X	X				X		X								X		X	X		X	X	
	EQUIPMENT/VEHICLES				X						X			X	X	X			X		X							X	X	X	X		X	X	X	
	EXCAVATION	X	X	X	X			X		X				X	X	X	X		X	X					X				X	X						
	FERTILIZATION				X																							X								
	MAINTENANCE				X									X	X	X	X		X								X	X								
	PIPELINE CONSTRUCTION AND TESTING	X	X	X	X	X		X				X	X	X	X	X	X		X	X	X							X	X	X						
	POWER	X	X	X	X	X	X	X	X	X				X	X														X	X	X		X		X	
	PRODUCT				X														X									X	X	X						
	RECLAMATION	X			X		X	X						X	X	X	X	X	X	X	X							X	X	X						
	REFORESTATION/RE-VEGETATION				X																								X	X						
	SHORELINE STRUCTURES	X		X			X							X	X	X	X		X	X																
	SITE/ROUTE CLEARING	X	X	X	X			X		X				X	X	X	X		X	X	X				X				X	X						
	SITE SURVEY													X	X	X																				
	SOIL TESTING													X	X	X	X		X																	
	SPILLS AND LEAKS				X									X	X	X			X								X	X	X	X	X		X		X	
	SPOIL AND OVERBURDEN REMOVAL	X		X	X		X	X						X	X																					
	STREAM CROSSING	X		X	X		X		X	X									X	X									X							
	WASTE				X														X	X								X	X	X	X	X		X	X	X
	WATER	X	X		X	X	X																				X		X							
	WILDLIFE/PEST MANAGEMENT				X																															
OPERATIONS & MAINTENANCE	ACCESS ROADS													X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT										X		X																		X		X	X		X
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE				X			X						X	X	X	X		X	X					X			X	X	X						
	BARGING				X		X			X									X																	
	BORROW RESOURCES													X	X	X			X	X					X				X	X						
	BURNING				X			X													X								X	X	X	X			X	
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X						X	X	X	X		X	X	X				X			X	X	X						
	CONSTRUCTION	X			X					X		X		X	X	X	X	X	X						X		X	X	X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X																															
	DEMOBILIZATION/DECONSTRUCTION				X									X	X	X	X	X	X	X					X				X	X						
	DRAINAGE/EROSION CONTROL	X		X	X			X											X	X																
	DREDGING				X		X			X																			X	X						
	DRILLING		X	X	X						X	X	X	X	X	X	X										X									
	DUST CONTROL				X														X		X								X			X				
	ENVIRONMENTAL SURVEY/MONITORING													X	X				X		X							X	X	X	X	X		X	X	
	EQUIPMENT/VEHICLES				X														X	X					X				X	X	X		X	X	X	
	FERTILIZATION				X																							X								
	FLARING																														X	X			X	X
	MAINTENANCE				X														X								X	X								
	OFFSHORE/NEAR SHORE STRUCTURES				X		X			X									X	X	X				X			X	X	X						
	PIPELINES	X		X	X		X	X		X			X	X	X	X	X	X	X	X	X							X	X	X						
	POWER	X	X	X	X	X	X	X	X	X																			X	X	X				X	X
	PRODUCT																		X									X	X	X						
	RECLAMATION				X									X	X	X	X	X	X	X	X							X	X	X						
	REFORESTATION/RE-VEGETATION				X																								X	X						
	RELOCATION				X														X										X							
	SPILLS AND LEAKS				X									X	X				X								X	X	X	X	X		X		X	
	WASTE				X														X	X								X	X	X	X	X			X	
	WATER	X	X	X	X	X	X	X																			X		X							
	WILDLIFE/PEST MANAGEMENT				X																															
ABANDONMENT AND RESTORATION	ACCESS ROADS	X		X	X		X			X				X	X	X	X		X	X	X				X				X	X						
	AIRCRAFT				X						X		X																		X		X	X	X	
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE																		X	X					X			X	X	X						
	BARGING	X		X	X		X			X									X																	
	BURNING				X															X								X	X	X	X			X	
	CAMPS/ACCOMMODATION	X		X	X		X	X		X				X	X	X	X		X	X	X				X			X	X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X																															
	DEMOBILIZATION/DECONTRUCTION				X									X	X				X	X					X				X	X						
	DRAINAGE/EROSION CONTROL	X		X	X					X				X	X	X	X		X	X																
	DUST CONTROL				X									X	X				X		X								X			X		X		
	ENVIRONMENTAL SURVEY/MONITORING													X	X				X		X							X	X	X						
	EQUIPMENT/VEHICLES				X						X	X							X	X					X				X	X	X		X			
	FERTILIZATION				X																							X								
	OFFSHORE/NEAR SHORE STRUCTURES			X	X		X			X									X	X	X				X			X	X	X						
	PIPELINES	X		X	X		X	X		X				X	X	X	X	X	X	X	X							X	X	X						
	POWER	X	X	X	X	X	X	X	X	X																			X	X	X		X			
	RECLAMATION	X		X	X									X	X	X	X	X	X	X	X															
	REFORESTATION/RE-VEGETATION				X																								X	X						
	RELOCATION				X														X										X							
	SPILLS				X														X								X	X	X	X	X		X		X	
	STREAM CROSSING	X		X	X		X		X	X									X	X									X							
	WASTE				X														X	X								X	X	X	X	X				
	WATER	X	X		X	X																					X		X							
	WILDLIFE/PEST MANAGEMENT				X																															

ECOLOGICAL EFFECTS

		POPULATIONS (SPECIES)								COMMUNITIES						LIFECYCLE													BIODIVERSITY	
		TERRESTRIAL				AQUATIC				TERRESTRIAL			AQUATIC			TERRESTRIAL							AQUATIC						TERRESTRIAL	AQUATIC
STAGE	ACTIVITY	VEGETATION/FOREST COVER	FAUNA (OTHER THAN WILDLIFE)	WILDLIFE	RARE & ENDANGERED SPECIES	FLORA	FAUNA (OTHER THAN FISH)	FISH	RARE & ENDANGERED SPECIES	COMMUNITY STRUCTURE	ECOLOGICAL RELATIONSHIP	HABITAT FRAGMENTATION	COMMUNITY STRUCTURE	ECOLOGICAL RELATIONSHIP	HABITAT FRAGMENTATION	MIGRATION ROUTES	JUVENILE DISPERSAL	CRITICAL HABITATS (WINTER, ESCAPE, ETC.)	FORAGE	BEARING YOUNG	GESTATION/INCUBATION	BREEDING	MIGRATION ROUTES	SPAWNING	REARING	NURSERY	FEEDING	OVER WINTERING	RICHNESS/ABUNDANCE	RICHNESS/ABUNDANCE
SEISMIC/DRILLING	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	AIRCRAFT			X	X						X	X				X	X	X	X	X	X	X								X	
	BLASTING	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X		X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X	X
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X				X	X	X								X	X	X	X	X	X	X	X
	DRILLING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X	X	X	X	X	X	X	X
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EXCAVATION	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	FLARING	X	X	X	X											X	X	X	X	X	X	X								X	X
	HYDROLOGICAL TESTING					X	X	X	X				X	X	X								X	X	X	X	X	X		X
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PRODUCT	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	X
	RELOCATION	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
	SEISMIC SURVEY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SITE/ROUTE CLEARING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SITE SURVEY					X	X	X	X				X	X	X								X	X	X	X	X	X		
	SOIL TESTING																													
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	STREAM CROSSING	X	X	X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X	X
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WELL TESTING																													
	WILDLIFE/PEST MANAGEMENT	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X			X	X	X	X	X	X	X	X
CONSTRUCTION	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	AIRCRAFT			X	X					X	X	X				X	X	X	X	X	X	X								X	
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BARGING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BLASTING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BORROW RESOURCES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	CONSTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X	X	X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X	X
	DEMOBILIZATION/DECONSTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X				X	X	X								X	X	X	X	X	X	X	X
	DREDGING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DRILLING	X	X	X	X					X	X	X																		X	
	DUST CONTROL	X	X	X	X					X	X					X		X	X											X	X
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EXCAVATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	FERTILIZATION	X	X	X	X					X	X							X	X											X	X
	MAINTENANCE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PIPELINE CONSTRUCTION AND TESTING	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PRODUCT	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	X
	RECLAMATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	REFORESTATION/RE-VEGETATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SHORELINE STRUCTURES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SITE/ROUTE CLEARING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SITE SURVEY					X	X	X	X				X	X	X								X	X	X	X	X	X		
	SOIL TESTING																													
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPOIL AND OVERBURDEN REMOVAL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	STREAM CROSSING	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X				X	X	X	X	X	X	X	X
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X	X	X	X	X										X	
OPERATIONS & MAINTENANCE	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	AIRCRAFT			X	X					X	X	X				X		X	X	X	X	X								X	
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BARGING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BORROW RESOURCES																													
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	CONSTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X				X	X	X	X	X	X	X	X
	DEMOBILIZATION/DECONSTRUCTION	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X	X	X		X	X	X								X	X	X	X	X	X	X	X
	DREDGING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DRILLING	X	X	X	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X	X	X	X	
	DUST CONTROL	X	X	X	X					X	X					X	X	X	X	X	X	X								X	X
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	FERTILIZATION	X	X	X	X					X	X							X	X											X	X
	FLARING	X	X	X	X					X	X							X	X											X	X
	MAINTENANCE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	OFFSHORE/NEAR SHORE STRUCTURES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PIPELINES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PRODUCT	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	X
	RECLAMATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	REFORESTATION/RE-VEGETATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	RELOCATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X	X	X	X	X										X	
ABANDONMENT AND RESTORATION	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	AIRCRAFT			X	X					X	X	X				X		X	X	X	X	X								X	
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BARGING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X								X	
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X	X				X	X	X	X	X	X	X	X
	DEMOBILIZATION/DECONTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X	X	X	X	X
	DUST CONTROL	X	X	X	X					X	X					X	X	X	X	X										X	X
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	FERTILIZATION	X	X	X	X					X	X							X	X											X	X
	OFFSHORE/NEAR SHORE STRUCTURES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	PIPELINES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	RECLAMATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	REFORESTATION/RE-VEGETATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	RELOCATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	SPILLS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	STREAM CROSSING	X	X	X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X	X
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X	X	X	X	X										X	

HERITAGE RESOURCES / TRADITIONAL KNOWLEDGE, LAND AND RESOURCES

		HERITAGE RESOURCES		TRADITIONAL LAND USE AND HARVESTING															LAND USE		
				COUNTRY FOOD (QUALITY)									GATHERING				WATER				
STAGE	ACTIVITY	ARCHAEOLOGICAL SITES	CULTURAL/SPIRITUAL SITES	FISH	CARIBOU	MOOSE	DUCKS	GEESE	SMALL FURBEARERS	HUNTING	FISHING	TRAPPING	BERRIES	PLANTS	CULTURAL LAND USE	SPIRITUAL LAND USE	DRINKING	OTHER	COMPATIBILITY OF LAND USES	UNIQUE PHYSICAL FEATURES	IDENTIFICATION OF ACTIVITIES
SEISMIC/DRILLING	ACCESS ROADS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT														X	X					
	BLASTING									X	X	X	X	X	X	X					
	BURNING									X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL														X	X	X	X			
	DRAINAGE/EROSION CONTROL			X							X				X	X	X	X			
	DRILLING														X	X					
	ENVIRONMENTAL SURVEY/MONITORING									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES									X	X	X	X	X	X	X					
	EXCAVATION														X	X					
	FLARING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	HYDROLOGICAL TESTING			X							X				X	X					
	POWER									X	X	X	X	X	X	X					
	PRODUCT			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	RELOCATION									X	X	X	X	X	X	X					
	SEISMIC SURVEY									X	X	X	X	X	X	X					
	SITE/ROUTE CLEARING			X	X	X	X	X	X	X	X	X	X	X	X	X					
	SITE SURVEY									X	X	X			X	X					
	SOIL TESTING														X	X					
	SPILLS AND LEAKS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	STREAM CROSSING			X							X				X	X	X	X			
	WASTE			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER			X							X				X	X	X	X			
	WELL TESTING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WILDLIFE/PEST MANAGEMENT									X	X	X	X	X	X	X					
CONSTRUCTION	ACCESS ROADS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT														X	X					
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE									X	X	X	X	X	X	X					
	BARGING			X							X				X	X					
	BLASTING									X	X	X	X	X	X	X					
	BORROW RESOURCES														X	X					
	BURNING									X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION														X	X					
	CONSTRUCTION														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL														X	X	X	X			
	DEMOBILIZATION/DECONSTRUCTION														X	X	X	X			
	DRAINAGE/EROSION CONTROL			X							X				X	X	X	X			
	DREDGING			X							X				X	X	X	X			
	DRILLING														X	X					
	DUST CONTROL														X	X					
	ENVIRONMENTAL SURVEY/MONITORING									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES									X	X	X	X	X	X	X					
	EXCAVATION														X	X					
	FERTILIZATION												X	X	X	X					
	MAINTENANCE														X	X					
	PIPELINE CONSTRUCTION AND TESTING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	POWER									X	X	X	X	X	X	X					
	PRODUCT			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	RECLAMATION									X	X	X	X	X	X	X					
	REFORESTATION/RE-VEGETATION									X	X	X	X	X	X	X					
	SHORELINE STRUCTURES			X							X				X	X	X	X			
	SITE/ROUTE CLEARING			X	X	X	X	X	X	X	X	X	X	X	X	X					
	SITE SURVEY														X	X					
	SOIL TESTING														X	X					
	SPILLS AND LEAKS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	SPOIL AND OVERBURDEN REMOVAL			X	X	X	X	X	X						X	X					
	STREAM CROSSING			X							X				X	X	X	X			
	WASTE			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT									X	X	X	X	X	X	X					
OPERATIONS & MAINTENANCE	ACCESS ROADS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT														X	X					
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE									X	X	X	X	X	X	X					
	BARGING			X							X				X	X					
	BORROW RESOURCES														X	X					
	BURNING									X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION														X	X					
	CONSTRUCTION														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL														X	X	X	X			
	DEMOBILIZATION/DECONSTRUCTION														X	X	X	X			
	DRAINAGE/EROSION CONTROL			X							X				X	X	X	X			
	DREDGING			X							X				X	X	X	X			
	DRILLING														X	X					
	DUST CONTROL														X	X					
	ENVIRONMENTAL SURVEY/MONITORING									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES									X	X	X	X	X	X	X					
	FERTILIZATION												X	X	X	X					
	FLARING			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	MAINTENANCE														X	X					
	OFFSHORE/NEAR SHORE STRUCTURES			X							X				X	X	X	X			
	PIPELINES			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	POWER									X	X	X	X	X	X	X					
	PRODUCT			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	RECLAMATION									X	X	X	X	X	X	X					
	REFORESTATION/RE-VEGETATION									X	X	X	X	X	X	X					
	RELOCATION														X	X					
	SPILLS AND LEAKS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WASTE			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT									X	X	X	X	X	X	X					
ABANDONMENT AND RESTORATION	ACCESS ROADS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT														X	X					
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE									X	X	X	X	X	X	X					
	BARGING			X							X				X	X					
	BURNING									X	X	X	X	X	X	X					
	CAMPS/ACCOMMODATION														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL														X	X	X	X			
	DEMOBILIZATION/DECONTRUCTION														X	X	X	X			
	DRAINAGE/EROSION CONTROL			X							X				X	X	X	X			
	DUST CONTROL														X	X					
	ENVIRONMENTAL SURVEY/MONITORING									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES									X	X	X	X	X	X	X					
	FERTILIZATION												X	X	X	X					
	OFFSHORE/NEAR SHORE STRUCTURES			X							X				X	X	X	X			
	PIPELINES			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	POWER										X	X	X	X	X	X					
	RECLAMATION										X	X	X	X	X	X	X	X			
	REFORESTATION/RE-VEGETATION										X	X	X	X	X	X					
	RELOCATION														X	X					
	SPILLS			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	STREAM CROSSING			X							X				X	X	X	X			
	WASTE			X	X	X	X	X	X		X	X	X	X	X	X	X	X			
	WATER			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT									X	X	X	X	X	X	X					

GENERIC MACKENZIE GAS PIPELINE PROJECT SCENARIO

PHYSICAL-CHEMICAL EFFECTS

Stage	ACTIVITIES IN VARIOUS STAGES OF GAS PIPELINE DEVELOPMENT IN THE MACKENZIE VALLEY	SURFACE WATER FLOW	WATER TABLE ALTERATION	INTERACTION WITH SURFACE DRAINAGE	SURFACE AND GROUNDWATER QUALITY	SURFACE AND GROUNDWATER QUANTITY	SHORELINE AND BOTTOM ALTERATIONS	WETLANDS	DRAINAGE/FLOOD CHARACTERISTICS	ICE	INTENSITY	DURATION	REPETITION	LANDFORM PHYSICAL CHARACTERISTICS	LANDFORM DELINEATION	PERMAFROST DISTRIBUTION	DRAINAGE CONDITIONS	TERRAIN HAZARDS	SOIL EROSION	SOIL STABILITY	SOIL COMPACTION AND SETTLING	FIRE SUSCEPTIBILITY	FLOOD PLAIN USAGE	BUFFER ZONES	SLOPE STABILITY (SLIDES & SLUMPS)	STRESS AND STRAIN (EARTHQUAKES)	FROST SUSCEPTIBILITY	IMPACTED SOIL	ALTERATION OF PERMAFROST REGIME	ACTIVE ZONE DISTURBANCE	AIR CHARACTERISTICS (QUALITY)	PARTICULATES	GREENHOUSE GAS EMISSIONS	WIND	INVERSION	ICE FOG
		WATER									NOISE			SURFICIAL GEOLOGY					LAND						GEOTECHNICAL						ATMOSPHERE					
PROJECT DEFINITION	ACCESS ROADS	X	X	X	X		X	X		X				X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT			X	X						X		X																		X		X	X		X
	BURNING				X														X						X			X	X	X	X	X				X
	CAMPS/ACCOMMODATION				X	X								X	X	X	X	X			X								X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X							
	DRILLING		X	X	X						X	X	X	X	X	X	X												X	X						
	ENVIRONMENTAL SURVEY/MONITORING													X	X						X								X	X						
	EQUIPMENT/VEHICLES				X																X									X	X		X		X	
	EXCAVATION	X		X	X			X		X	X	X	X	X	X	X	X		X	X									X	X						
	POWER				X																										X		X		X	X
	RELOCATION																																			
	SITE/ROUTE CLEARING	X		X	X			X		X				X	X	X	X	X	X	X					X				X	X						
	SITE SURVEY	X		X	X																															
	SOIL TESTING													X	X	X	X												X							
	SPILLS AND LEAKS				X									X	X	X	X										X	X	X	X	X		X	X	X	
	STREAM CROSSING	X		X	X		X	X		X				X	X	X	X		X	X					X				X							
	WASTE				X																						X	X	X		X			X	X	X
	WATER	X	X	X	X																								X							
	WILDLIFE/PEST MANAGEMENT				X																															
CONSTRUCTION	ACCESS ROADS	X	X	X	X		X	X		X				X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT			X	X						X		X																		X		X	X		X
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X		X	X		X	X		X				X	X	X	X	X										X	X	X						
	BARGING				X		X			X																										
	BLASTING				X						X		X						X		X				X						X	X				
	BORROW RESOURCES													X	X	X	X																			
	BURNING				X														X						X				X	X	X	X		X	X	X
	CAMPS/ACCOMMODATION		X	X	X									X	X	X	X	X			X								X	X						
	CONSTRUCTION	X	X	X	X		X	X		X	X	X		X	X	X	X	X	X		X							X	X	X		X				
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X	X						
	DEMOBILIZATION/DECONSTRUCTION			X	X									X	X	X	X	X	X	X																
	DRAINAGE/EROSION CONTROL	X		X	X									X	X	X	X		X	X					X		X		X	X						
	DREDGING			X	X		X	X		X				X	X				X																	
	DRILLING		X	X	X						X	X																	X	X						
	DUST CONTROL				X									X	X	X	X										X					X		X		
	ENVIRONMENTAL SURVEY/MONITORING													X	X														X	X						
	EQUIPMENT/VEHICLES				X									X	X	X					X									X	X		X			X
	EXCAVATION	X		X	X			X			X	X		X	X	X	X		X	X									X	X		X				
	FERTILIZATION				X																						X	X	X							
	MAINTENANCE				X									X	X	X	X																			
	PIPELINE CONSTRUCTION AND TESTING	X	X	X	X									X	X	X	X		X						X		X		X		X		X			
	POWER	X	X	X	X	X	X	X	X	X				X	X																X		X		X	X
	RECLAMATION	X		X	X									X	X	X	X	X	X										X	X						
	REFORESTATION/RE-VEGETATION			X	X														X	X					X				X	X						
	SITE/ROUTE CLEARING	X		X	X		X	X						X	X	X	X		X	X					X				X	X						
	SITE SURVEY													X	X	X																				
	SOIL TESTING													X	X	X	X												X							
	SPILLS AND LEAKS				X									X	X	X											X	X	X	X	X		X	X	X	
	SPOIL AND OVERBURDEN REMOVAL	X		X	X		X	X						X	X				X	X				X					X	X						
	STREAM CROSSING	X		X	X		X	X		X									X	X				X					X							
	TRENCHING			X	X		X	X											X	X	X								X	X						
	WASTE				X																						X	X	X		X	X		X	X	
	WATER		X		X																								X							
	WILDLIFE/PEST MANAGEMENT				X																															
OPERATIONS & MAINTENANCE	ACCESS ROADS	X		X	X			X						X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT			X	X						X		X																		X		X	X		X
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X		X	X			X						X	X	X	X	X										X	X	X						
	BORROW RESOURCES													X	X	X																				
	BURNING				X														X						X				X	X	X	X			X	
	CAMPS/ACCOMMODATION	X		X	X									X	X	X	X				X								X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X	X						
	DRAINAGE/EROSION CONTROL	X		X	X			X											X	X					X		X		X	X						
	DUST CONTROL				X																						X					X				
	ENVIRONMENTAL SURVEY/MONITORING													X	X														X	X	X	X		X	X	
	EQUIPMENT/VEHICLES				X							X	X								X									X	X		X			
	MAINTENANCE				X						X	X																								
	POWER	X	X	X	X	X	X	X	X	X																					X		X			X
	PRODUCT																										X	X	X	X						
	SPILLS AND LEAKS				X									X	X												X	X	X	X			X			
	WASTE				X																						X	X	X		X	X				
	WATER		X		X																								X							
	WILDLIFE/PEST MANAGEMENT				X																															
ABANDONMENT AND RESTORATION	ACCESS ROADS	X		X	X		X	X		X				X	X	X	X	X	X	X	X				X				X	X						
	AIRCRAFT			X	X						X		X																		X		X			
	BURNING				X														X						X				X	X	X	X				
	CAMPS/ACCOMMODATION	X		X	X									X	X	X	X				X								X	X						
	DE-ICING/SNOW REMOVAL AND DISPOSAL				X														X						X		X	X	X	X						
	DEMOBILIZATION/DECONTRUCTION			X	X									X	X				X	X																
	DRAINAGE/EROSION CONTROL	X		X	X									X	X	X	X		X	X					X		X		X	X						
	DUST CONTROL				X									X	X												X				X	X				
	ENVIRONMENTAL SURVEY/MONITORING													X	X														X	X		X				
	EQUIPMENT/VEHICLES				X																X									X	X		X			
	FERTILIZATION				X																						X	X	X							
	POWER	X	X	X	X	X	X	X	X	X																					X		X			
	RECLAMATION	X	X	X	X		X	X						X	X	X	X	X	X																	
	REFORESTATION/RE-VEGETATION			X	X														X	X					X				X	X						
	RELOCATION				X																															
	SPILLS AND LEAKS				X																						X	X	X	X			X			
	STREAM CROSSING	X		X	X		X	X											X	X				X					X							
	WASTE				X																						X	X	X		X					
	WATER	X	X		X																								X							
	WILDLIFE/PEST MANAGEMENT				X																															

ECOLOGICAL EFFECTS / HERITAGE RESOURCES / TRADITIONAL KNOWLEDGE, LAND AND RESOURCES

Stage	ACTIVITIES	VEGETATION/FOREST COVER	FAUNA (OTHER THAN WILDLIFE)	WILDLIFE	RARE & ENDANGERED SPECIES	FLORA	FAUNA (OTHER THAN FISH)	FISH	RARE & ENDANGERED SPECIES	COMMUNITY STRUCTURE	ECOLOGICAL RELATIONSHIP	HABITAT FRAGMENTATION	COMMUNITY STRUCTURE	ECOLOGICAL RELATIONSHIP	HABITAT FRAGMENTATION	MIGRATION ROUTES	JUVENILE DISPERSAL	CRITICAL HABITATS (WINTER, ESCAPE, etc.)	FORAGE	REARING YOUNG	GESTATION/INCUBATION	BREEDING	MIGRATION ROUTES	SPAWNING	REARING	NURSERY	FEEDING	OVER WINTERING	RICHNESS/ABUNDANCE	RICHNESS/ABUNDANCE	ARCHAEOLOGICAL SITES	CULTURAL/SPIRITUAL SITES	FISH	CARIBOU	MOOSE	DUCKS	GEESE	SMALL FURBEARERS	HUNTING	FISHING	TRAPPING	BERRIES	PLANTS	CULTURAL LAND USE	SPIRITUAL LAND USE	DRINKING	OTHER	COMPATIBILITY OF LAND USES	UNIQUE PHYSICAL FEATURES	IDENTIFICATION OF ACTIVITIES
		ECOLOGICAL EFFECTS																													HERITAGE RESOURCES		TRADITIONAL KNOWLEDGE, LAND AND RESOURCES																		
		POPULATIONS (SPECIES)								COMMUNITIES						LIFECYCLE													BIODIVERSITY				TRADITIONAL LAND USE AND HARVESTING																		
		TERRESTRIAL				AQUATIC				TERRESTRIAL			AQUATIC			TERRESTRIAL							AQUATIC						TERRESTRIAL	AQUATIC			COUNTRY FOOD (QUALITY)									GATHERING				WATER		LAND USE		
PROJECT DEFINITION	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT			X	X					X	X	X				X	X	X	X	X	X	X							X															X	X					
	BURNING	X	X	X	X											X	X	X	X	X	X	X							X										X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X	X	X	X	X	X																X	X	X	X			
	DRILLING	X	X	X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X																X	X					
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X										X	X	X	X	X	X	X					
	EXCAVATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	RELOCATION	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	SITE/ROUTE CLEARING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X					
	SITE SURVEY					X	X	X	X				X	X	X								X	X	X	X	X	X											X	X	X			X	X					
	SOIL TESTING																																										X	X					
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	STREAM CROSSING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X																		X										X	X	X	X	X	X	X					
CONSTRUCTION	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X															X	X					
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X										X	X	X	X	X	X	X					
	BARGING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X					
	BLASTING	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	BORROW RESOURCES																																										X	X					
	BURNING		X	X	X											X	X	X	X	X	X	X							X										X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	CONSTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X		X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X																X	X	X	X			
	DEMOBILIZATION/DECONSTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X	X	X			
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X				X	X	X								X	X	X	X	X	X		X			X							X				X	X	X	X			
	DREDGING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	DRILLING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X		X		X	X	X	X	X	X																X	X					
	DUST CONTROL	X	X	X	X											X	X	X	X	X	X	X							X	X														X	X					
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	EXCAVATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X				X	X	X	X	X	X	X	X														X	X					
	FERTILIZATION	X	X	X	X					X	X					X	X	X	X	X	X	X							X	X												X	X	X	X					
	MAINTENANCE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	PIPELINE CONSTRUCTION AND TESTING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	RECLAMATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	REFORESTATION/RE-VEGETATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	SITE/ROUTE CLEARING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X					
	SITE SURVEY	X	X	X	X	X	X	X	X				X	X	X								X	X	X	X	X	X																X	X					
	SOIL TESTING	X	X	X	X																																						X	X					
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	SPOIL AND OVERBURDEN REMOVAL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X						X	X					
	STREAM CROSSING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	TRENCHING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	X					
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X		X	X										X										X	X	X	X	X	X	X					
OPERATIONS & MAINTENANCE	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X															X	X					
	ANCILLARY TRANSMISSION LINES, PIPELINES & ASSOCIATED INFRASTRUCTURE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	BORROW RESOURCES																																										X	X					
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X	X									X	X	X	X	X	X	X	X	X			
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X		X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X															X	X	X	X			
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X				X	X	X								X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	DUST CONTROL	X	X	X	X													X	X										X	X														X	X					
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	MAINTENANCE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	PRODUCT	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X	X			X	X	X	X	X	X	X	X	X	X	X	X	X					
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X	X	X	X										X										X	X	X			X	X					
ABANDONMENT AND RESTORATION	ACCESS ROADS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	AIRCRAFT	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X															X	X					
	BURNING	X	X	X	X					X	X	X				X	X	X	X	X	X	X							X										X	X	X	X	X	X	X					
	CAMPS/ACCOMMODATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	DE-ICING/SNOW REMOVAL AND DISPOSAL	X	X	X	X	X	X	X	X				X	X	X	X		X	X				X	X	X	X	X	X	X															X	X	X	X			
	DEMOBILIZATION/DECONTRUCTION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X	X	X			
	DRAINAGE/EROSION CONTROL	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	DUST CONTROL	X	X	X	X													X	X										X	X														X	X					
	ENVIRONMENTAL SURVEY/MONITORING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	EQUIPMENT/VEHICLES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	FERTILIZATION	X	X	X	X					X	X	X						X	X										X	X												X	X	X	X					
	POWER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	RECLAMATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X	X	X			
	REFORESTATION/RE-VEGETATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X									X	X	X	X	X	X	X					
	RELOCATION	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X														X	X					
	SPILLS AND LEAKS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	STREAM CROSSING	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WASTE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
	WATER	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X							X				X	X	X	X			
	WILDLIFE/PEST MANAGEMENT	X	X	X	X					X	X					X	X	X	X	X	X	X							X										X	X	X	X	X	X	X					

Appendix D

Project Advisory Team

Appendix D
Project Advisory Team

Members of the Project Advisory Team

Ray Case
Manager Technical Support
Wildlife and Fisheries Division
Resources, Wildlife and Economic Development,
Government of the Northwest Territories
600, 5102-50th Ave.
Yellowknife, NT X1A 3S8
Phone: 867-920-8064 or 873-7411
Fax: 867-873-0293
ray_case@gov.nt.ca

Ruth McKechnie
Senior Advisor
Northern Pipeline Group
Indian Affairs and Northern Development
10 Wellington Street, Room 907
Hull, QC K1A 0H4
Phone: 819-953-0031
Fax: 819-953-2590
mckechnier@inac.gc.ca

Heidi Heder
Pipeline Readiness Office,
Indian Affairs and Northern Development
4914 50th St. 9th floor
Bellanca Bldg
P.O. Box 1500
Yellowknife, NT X1A 2R3
Phone: 867-669-2471
Fax: 867-669-2406
hederh@inac.gc.ca

Alan Kennedy
Environmental Manager
Safety, Health and Environment
Imperial Oil Resources
Room 11089 FAP,237-4th Avenue S.W.
Calgary, AB T2P 0H6
Phone: 403-237-3485
Fax: 403-237-2102
alan.j.kennedy@esso.ca

Ian Scott
Manager, Northern Canada and Pipeline
Canadian Association of Petroleum Producers
2100,350-7th Avenue S.W.
Calgary, AB T2P 3N9
Phone: 403-267-1132
Fax:: 403-266-3214
scott@capp.ca

Chief Frank T'Seleie
Chief and Mayor
K'Asho Got'ine Charter Community
P.O. Box 80
Fort Good Hope, NT X0E 0H0
Phone: 867-598-2231
Fax: 867-598-2024
ftseleie@yahoo.ca

Gordon Yakeleya
President
Tulita Land and Financial Corporation
Tulita , NT X0E 0K0
Phone: 867-588-3734
Fax: 867-588-4025
(no email address)

Jody Snortland
Executive Director
Sahtu Renewable Resources Board
P.O. Box 134
Tulita, NT   X0E 0K0
Phone: 867-588-4040
Fax: 867-588-3324
director@srrb.nt.ca
harvestc@srrb.nt.ca

Alison de Pelham
Executive Director
Deh Cho First Nations
Box 89
Fort Simpson, NT   X0E 0N0
Phone: 867-695-2355
Fax: 867-695-2038
alisondcfn@yahoo.com

Norman Snowshoe
Resource Manager
Gwich'in Tribal Council
1-3 Council Cresent
Box 1509
Inuvik, NT   X0E 0T0
Phone: 867-777-4869
Fax: 867-777-4538
snowshoe@inuvik.net

Stephen Harbicht
Head, Assessment and Monitoring
Environment Canada
Northern Division
Suite 301, 5204 50th Avenue
Yellowknife, NT
X1A 1E2
Phone: 867-669-4733
Fax: 867-873-8185
stephen.harbicht@ec.gc.ca

Ross Tallman
Research Scientist
Fisheries and Oceans Canada
Science
501 University Crescent
Winnipeg, MB R3T 2N6
Phone: 204-983-3362
Fax: 204-984-2403
tallmanr@dfo-mpo.gc.ca

Bill Carpenter
NWT Regional Conservation Director
Arctic Program, World Wildlife Fund- Canada
Moraine Point, NWT
c/o Postal Box 1978
Yellowknife. NT X1A 2P5
Satellit Tel: (402) 997-6335
Fax: (604) 6083-128
wwfnwt@mailmarinenet.net

Tony Iacobelli
Senior Manager, Landscape
Conservation and Planning
World Wildlife Fund Canada
245 Eglinton Ave. E. Ste 410
Toronto ON M4P 3J1
Phone: (416) 489-4567 ext. 269
Fax: (416) 489-3611
tiacobelli@wwfcanada.org

Assistance to DIAND
Fred McFarland
Rural Route 2,
269 Wolford Road,
Merrickville, ON K0G 1N0
Phone: 613-269-4415
Fax: 613-269-4398
mcfar@storm.ca

Members of the Northern Oil and Gas Science Steering Committee

Environment Canada

Tim Coleman
Manager, Northern Strategies
Northern Corporate Affairs
Environment Canada
5204 - 50th Avenue, Suite 301
Yellowknife, NT X1A 1E2
Tel: (867) 669-4701
Fax: (867) 873-8185
tim.coleman@ec.gc.ca

John Reid
Senior Advisor
Northern Energy Development
Environment Canada
Place Vincent Massey
351 St. Joseph Blvd.
17th Fl., Rm. 1725
Hull, QC K1A 0H3
Tel: (819) 956-9828
Fax (819) 956-9829
johnR.reid@ec.gc.ca

Fisheries and Oceans Canada

Dr. Martin Bergmann
Director , Arctic Science Program Development
Fisheries and Oceans Canada
501 University Crescent
Winnipeg, MB R3T 2N6
Tel: (204) 983-3776
Fax: (204) 984-2403
BergmannM@DFO-MPO.GC.CA

Hugh Bain
Sr Advisor, Habitat Science
Environmental Science
Branch
Fisheries and Oceans Canada
200 Kent Street
Ottawa, ON K1A0E6
Tel: (613) 990-0283
Fax: (613) 998-3329

Lisa Noble
Senior Habitat Biologist
Fisheries and Oceans Canada
Habitat Operations Branch
200 Kent Street
Ottawa, ON K1A 0E6
Tel: (613) 998-1169
Fax: (613) 993-7493
NobleL@DFO-MPO.GC.CA

Natural Resources Canada

Dr. Ron DiLabio
Chief, Quaternary Geology Subdivision
Earth Sciences Sector
Natural Resources Canada
601 Booth Street
Ottawa, ON K1A 0E8
Tel: (613 992-1380
Fax: (613) 992-0190
dilabio@gsc.nrcan.gc.ca

Industry Canada

David Harary
Industry Analyst
Energy and Marine Branch, Industry Canada
235 Queen Street, 10 Fl. E.
Ottawa, ON K1A 0H5
Tel: (613) 954-3227
Fax: (613) 941-2463

Harary.David@ic.gc.ca

Appendix E

Gartner Lee Project Team

Appendix E
Gartner Lee Project Team

Name	Company
Anderson, Robert	Gartner Lee Limited
Barnaby, Joanne	Joanne Barnaby Consulting
Budgen, Melanie	Highwood Environmental Management
Burn, Chris	Independent
Cassie, Jim	BGC Engineering Inc.
Caton, Bob	RWDI West Inc.
Ford, Bruce	Gartner Lee Limited
Francis, Shawn	Gartner Lee Limited
Fratton, Glenda	Gartner Lee Limited
Gutsell, Jeff	Gartner Lee Limited
Hewitt, Lisa	Gartner Lee Limited
Hutchinson, Neil	Gartner Lee Limited
Isherwood, Andy	BGC Engineering Inc.
Jackson, Wayne	Gartner Lee Limited
Klassen, Bill	W.J. Klassen & Associates Ltd.
Klein, Heidi	Gartner Lee Limited
Morison, Steve	Gartner Lee Limited
Parlee, Brenda	Gartner Lee Limited
Pye, Tom	Gartner Lee Limited
Sibbetson, Stephanie	Deh Cho Environmental
Stewart, Gordon	Gartner Lee Limited
Windle, Su	Gartner Lee Limited
Zimmerling, Todd	Gartner Lee Limited

Appendix F

Summary of Biophysical Information and Research Gaps

Appendix F
Summary of Baseline and Impact Knowledge Gaps

Appendix F forms a summary of the baseline and impact gaps identified in the main body of the Background Paper Report. It also provides a cross-reference to the Action Plan report, developed as part of the biophysical gap analysis project..

Terrain and Surficial Geology

Baseline Knowledge Gaps	***Action Plan Section Ref.***
1. Need to gather TK and/or interpret TK as it may relate to terrain and surficial geology.	2.2.1
2. Surficial Geology Mapping:	
a) Need surficial geology mapping at a scale of 1:100,000 or more detailed for the development areas especially Colville Hills, Peel Plateau, Liard Plateau and Cameron Hills and along the potential pipeline route south from Great Bear River.	2.2.2, part 1
b) Need to map the surficial deposit thickness, terrain hazards and slope stability conditions in the Mackenzie Valley.	2.2.2 part 2
3. Update and verify granular resources information in terms of location, quantity and quality parameters.	2.2.3
4. Need to assess the earthquake potential in the oil and gas development areas in the Mackenzie Valley, particularly in the Liard Plateau area.	2.3.1
5. Need to document the general locations of terrain and soils that are susceptible to instability due to thaw[1].	2.3.3

Impact Knowledge Gaps	***Action Plan Section Ref.***
1. Slope Movement Mechanics:	
a) Need to assess forest fire as a landslide trigger along the potential pipeline route.	2.3.2, part 1
b) Need to assess susceptibility of slope destabilization caused by ROW thawing.	2.3.2, part 2
c) Need to assess creep of frozen ground as a cause of pipeline deformation.	2.3.2, part 3
d) Need to assess slope failures in the Liard Plateau and Peel Plateau.	2.3.2, part 4
2. Identify environmental impacts and appropriate mitigation measures related to soil compaction and rutting.	2.3.4

Permafrost

Baseline Knowledge Gaps	*Action Plan Section Ref.*
1. Need to establish ground temperature and ground ice conditions, particularly along the potential pipeline corridor between Inuvik and Norman Wells.	2.4.1

Impact Knowledge Gaps	*Action Plan Section Ref.*
1. Need to understand the effects of frost heave on the integrity of a chilled pipeline in permafrost.	2.4.2
2. Drilling Waste Fluid (Mud) Containment Sumps:	
a) Need to establish the long-term viability and best practices of using permafrost excavated pits (sumps) for containing drilling muds.	2.4.3, part 1
b) Need to research alternatives to using sumps for projects in the Mackenzie Valley.	2.4.3, part 2
c) Identify the locations and conditions of existing sumps in the Mackenzie Valley, and determine which sumps need clean-up or remediation, and how this would be done.	2.4.3, part 3

Hydrogeology

Baseline Knowledge Gaps	*Action Plan Section Ref.*
1. Need to characterize (quality/quantity) near surface groundwater flow along the potential pipeline corridor.	2.5.1

Impact Knowledge Gaps	*Action Plan Section Ref.*
1. Need to identify the effects of permafrost degradation and creation (e.g., frost bulb development) on groundwater flow regimes along the potential pipeline corridor and at stream crossings.	2.5.2

Surface Water

Baseline Knowledge Gaps	*Action Plan Section Ref.*
1. Need to determine natural background hydrocarbon levels (e.g., polyaromatic hydrocarbons – PAHs) in streams and lakes in oil development areas and along potential oil pipeline corridors.	2.6.1, part 1

---

[1] A general determination can be obtained through interpretation of surficial geology mapping and aerial photographs. Detailed information on terrain instability can only be obtained through specific sampling (boreholes) of soil and ground ice conditions

2.	Existing hydrologic models need to be adapted to Mackenzie Valley conditions.	2.6.2
3.	Additional hydrometric data for tributaries of the Mackenzie River are required.	2.6.3
4.	Expansion of the snow survey data collection program is required.	2.6.4
5.	Requirement to understand the natural processes that lead to rapid lake drainage and identify areas where there is potential for this phenomenon to occur in relation to oil and gas activities.	2.6.5
6.	Improved database (including grain size) on geomorphology settings at stream crossings is required	2.6.6
7.	Need to determine the baseline water quality and quantity regimes by improving upon the available data in oil and gas development areas.	2.6.7

	Impact Knowledge Gaps	***Action Plan Section Ref.***
1.	Need to research how stream and lake water quality is affected by natural hydrocarbon seeps.	2.6.1, part 2
2.	Need to determine how background hydrocarbon levels in streams and lakes can be distinguished from those resulting from exploration and development activities.	2.6.1, part 3
3.	Requirement to understand long term environmental impacts to surface water as a result of oil and gas development activities in existing oil and gas development areas	2.6.8

Fish and Fish Habitat

	Baseline Knowledge Gaps	***Action Plan Section Ref.***
1.	Baseline Surveys:	
	a) Need abundance and distribution information on fish and invertebrates, and the following lakes and rivers should be considered in addressing this gap:	2.7.1, part 1

Lakes[2]

- Gwich'in Settlement Area: North Caribou, Caribou, Hill, Sandy, Tregnantchiez, unnamed lake (67 51'N; 131 33'W), and Travaillant.

[2] These lakes are based on proximity to the proposed pipeline route (within 10 km of pipeline route), importance to communities, and lake size (assuming larger lakes are more likely to be of importance to communities, to contain harvested fish populations and have greater biodiversity)

- Sahtu Settlement Area: Tutsieta, Yeltea, Loon, Ontadek, Chick, and Mio.
- Deh Cho Region: Eentsaytoo, Goodall, McGill, unnamed lake (61 05'N; 120 30'W), and Trainor.

Rivers[3]:

- Gwich'in Settlement Area: Travaillant R. and Thunder R.
- Sahtu Settlement Area: Oscar Ck., Donnelly R., Hare Indian R., and Loon R.
- Deh Cho Region: Trail R. and Willow Lake R.

b) Need information on distribution of contaminants (associated with oil and gas development) in sediments and in harvested fish, especially for known spawning grounds, areas of fishing for human consumption, exploration areas and seeps[4].	2.7.1, part 2
c) Need to gather information on the ecological characteristics of inland lakes and the natural variability, vital rates and status of fish populations (pre-pipeline) in these lakes, particularly for the lakes listed above in part a).	2.7.1, part 3
d) Aquatic surveys (which should include game fish, forage fish and invertebrates) need to be conducted at stream crossings.	2.7.1, part 4

2. Ecological Knowledge Gaps:

a) Need to identify important spawning, rearing and over-wintering habitats for fish and invertebrates, particularly for the lakes and rivers listed in the above gap (Baseline Surveys, Gap 1, part a).	2.7.2, part 1
b) Need to identify the key migration (spatial/temporal) corridors and habitats for harvested fish and invertebrates, particularly for the lakes and rivers listed in the above gap (Baseline Surveys, Gap 1, part a).	2.7.2, part 2
c) Need to identify the factors that govern the abundance of economically important and rare species (following baseline data collection).	2.7.2, part 3
d) Need to identify the critical trophic linkages that may be affected by developments.	2.7.2, part 4

3. Monitoring Programs:

a) Need to identify the impacts of projects on vital rates (reproduction, growth, mortality) and abundance of populations, and in harvest rates.	2.7.3, part 1
b) Need to identify project-related changes in abundance and species composition of invertebrates.	2.7.3, part 2
c) Need to identify project related spatial and temporal trends of contaminants (associated with oil and gas development).	2.7.3, part 3

[3] The selection of these rivers is based on: proximity to pipeline route, likelihood of suitability for spawning or being used as a migratory corridor for spawning, rearing or over-wintering migrations and existing information suggests important species occur in these rivers.

[4] Background information to support this gap is found is also found in Section 4.5.2

Impact Knowledge Gaps	***Action Plan Section Ref.***
1. In existing oil and gas development areas and along existing pipeline corridors, need to identify and quantify impacts on fish and fish habitat as a result of development.	2.7.4, part 1
2. In existing oil and gas development areas and along existing pipeline corridors, need to determine what mitigation measures have been implemented and determine their effectiveness.	2.7.4, part 2
3. Need sensitivity mapping in particular for fish habitat and other important environmental attributes of the Mackenzie River and its tributaries north of Norman Wells	2.7.5

Vegetation and Forests

Baseline Knowledge Gaps	***Action Plan Section Ref.***
1. Need landcover (vegetation) mapping including identification of terrestrial and wetland vegetation types.	2.8.1
2. An ecological land classification (ELC) system needs to be developed.	2.8.2
3. Need to identify and map locations of rare and medicinal plants.	2.8.3

Impact Knowledge Gaps	***Action Plan Section Ref.***
1. Need to document TK with respect to project effects on vegetation and forests.	2.8.4
2. Need to determine long-term recovery rates of disturbed vegetation communities.	2.8.5
3. Native Seeds:	
a) Need to research the use of native plant species (seeding and natural recovery) and their success for re-vegetation of disturbed land in the Mackenzie Valley.	2.8.6, part 1
b) Need to develop methods/standards for obtaining a native seed supply, and identify facility needs for storing the seed (seed bank[5]).	2.8.6, part 2
4. Need information for the Mackenzie Valley on non-native species, including current locations of non-native species, the means by which non-native species are introduced into an area, the potential for non-native species to invade areas and where they may become a concern.	2.8.7

[5] The meaning of seed bank in this case context: usually a temperature- and humidity-controlled facility used to store seed (or other reproductive materials) for future use.

Wildlife and Wildlife Habitat

Baseline Knowledge Gaps	***Action Plan Section Ref.***
1. Need to research the baseline level of contaminants (associated with oil and gas development) in harvested wildlife species and assess the potential for release of contaminants.	2.9.3
2. Boreal Woodland Caribou - Need information on extent of occurrence, area of occupancy, population structure and demographics, and habitat use and effectiveness.	2.9.4, part 1
3. Northern Mountain Woodland Caribou - Need information on extent of occurrence, area of occupancy, population demographics and habitat use.	2.9.5
4. Bluenose West Caribou Herd - Information on movements and winter range use is needed.	2.9.6
5. Furbearers - Estimates of furbearer distribution and abundance need to be developed based on habitat type, existing access and harvest data, with focus on key harvested species (lynx, marten, wolverine, beaver and muskrat).	2.9.7
6. Dall's Sheep - Need information on population dynamics, health and abundance in the Liard Plateau.	2.9.8
7. Moose - Need population abundance, trend and resilience data for Moose, including information on productivity, predation rates, and habitat status.	2.9.10
8. Forest Birds:	
a) Information is required on population presence, density and inventory, and population-habitat association data of forest birds.	2.10.1, part 1
b) TK information on forest birds is required.	2.10.1, part 2
9. Waterfowl and Shore Birds - Need information on breeding behaviour and habitat use in the Mackenzie Valley.	2.10.2

Impact Knowledge Gaps	***Action Plan Section Ref.***
1. Need to study the potential effects of habitat fragmentation on different wildlife species.	2.9.1
2. Need to study the behavioural responses of wildlife to development activities, including inter-species behaviour changes, i.e. changes in prey vulnerability	2.9.2

3. Boreal Woodland Caribou - Need information on factors affecting caribou survival and responses to human activities.	2.9.4, part 2
4. Bison - Information is needed on how linear developments contribute to re-colonization of Bison.	2.9.9
5. Raptors - Information is needed on how specific development activities affect nesting success rates and nest site abandonment.	2.10.3
6. Moose - Need information on effects of increased access resulting from development.	2.9.10
7. Forest Birds - Information is required on effects of rights-of-way on predation rates on forest birds.	2.10.1. part 3

Biodiversity

Baseline Knowledge Gaps	***Action Plan Section Ref.***
1. Need TK that conveys information about biodiversity.	2.11.1
2. Genetically distinct species sub-populations of 'species at risk' need to be identified	2.11.2

Impact Knowledge Gaps	***Action Plan Section Ref.***
1. Methodologies for assessing impacts to biodiversity need to be improved.	2.11.3

Air

Baseline Knowledge Gaps	***Action Plan Section Ref.***
1. Air Quality Monitoring:	
a) Need to upgrade air quality monitoring stations at Inuvik, Norman Wells, and Fort Liard to measure for particulate matter (TSP, PM_{10} and $PM_{2.5}$), nitrogen oxides (NO_x), VOCs, and ground level ozone (O_3). The current acid precipitation station at Snare Rapids would provide true background concentrations (unaffected by any emission sources) but needs to be expanded such that it can measure TSP, PM_{10} and $PM_{2.5}$, NO_x, VOCs, O_3 as well as hydrogen sulphide (H_2S) and sulphur dioxide (SO_2).	2.12.1, part 1
b) Baseline air quality monitoring for TSP, PM_{10} and $PM_{2.5}$, NO_x, VOCs, O_3, H_2S, and SO_2 needs to be established at other locations where emission producing equipment, such as compressor stations, are proposed.	2.12.1, part 2
c) Using the above noted stations, need to establish baseline air quality conditions and to	2.12.1, part 3

use these data for modelling air emissions.

2.	Requirement for meteorological data sufficient to allow for point-source and multiple-source dispersion modelling studies of contaminant releases from oil and gas exploration and development sites.	2.12.2

Impact Knowledge Gaps		***Action Plan Section Ref.***
1.	Biological Indicators of Air Quality:	
a)	Need to research the sensitivity of wildlife and vegetation species to air quality changes, and determine which species would be good indicators of poor air quality.	2.12.3, part 1
b)	Need to research the appropriate ambient air quality standards for wildlife.	2.12.3, part 2

Climate Change and Climate Change Effects

Baseline Knowledge Gaps		***Action Plan Section Ref.***
1.	Need to develop an understanding of the range and type of climate change scenarios along the entire Mackenzie Valley, including hydrocarbon development areas such that the impact on the physical environment (land/vegetation, water and permafrost) can be evaluated for environmental assessment predictions	2.13.1

Impact Knowledge Gaps		***Action Plan Section Ref.***
1.	Climate Change Effects on the Physical Environment:	
a)	Along the Mackenzie Valley pipeline ROW, the impact of climate change on shallow ground temperatures (upper 5 metres of the ground) requires assessment, especially in widespread and sporadic discontinuous permafrost zones.	2.13.2, part 1
b)	The impact of climate changes on forest fire frequency along the entire length of the Mackenzie Valley and the risk to infrastructure development needs to be assessed.	2.13.2, part 2
c)	The impact of climate change on ice thickness in rivers and lakes for ice bridges and winter roads along the entire length of the Mackenzie Valley.	2.13.2, part 3
d)	The impact of climate change on snow conditions and associated winter trafficability associated with hydrocarbon developments including drilling and pipeline development.	2.13.2, part 4
e)	The impact of climate change on regional hydrology.	2.13.2, part 5
2.	Permafrost Response to Climate Change / Pipeline Integrity:	
a)	Need to document spatial and temporal variability in permafrost response to climate change.	2.13.3, part 1
b)	Need to continue development of predictive models of permafrost thermal changes, distribution changes and terrain sensitivity, with focus on improving the	2.13.3, part 2

scale/resolution, as well as moving from the pipeline corridor to the development areas.

c) Need to understand impacts to pipeline integrity as a result of changes to permafrost from climate change. — 2.13.3, part 3

3. Need to continue analyses on the effects of vegetation removal (e.g., rights-of-way) on permafrost conditions in the context of climate change. — 2.13.4

4. Require research on the potential impact of climate change scenarios on the terrestrial and aquatic ecology in the Mackenzie Valley and the linkage of these predicted changes with the environmental conditions that will be assessed for any hydrocarbon development. — 2.13.5

Land and Resource Use/Harvesting/Protected Areas

Baseline Knowledge Gaps	*Action Plan Section Ref.*
1. A specific study to document and analyze baseline biophysical data along a proposed pipeline corridor and in the hydrocarbon regions south of the ISR[6] to identify unique landscapes, unusual features, rare, threatened or endangered species and associated habitat, areas of high biodiversity or other important biological and cultural resource use areas that will contribute to identifying potential protected areas which would contribute to ecoregion representation goals.	2.14.1, part 1
2. Detailed non-renewable, ecological and cultural resource assessments i.e., specific studies for each site, will then be needed for each potential candidate protected area.	2.14.1, part 2

Cumulative Effects Analysis

Baseline Knowledge Gaps	*Action Plan Section Ref.*
1. Need to gather regional baseline information for the purposes of cumulative effects assessment	2.15.2

Impact Knowledge Gaps	*Action Plan Section Ref.*
1. Need to undertake preliminary cumulative effects analysis of each development area to establish a baseline which can be used to determine significance and impact thresholds	2.15.1

[6] This work also needs to be undertaken in the ISR as described in the NWT-PAS *Mackenzie Valley Five-Year Action Plan*. The ISR is not included in the study area identified for this biophysical gap analysis project.

Appendix G

Environment Canada Hydrometric Stations: 2003-04 Historic Network Database

Appendix G: Environment Canada Hydrometric Stations: 2003-04 Historic Network Database

ADMINISTRATIVE DISTRICT	LAND CLAIM REGION	STATION NUMBER	STATION NAME	YEAR EST.	LAST DATE	STATUS	Latitude	Longitude	CLIMATE STA
INUVIK	Gwich'in	10LA002	Arctic Red River near the mouth	1968		Active	66.7900000000	-133.0816666667	Y
NORMAN WELLS	Sahtu	10HC003	Big Smith Creek near Highway No. 1 (Mackenzie Highwa	1972	1993	Discontinued	64.5961111111	-124.8369444444	
FORT SIMPSON	Deh Cho	10ED003	Birch River at Highway No. 7	1974		Active	61.3369444444	-122.0866666667	
FORT SIMPSON	Deh Cho	10ED007	Blackstone River at Highway No. 7	1991		Active	61.0611111111	-122.8944444444	
FORT SIMPSON	Deh Cho	10HC006	Blackwater River at Outlet of Blackwater Lake	1986	1993	Discontinued	63.9016666667	-123.3227777778	
FORT SIMPSON	Deh Cho	10HC005	Blackwater River near the mouth	1983	1985	Discontinued	63.9280555556	-124.0655555556	
NORMAN WELLS	Sahtu	10KA003	Bosworth Creek at Norman Wells	1973	1979	Discontinued	65.2905555556	-126.8744444444	
NORMAN WELLS	Sahtu	10KA007	Bosworth Creek near Norman Wells	1980	1993	Discontinued	65.3283333333	-126.8700000000	
FORT SMITH	Deh Cho	07PA001	Buffalo River at Highway No. 5	1968	1990	Discontinued	60.7122222222	-114.9030555556	
INUVIK	Gwich'in	10LC009	Cabin Creek above Highway No. 8 (Dempster Highway)	1980	1996	Discontinued	68.2605555556	-133.2550000000	
INUVIK	Gwich'in	10LC004	Cambell Creek near Inuvik	1973	1974	Discontinued	68.2677777778	-133.2630555556	
NUNAVUT	Sahtu	10JA002	Camsell River at Outlet of Clut Lake	1933		Active	65.5978611111	-117.7596944444	
INUVIK	Sahtu	10KB001	Carcajou River below Imperial River	1976		Active	65.2963888889	-127.6802777778	Y
INUVIK	Gwich'in	10LC007	Caribou Creek above Highway No. 8 (Dempster Highway	1975		Active	68.0891666667	-133.4841666667	Y
FORT SIMPSON	Deh Cho	10EA002	Flat River at Cantung Camp	1959	1988	Discontinued	61.9730555556	-128.2344444444	
FORT SIMPSON	Deh Cho	10EA004	Flat River at Tungsten Airstrip	1988	1992	Discontinued	61.9525000000	-128.1977777778	
FORT SIMPSON	Deh Cho	10EA003	Flat River near the mouth	1960		Active	61.5302777778	-125.4105555556	Y
NORMAN WELLS	Sahtu	10JC002	Great Bear Lake at Fort Franklin (Deline)	1961	1967	Discontinued	65.1916666667	-123.4166666667	
NUNAVUT	Sahtu	10JE002	Great Bear Lake at Hornby Bay	1983		Active	66.6128055556	-117.6062222222	
NORMAN WELLS	Sahtu	10JA001	Great Bear Lake at Port Radium	1934	1984	Discontinued	66.0833333333	-118.0333333333	
INUVIK	Sahtu	10JC003	Great Bear River at Outlet of Great Bear Lake	1961		Active	65.1344444444	-123.5119444444	
FORT SIMPSON	Deh Cho	07OB002	Great Slave Lake at Hay River	1959		Active	60.8500000000	-115.8000000000	
NUNAVUT	Sahtu	10JD001	Haldane River near the Mouth	1974	1990	Discontinued	66.8583333333	-121.2652777778	
FORT SIMPSON	Deh Cho	10GC002	Harris River near the Mouth	1972		Discontinued	61.8780555556	-121.2905555556	Y
INUVIK	Gwich'in	10LC017	Havikpak Creek near Inuvik	1993		Active	68.3144444444	-133.5208333333	
FORT SIMPSON	Deh Cho	07OB008	Hay River near Alberta/NWT Boundary	1986		Discontinued	60.0044444444	-116.9744444444	
FORT SIMPSON	Deh Cho	07OB001	Hay River near Hay River	1921		Active	60.7450000000	-115.8600000000	
NORMAN WELLS	Sahtu	10LD002	Jackfish Creek near Fort Good Hope	1980	1986	Discontinued	66.2611111111	-128.5972222222	
FORT SIMPSON	Deh Cho	10FB005	Jean-Marie River at Highway No. 1	1972		Active	61.4458333333	-121.2411111111	
NORMAN WELLS	Sahtu	10JB001	Johnny Hoe River above Lac Ste. Therese	1969	1992	Discontinued	64.5675000000	-121.7469444444	
NORMAN WELLS	Sahtu	10KA006	Jungle Ridge Creek near the Mouth	1979	1994	Discontinued	65.0638888889	-126.0622222222	
FORT SMITH	Deh Cho	07UC002	Kakisa Lake near Kakisa Village	1973	1976	Discontinued	60.9250000000	-117.4166666667	
FORT SMITH	Deh Cho	07UC001	Kakisa River at Outlet of Kakisa Lake	1962	1990	Discontinued	60.9402777778	-117.4216666667	
INUVIK	Sahtu	10HA004	Keele River above Twitya River	1994		Active	64.1322222222	-128.2111111111	
FORT SIMPSON	Sahtu	10EB003	Lened Creek above little Nahanni River	1982	1992	Discontinued	62.3666666667	-128.6769444444	
FORT SIMPSON	Deh Cho	10ED001	Liard River at Fort Liard	1942		Active	60.2430555556	-123.4791666667	
FORT SIMPSON	Deh Cho	10ED008	Liard River at Lindberg Landing	1991		Discontinued	61.1180555556	-122.8597222222	
FORT SIMPSON	Deh Cho	10ED002	Liard River near the mouth	1972		Active	61.7472222222	-121.2236111111	
FORT SIMPSON	Deh Cho	10EB002	Mac Creek near the Mouth	1977	1992	Discontinued	62.2119444444	-128.7647222222	
INUVIK	Gwich'in	10LA003	Mackenzie River above Arctic Red River	1972	1983	Discontinued	67.3583333333	-133.5583333333	
NORMAN WELLS	Sahtu	10KD007	Mackenzie River above Sans Sault Rapids	1994		Discontinued	65.6733333333	-128.7683333333	
NORMAN WELLS	Sahtu	10KD005	Mackenzie River above the Ramparts (km 1081)	1988	1993	Discontinued	66.1497222222	-128.9852777778	
INUVIK	Gwich'in	10LC014	Mackenzie River at Arctic Red River	1985		Active	67.4583333333	-133.7447222222	

Appendix G: Environment Canada Hydrometric Stations: 2003-04 Historic Network Database

ADMINISTRATIVE DISTRICT	LAND CLAIM REGION	STATION NUMBER	STATION NAME	YEAR EST.	LAST DATE	STATUS	Latitude	Longitude	CLIMATE STA
FORT SMITH	Deh Cho	07UB001	Mackenzie River at Beaver Lake	1971	1971	Discontinued	61.2194444444	-117.3694444444	
FORT SIMPSON	Deh Cho	10GB002	Mackenzie River at Camsell Bend	1971	1972	Discontinued	62.2672222222	-123.3522222222	
INUVIK	Gwich'in	10LC015	Mackenzie River at confluence of East Channel	1988		Active	67.7944444444	-134.1297222222	
NORMAN WELLS	Sahtu	10KD008	Mackenzie River at Dummit Island	1994	1996	Discontinued	65.7250000000	-128.7766666667	
INUVIK	Sahtu	10LD001	Mackenzie River at Fort Good Hope	1963		Active	66.2522222222	-128.6397222222	
NORMAN WELLS	Sahtu	10JC001	Mackenzie River at Fort Norman	1938	1945	Discontinued	64.9083333333	-125.5916666667	
FORT SIMPSON	Deh Cho	10GC001	Mackenzie River at Fort Simpson	1938		Active	61.8686111111	-121.3569444444	
FORT SIMPSON	Deh Cho	10FB003	Mackenzie River at Head-of-the-line	1971	1971	Discontinued	61.3505555556	-120.0166666667	
NORMAN WELLS	Sahtu	10KD003	Mackenzie River at km 1070	1973	1973	Discontinued	66.0833333333	-129.0747222222	
INUVIK	Gwich'in	10LB003	Mackenzie River at km 1291	1973	1973	Discontinued	67.4500000000	-130.9000000000	
INUVIK	Gwich'in	10LB002	Mackenzie River at km 1361	1973	1973	Discontinued	67.3000000000	-132.3666666667	
INUVIK	Gwich'in	10LC005	Mackenzie River at km 1503	1973	1973	Discontinued	67.8833333333	-134.3333333333	
FORT SIMPSON	Deh Cho	10GB004	Mackenzie River at km 518	1973	1973	Discontinued	62.7791666667	-123.2083333333	
FORT SIMPSON	Deh Cho	10HB002	Mackenzie River at km 681	1973	1976	Discontinued	64.0180555556	-124.4236111111	
FORT SIMPSON	Sahtu	10HC004	Mackenzie River at km 710	1973	1973	Discontinued	64.2652777778	-124.4750000000	
NORMAN WELLS	Sahtu	10KA004	Mackenzie River at km 853	1973	1973	Discontinued	64.9855555556	-126.1794444444	
FORT SIMPSON	Deh Cho	10GB003	Mackenzie River at McGern Island	1972	1972	Discontinued	62.6569444444	-123.2250000000	
FORT SIMPSON	Deh Cho	10FB004	Mackenzie River at Mills Lake	1971	1971	Discontinued	61.4725000000	-118.0500000000	
FORT SIMPSON	Deh Cho	10GC006	Mackenzie River at Ndulee Crossing	1993		Discontinued	62.1377777778	-122.5366666667	
INUVIK	Sahtu	10KA001	Mackenzie River at Norman Wells	1943		Active	65.2738888889	-126.8441666667	
FORT SIMPSON	Sahtu	10HA001	Mackenzie River at Old Fort Point	1972	1972	Discontinued	64.6855555556	-125.0013888889	
FORT SIMPSON	Deh Cho	10FB002	Mackenzie River at Rabbitskin River	1971	1971	Discontinued	61.7777777778	-120.6930555556	
INUVIK	Sahtu	10KD001	Mackenzie River at Sans Sault Rapids	1962		Active	65.7619444444	-128.7286111111	
FORT SIMPSON	Deh Cho	10FB006	Mackenzie River at Strong Point	1991		Active	61.8180555556	-120.7902777778	
NORMAN WELLS	Sahtu	10KD002	Mackenzie River at the Ramparts	1972	1973	Discontinued	66.1833333333	-129.0416666667	
INUVIK	Gwich'in	10LC011	Mackenzie River below Point Separation	1982	1985	Discontinued	67.6611111111	-134.1361111111	
NORMAN WELLS	Sahtu	10KD006	Mackenzie River in the Ramparts (km 1086)	1988	1993	Discontinued	66.1930555556	-128.9011111111	
INUVIK	Gwich'in	10LA001	Mackenzie River near Arctic Red River	1962	1964	Discontinued	67.4500000000	-133.7500000000	
FORT SIMPSON	Deh Cho	10HC002	Mackenzie River near Blackwater River	1972	1976	Discontinued	63.9736111111	-124.2666666667	
NORMAN WELLS	Sahtu	10KA002	Mackenzie River near Fort Norman	1962	1964	Discontinued	64.9000000000	-125.6500000000	
FORT SIMPSON	Deh Cho	10FB001	Mackenzie River near Fort Providence	1958	1997	Discontinued	61.2608333333	-117.5447222222	
INUVIK	Sahtu	10LB001	Mackenzie River near Little Chicago	1962	1964	Discontinued	67.2333333333	-130.2666666667	
FORT SIMPSON	Deh Cho	10HC001	Mackenzie River near Wrigley	1963	1993	Discontinued	63.2661111111	-123.5972222222	
FORT SIMPSON	Deh Cho	10GC003	Martin River at Highway No. 1	1972		Active	61.8972222222	-121.6075000000	
FORT SIMPSON	Deh Cho	10GB005	Metahdali Creek above Willowlake River	1976	1987	Discontinued	62.6497222222	-122.9063888889	
FORT SIMPSON	Deh Cho	10ED005	Mile 14 Creek at Highway No. 7	1979	1981	Discontinued	61.4250000000	-121.6250000000	
NORMAN WELLS	Sahtu	10KC001	Mountain River below Cambrian Creek	1974		Discontinued	65.2272222222	-128.5666666667	
INUVIK	Gwich'in	10MC002	Peel River above Fort McPherson	1969		Active	67.2488888889	-134.8830555556	
INUVIK	Gwich'in	10MC022	Peel River at Frog Creek			Active	67.6152777778	-134.6730555556	
FORT SIMPSON	Deh Cho	10EC002	Prairie Creek At Cadillac Mine	1974	1990	Discontinued	61.5583333333	-124.8125000000	
FORT SIMPSON	X	10EC?	Prairie Creek at mouth			Discontinued			
FORT SIMPSON	Deh Cho	10ED006	Rabbit Creek at Highway No. 7	1985	1990	Discontinued	60.4638888889	-123.3650000000	
FORT SIMPSON	Deh Cho	10ED004	Rabbit Creek below Highway No. 7	1978	1983	Discontinued	60.4613888889	-123.4127777778	

Appendix G: Environment Canada Hydrometric Stations: 2003-04 Historic Network Database

ADMINISTRATIVE DISTRICT	LAND CLAIM REGION	STATION NUMBER	STATION NAME	YEAR EST.	LAST DATE	STATUS	Latitude	Longitude	CLIMATE STA
FORT SIMPSON	X	10EB?	Rabbitkettle River at mouth	1900		Discontinued			
NORMAN WELLS	Sahtu	10KD004	Ramparts River near Fort Good Hope	1983	????	Discontinued	66.1166666667	-129.2711111111	
INUVIK	Gwich'in	10MC007	Rat River near Fort Mcpherson	1981	1990	Discontinued	67.6769444444	-135.7180555556	
INUVIK	Sahtu	10HB005	Redstone River 63 km above the mouth	1975		Active	63.9250000000	-125.2983333333	
NORMAN WELLS	Sahtu	10HB001	Redstone River near the mouth	1963	1974	Discontinued	64.1822222222	-124.6644444444	
INUVIK	Gwich'in	10LC003	Rengleng River below Highway No. 8 (Dempster Highway	1972		Active	67.7533333333	-133.8580555556	Y
FORT SIMPSON	Deh Cho	10GA001	Root River near the mouth	1974		Active	62.4802777778	-123.4327777778	Y
FORT SIMPSON	Deh Cho	10GC005	Sahndaa Creek at Highway No. 7	1982	1990	Discontinued	62.0619444444	-122.2100000000	
FORT SIMPSON	Deh Cho	10ED009	Scotty Creek at Highway No. 7	1994		Active	61.4163888889	-121.4555555556	
NORMAN WELLS	Sahtu	10KA005	Seepage Creek at Norman Wells	1974	1978	Discontinued	65.2638888889	-126.7222222222	
FORT SIMPSON	Deh Cho	10HB004	Silverberry River near Little Dal Lake	1980	1990	Discontinued	62.7655555556	-126.6922222222	
NUNAVUT	Sahtu	10JE001	Sloan River near the Mouth	1932	1991	Discontinued	66.5219444444	-117.2738888889	
FORT SIMPSON	Deh Cho	10EC001	South Nahanni River above Clausen Creek	1959		Discontinued	61.2552777778	-124.0577777778	
FORT SIMPSON	X	10EC?	South Nahanni River above Nahanni Butte			Discontinued			
FORT SIMPSON	X	10EB?	South Nahanni River above Rabbitkettle River			Discontinued			
FORT SIMPSON	Deh Cho	10EB001	South Nahanni River above Virginia Falls	1960		Active	61.6358333333	-125.7952777778	Y
FORT SIMPSON	Deh Cho	10FA002	Trout River at Highway No. 1	1969		Active	61.1397222222	-119.8358333333	
FORT SIMPSON	Deh Cho	10FA001	Trout River near outlet of Trout Lake	1965	1968	Discontinued	60.7666666667	-121.1083333333	
FORT SIMPSON	Sahtu	10HA002	Tsichu River at Canol Road	1975	1992	Discontinued	63.3030555556	-129.7952777778	
FORT SIMPSON	Sahtu	10HA003	Twitya River near the Mouth	1980	1990	Discontinued	64.1605555556	-128.2991666667	
FORT SIMPSON	Deh Cho	10EA001	Unnamed Creek near Watson Lake	1959		Discontinued	61.9583333333	-128.2083333333	
INUVIK	Gwich'in	10LA004	Weldon Creek near the Mouth	1977	1990	Discontinued	66.4136111111	-132.6947222222	
NORMAN WELLS	Sahtu	10JD002	Whitefish River near the Mouth	1977	1992	Discontinued	65.7344444444	-124.6227777778	
FORT SIMPSON	Deh Cho	10GB006	Willowlake River above Metahdali Creek	1974		Active	62.6505555556	-122.9000000000	Y
FORT SIMPSON	Deh Cho	10GB001	Willowlake River below Metahdali Creek	1963	1974	Discontinued	62.6527777778	-122.9058333333	
FORT SIMPSON	Deh Cho	10HB003	Wrigley River near the mouth	1976	1988	Discontinued	63.1761111111	-123.6902777778	