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

SCIENTISTS' WORKSHOP RESULTS APRIL 8-9, 2003

prepared for:

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Executive Summary

A Scientists' Workshop was held to partially fulfill requirements of a project entitled, *Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley*. This biophysical gap analysis 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.

The Scientists' Workshop was held with federal and territorial government scientists' and representatives from the Gwich'in and Sahtu Renewable Resources Boards. This report is a summary of the workshop held in Yellowknife on April 8 and 9, 2003. The workshop was arranged to complement workshops held with community representatives from the Mackenzie Valley to discuss and confirm the information and research gaps identified in a draft of the *Background Paper Report*, produced as part of the biophysical gap analysis project. Experts from the federal and territorial government and representatives from the Gwich'in and Sahtu Renewable Resources Boards in the fields of surficial geology, permafrost, hydrogeology, water (surface and sub surface), air quality, wildlife, fisheries, vegetation, as well as regulatory, environmental assessment and traditional knowledge experts were asked to contribute to the *Background Paper Report*.

Representatives at the Scientists' Workshop gave short presentations that described the current state of biophysical research and information held by these organizations. The presentations also detailed biophysical information and research gaps within this information and described work they felt was a priority in order to address these gaps. Participants critically evaluated the biophysical information and research gaps from a draft of the *Background Paper Report* and those identified in the workshop presentations.

The information from this workshop was used to assist in the preparation of an *Action Plan*, which identifies, confirms and prioritizes biophysical information and research gaps associated with oil and gas exploration, development and transmission in the Mackenzie Valley. The information was also used as support to the *Background Paper Report*.

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1. Workshop Goals and Objectives

The Scientists' Workshop was arranged to allow federal and territorial scientists' and Gwich'in and Sahtu Renewable Resource Board representatives the opportunity to review the findings of a draft of the *Background Paper Report* prepared in partial fulfillment of the objectives of the *Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley* project. This biophysical gap analysis 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.

The review process involved confirming and refining the identified gaps, identifying new biophysical gaps, prioritizing the gaps, and identifying lead agencies that could be responsible to fill the gaps. This information was used to support the *Background Paper Report* and to assist in the preparation of the *Action Plan* for this project.

2. Methodology

The workshop was designed and delivered over two days. The first day consisted of introductions and background presentations by Gartner Lee Limited about the *Identification of the Biophysical Information and Research Gaps Associated with Hydrocarbon Exploration, Development and Transmission in the Mackenzie Valley* project. This involved an explanation of how the biophysical priority research areas were identified and how they related to the development scenarios. Included in the development scenario presentations was information that linked the activities in the Mackenzie Delta to the activities in the Mackenzie Valley considered in this project. Federal and territorial government scientists' and Renewable Resource Board representatives attending the workshop then gave presentations about the work they were involved in, and provided an indication of the research gaps they were aware of. Some of the identified gaps were specific to the Mackenzie Delta, and are considered outside of the scope of this project. However, the noted gaps specific to the Mackenzie Delta have been compiled in a separate Appendix to this report, as referred to in Section 3.3.

On day two of the workshop, the participants were split into breakout groups to discuss the identified gaps, to confirm and determine the information and research required to:

- Assess the impact of oil and gas development activities (e.g., exploration, development and transmission) in the Mackenzie Valley;
- Regulate existing and future hydrocarbon activities (e.g., exploration, development and transmission) in the Mackenzie Valley; and,
- Undertake environmental monitoring in order to assess: the validity of the impact predictions; the performance of mitigative measures or performance standards; and the cumulative effects of development activities.

Breakout groups were then asked to:

- Establish a priority ranking for the information/research requirements to meet the environmental assessment, regulatory or monitoring process needs. Criteria for setting priorities are to include: when the information or results of the research are required; the time required to undertake the research; and valued ecosystem components; and,
- Identify immediate science/information needs which could be supported with new resources in 2003/2004.

In order to prioritize and further understand the information and research gaps presented in the draft *Background Paper Report* a series of biophysical attribute sheets were developed. These sheets, which were handed out to all participants, listed all the gaps from the draft *Background Paper Report.* Any additional information/research gaps presented during day one of the workshop were added to the appropriate attribute sheet. The attribute sheets asked a series of questions with respect to each gap. The answers to these questions, resulting from group analysis and discussion, enabled participants to challenge, confirm and further categorize the gaps.

Table 1 lists the organizations and their representatives that attended the workshop.

Table 1. Workshop Participants

Organization	Participant
Environment Canada	Tim Coleman, Vanessa Charlwood, Kevin McCormick, Jesse Jasper Phillip Marsh, Steve Harbicht, John Reid, Doug Halliwell
Fisheries and Oceans Canada	Ross Tallman, Lois Harwood, Brian Billeck, Hugh Bain, Sam Stephenson, Cheryl Podemski, Gregg Tomy, Doug Chiperzak
Indian and Northern Affairs Canada	Robin Staples, Ruth McKechnie, Giles Morrell, Lorraine Seale Ricki Hurst, Sarah Aho, Marjorie Fraser, Kirstie Simpson, Brian Latham, Bob Reid, Fred McFarland
Resources, Wildlife and Economic Development. GNWT	John Fox
National Energy Board	Ray Case, Graham Veale, Suzanne Carriere, Steve Matthews, Len Gal (sub. Tues. only), Tracy Hillis, Bas Oosenbrug, Evelyn Gah, Ron Graf (absnt. 2nd day)
Canadian Environmental Assessment Agency	Jon Pierce

Organization	Participant
Sahtu Renewable Resources Board	Jody Snortland, Shelia Mackenzo
Gartner Lee Limited (Consultant to DIAND)	Heidi Klein, Steve Morison, Gordon Stewart, Wayne Jackson

Table 2 presents the agenda for the two day workshop.

Table 2. Agenda for the Scientists' Two-day Workshop

Day 1 - April 8, 2003

Time	Agenda Item	Presenter
8:30 - 8:50	Welcome and Purpose of Meeting – expected results	Ray Case RWED and Ruth McKechnie DIAND
8:50 - 9:05	Introductions - organisation	All
8:50 - 9:05	Introductions - organisation	All
9:05 - 9:30	Overview of the Development Scenarios for the Mackenzie Valley and Mackenzie Delta onshore	Gordon Stewart Gartner Lee Ltd.
9:30 - 10:15	Presentation on Biophysical Gaps Study - Terrain and Water	Steve Morison Gartner Lee Ltd.
10:15 - 10:30	Health Break	
10:30 - 11:15	Presentation on Biophysical Gaps Study - Fish, Wildlife, Land Use	Heidi Klein Gartner Lee Ltd.
11:15 - 12:00	Discussion	
12:00 - 1:00	Lunch	
1:00 - 1:30	Community Workshop Report and Discussion	Heidi Klein Gartner Lee
1:30 - 2:00	ESRF and PERD Research Priorities for the North	Ruth McKechnie DIAND Sheri-Lynne Marshall NRCan
2:00 - 2:20	DFO Presentation - information and research priorities	Ross Tallman DFO

Time	Agenda Item	Presenter
2:20 - 2:40	DOE Presentation - information and research priorities	Kevin McCormick DOE
2:40 - 3:00	Questions/Discussion	
3:00 - 3:15	Health Break	
3:15 - 3:35	NRCan Presentation - information and research priorities	Ron DiLabio NRCan
3:35 - 3:55	DIAND Presentation- information and Research priorities	Rick Hurst DIAND
3:55 - 4:15	RWED – Information and Research Priorities including GNWT Mackenzie Valley Biophysical Study	Ray Case GNWT - RWED
4:15 - 4:45	Gwich'in Renewable Res. Bd. Sahtu Renewable Res. Bd.	Denise Auriat Jody Snortland
4:45 - 5:00	Questions and Wrap-up	

Day 2 - April 9, 2003

Time	Agenda Item	Presenter
8:30 - 8:45	Instructions for Day 2	Ruth McKechnie
8:45 -10:15	Breakout groups	Facilitator
10:15 - 10:30	Health break	
10:30 - 12:00	Breakout groups cont.	Facilitator
12:00 - 1:00	Lunch	
1:00 - 2:15	Breakout groups wrap-up	
2:15 - 3:15	Reports from each breakout group to Plenary	

Time	Agenda Item	Presenter
3:15 - 3:30	Health break	
3:30 - 4:00	Reports from each breakout group to Plenary	Facilitator
4:00- 4:50	Plenary – Identification of Common Priorities MV and MD	
4:50 - 5:00	plenary - wrap up	DIAND

3. Results

3.1 Day 1

Ruth McKechnie of the **Department of Indian Affairs and Northern Development (DIAND)** – workshop facilitator and project manager – welcomed workshop participants and thanked all for their attendance. She provided an explanation of the workshop format and expected results. Ms. McKechnie reviewed the biophysical attribute sheets that were handed out to all participants.

Gordon Stewart of **Gartner Lee Limited** provided an overview of the gap analysis approach that was used in preparing of the draft *Backgr*ound *Paper Report*, and provided an explanation of the purpose of the analysis as well as background information on the gap analysis project.

He explained the specific methodology used for the gap research and analysis and described the possible development scenarios in detail (e.g., seismic, exploratory drilling, development and transmission) for oil and gas exploration, production and transmission in the oil and gas development areas in the Mackenzie Valley. The oil and gas development scenarios were prepared for a potential Mackenzie Valley pipeline; and, oil and gas exploration and development activities in the Peel Plateau, Colville Hills, Norman Wells, Liard Plateau, and Cameron Hills oil and gas development areas.

Steve Morison and **Heidi Klein** of **Gartner Lee Limited** presented the findings of the *Backgr*ound *Paper Report*. Mr. Morison and Ms. Klein reviewed the existing information along with information and research gaps for each of the biophysical attributes. The gaps were taken directly from the draft *Backgr*ound *Paper Report* and provided the starting point for discussions at the workshop (Appendix A). Appendix B contains the visual PowerPoint presentation provided by Gartner Lee.

Ruth McKechnie of **DIAND** discussed the Environmental Studies and Research Funds (ESRF). The ESRF implemented in 1983, sponsors environmental and social research in Canada. It receives its mandate through the Canadian Petroleum Resources Act and is funded through levies on frontier lands paid by permit holding oil and gas exploration companies. The presentation was a review of the fund, a review of past funding, and a first draft of priorities for 2004 (Appendix C).

Sheri-Lynne Marshall of **Natural Resources Canada (NRCan)** discussed the Program of Energy Research and Development (PERD). The PERD provides funding through federal government departments for research and development into non-nuclear energy. It enables the federal government to fulfil its direct energy responsibilities (e.g., by providing standards, regulations, and policy knowledge), to conduct energy research and development for the public good, provides reactive funding programs to identified needs, and allows programs to be undertaken for demonstration, deployment, and engineering. Ms. Marshall's PowerPoint presentation can be found in Appendix D.

Ross Tallman of **Fisheries and Oceans Canada (DFO)** presented the mandate of DFO and their areas of interest (Appendix E). Generally, DFO is concerned with the conservation, protection and management of fish stocks, fish habitat, species at risk, and the management of the oceans. Information and research gaps for fisheries are quite extensive in the north, some areas having quite a lot of data available while very little is known for other areas.

Kevin McCormick of **Environment Canada** described the mandate of Environment Canada as covering environmental conservation (migratory birds, species at risk, protected areas and water quality), environmental protection (environmental assessment, contaminants, deleterious substances, environmental emergencies), meteorological services (weather, air quality, climate, water quality) and National Water Research institute (freshwater research). He then explained the areas where issues and, information and research gaps exist, including resource management, environmental assessment, cumulative impacts, environmental emergencies and climate change gaps. Environment Canada's PowerPoint presentation can be found in Appendix F.

Ron DiLabio of **NRCan** provided an overview of the science and information needs of NRCan in the Mackenzie Valley and Mackenzie Delta (Appendix G). The areas of interest for NRCan relate to topographic maps; geology; permafrost; coastlines; pipelines; slope, terrain and pipeline stability; geotechnical and geological databases (sharing of information); and climate change. Specific information and research gaps identified related to: baseline data on permafrost, soil properties and terrain stability; updates of old databases; performance of existing pipeline and new pipeline materials; monitoring sites along existing and possible rights-of-way; digital topographic base maps; surficial geology maps; hydrocarbon assessments; coastal flooding models (delta subsidence vs. sea level); and, predictions of climate change impacts.

Rick Hurst of **DIAND** provided an overview of the role of DIAND in the Mackenzie Valley and the information and research gaps identified through initiatives and programs undertaken in the north (Appendix H). Areas of interest and areas where gaps have been identified included: Water resources

(baseline conditions of water resources (quantity and quality), sumps and ground thermal conditions, drilling waste characterization); Environment and Conservation (NWT Protected Areas Strategy, Cumulative Effects Assessment and Monitoring Framework and Cumulative Impact Monitoring Program); geoscience baseline research and mapping; Land Resources (granular resources); and land and water management.

Ray Case of **Resources, Wildlife and Economic Development (RWED), GNWT** discussed the mandate of RWED. He identified information and research gaps in areas covering wildlife, vegetation and forests, and endangered species (Appendix I).

Denise Auriat of the **Gwich'in Renewable Resources Board (GRRB)** identified information and research gaps important to the Gwich'in communities as: status report on water quality and quantity in the Gwich'in Settlement Area should be available in plain language for communities; "best practices" for northern environments should be determined and implemented; thresholds on development should be determined; appropriate disposal of drilling fluids; impacts of linear disturbance and habitat fragmentation to wildlife; impacts to upland lakes and watercourses along the potential pipeline route; site reclamation using native seeds; natural revegetation of disturbed sites; and, current distribution of non-native plant species. The GRRB presentation is contained in Appendix J.

Jody Snortland of the **Sahtu Renewable Resources Board (SRRB)** gave an overview of Sahtu community concerns and SRRB identified gaps as: there is a need for standards for traditional knowledge consultation and documentation; the communities feel that the pipeline development is moving too fast, that there is not enough discussion with the community people; community people want to be included in the research. She indicated that a long list of research gaps have been identified in this project, and now is the time to prioritize and begin the work of filling these gaps. Jody's presentation material was not provided for inclusion in this workshop report.

3.2 Day 2

On the second day of the workshop participants formed three breakout groups. Each group was tasked with challenging, characterizing, and confirming the biophysical information and research gaps. Three groups were tasked with the following specific biophysical attributes to review:

Group One – surficial geology, permafrost, terrain, water (surface and subsurface), air.
Group Two – wildlife and wildlife habitat, vegetation and forestry, biodiversity, migratory birds and their habitat.
Group Three – fish and fish habitat.

Each group was responsible for discussing the effects of climate change and cumulative effects on these biophysical attributes. Specifically, the breakout groups were asked to:

1. Review information deficiencies and science/research needs identified for each development area in the Mackenzie Valley, including the onshore Mackenzie Delta and a possible pipeline route.
2. For each development area, or development activity (seismic exploration, production drilling, collector pipelines, main line construction etc.) identify the main information deficiencies and research needs associated with the following biophysical and land use topics:
   - Terrain/soils/surficial geology;
   - Permafrost;
   - Water - surface and ground water;
   - Air quality;
   - Fish and fish habitat;
   - Wildlife and wildlife habitat;
   - Migratory birds and their habitat;
   - Vegetation and forests;
   - Biodiversity;
   - Climate change;
   - Land use and resource use (protected areas); and
   - Cumulative effects.

The biophysical attribute tables were used to facilitate the above tasks. Through group discussion each gap listed on the table was initially assessed for its validity. Once the group agreed the gap was valid the following questions were addressed:

- Why is the gap valid?
- When is the information needed?
- What phase of development is the information needed for?
- What is it's priority?
- What is the research/science question?
- Who could do the research science?

The attribute sheets were completed with the answers to these questions. The completed attribute sheets are contained in Appendix K under the following topics:

- Terrestrial and Surficial Geology;
- Permafrost;
- Hydrogeology and Groundwater;
- Surface Water;
- Fish and Fish Habitat;
- Vegetation and Forestry;
- Wildlife – Mammals;
- Wildlife – Migratory Birds;

- Biodiversity;
- Air; and
- Climate Change

3.3 Mackenzie Delta Information and Research Gaps

During the course of the Scientists' Workshop, gaps were identified for the Mackenzie Delta. This information can be found in Appendix L.

Appendices

Appendix A

Initial Biophysical Information and Research Gaps Identified in draft Background Paper Report

Appendix A: Initial Biophysical Information and Research Gaps Identified in draft *Background Paper Report*

TERRAIN AND SURFICIAL GEOLOGY

Baseline Gaps

1. Traditional knowledge about terrain and surficial geology is lacking.

2. The kinds of information needed to support project design, any environmental assessments, and regulatory processes include:
   - knowledge about the types and distribution of granular resources;
   - estimating future demands for granular resources;
   - knowledge about permafrost;
   - knowledge about landform types and distribution;
   - knowledge about drainage conditions, deposit thickness and terrain hazards; and,
   - knowledge about earthquakes and slope stability.

3. A greater understanding of the dynamics of slope movement is required to improve the accuracy of slope movement predictions. This would aid in the location, design, construction, and maintenance of new and existing pipelines in an economic and environmentally acceptable manner. The primary goal would be to provide a means for isolating problematic areas prior to pipeline construction, as will as to predict slope movement in aid of pipeline maintenance (PERD Pipeline POL 2002).

4. The location of locally significant soils, soils susceptible to compaction and terrain units that would modify drainage patterns is required. This would assist in better planning for pipeline routing and construction.

5. There is a need for geophysical and remote sensing technique development to improve upon and facilitate spatial and temporal characterization of surface and subsurface terrain conditions. This would assist in design, routing and performance monitoring of a pipeline.

Impact Gaps

1. Little traditional knowledge has been recorded regarding project effects or impacts on the terrain and surficial geology. Traditional knowledge could be used to predict project effects with relation to access roads and land clearing by pointing to what is known about the terrain by the inhabitants of the area.

2. While much has been studied of the impacts of a pipeline on terrain and surficial geology, more research is still required to fully understand the impacts of soil compaction and rutting if traffic is operating on partially thawed soil or soils which are susceptible to compaction. This compaction or rutting can have adverse effects on land drainage patterns. Locations of significant soils susceptible to compaction should be studied (Kavik-Axys and LGL 2001). Likewise, specific criteria are required, by regulators to reduce the potential for impact and mitigate for terrain rutting (MVEIRB, 2003).

3. Further work identifying acceptable granular resources and reducing impacts is also required to ensure pipeline construction can occur with the use of minimal amounts of lower quality granular resources.

PERMAFROST

Baseline Gaps

1. There are several baseline gaps that, at present, will affect the evaluation of environmental impacts of oil and gas development activities in the five development areas or along any potential Mackenzie Valley pipeline corridor.

2. There is a need to record any traditional knowledge for areas of known slope instability, poor ice conditions and other features or information e.g., place names that may convey information about the status of permafrost.

3. There is inadequate baseline data on ground temperatures and near-surface ground ice conditions along a potential pipeline right-of-way (ROW) between Inuvik and Norman Wells. The same applies for the five (5) developments areas.

4. The absence of information on surficial materials (e.g., granular resources (see earlier)), and on ground temperature and near-surface ground ice conditions creates a deficiency that will prevent adequate assessment of the sensitivity of permafrost to disturbance along a potential ROW. This gap exists from a spatial perspective, at sites with frozen/ unfrozen interfaces; and from a temporal perspective (i.e., climate change), ROW clearing, and frost heave.

5. A summary and succinct analysis of the above factors for the Enbridge pipeline is required. Data from the monitoring program conducted on the existing Norman Wells pipeline right-of-way has accumulated since 1986. Although there is an interim analysis of these data, a full analysis and assessment of the impact of the right-of-way on terrain conditions is required. Further, data on near-surface ground temperatures and active-layer conditions must be summarized and assessed; and all information on slope movement and stability on the approaches to pipeline river crossings should be summarized and assessed.

6. An assessment of soil-pipe interactions on hill slopes experiencing ground-ice creep is required.

7. There is a need for constraint mapping that would include information on the distribution of soil by type and permafrost proximity to water bodies. Mapping thawed to frozen interface areas, and ice-poor to ice-rich interface areas is required. Improved mapping of the spatial distribution of permafrost, ground ice, active layer and ground temperature data is also needed.

Impact Gaps

1. There is generally a one - two year lag between pipeline instillation and pipeline operation, based on the experience gained in developing the Norman Wells to Zama pipeline. During this lag, the pipeline will be the same temperature as the surrounding soil. The possible effects of this lag on the terrain should be addressed. The possible effects of the decommissioning of the pipeline should also be addressed.

2. The effect of chilled gas in that zone of transition between frozen and unfrozen ground needs to be studied. There is the possibility of frost aggradation and associated heave across the boundary (Burgess et al. 2003, Burgess pers. comm.).

3. Research and analysis is required to assess the long-term effectiveness of drilling mud sumps within the study area.

4. North of Norman Wells to Inuvik, there is little to no data on near-surface ground temperatures. This represents a major deficiency in our knowledge of ground conditions and hence our ability to assess the impact of the pipe on the surrounding permafrost.

5. A full analysis of the data collected for the existing Norman Wells pipeline is required, particularly of the data on near-surface ground temperatures and active-layer conditions, and all information on slope movement and stability on the approaches to river crossings.

6. The effects of operating a chilled pipeline in permafrost conditions requires more research, particularly on the efficacy of standard frost heave tests to predict the long-term behaviour of freezing soil, and the relationship between the performance of laboratory tests and field behaviour of similar soils. These issues are critical to the assessment of pipeline integrity beneath river channels, and at frozen/unfrozen interfaces in discontinuous permafrost zones.

7. A comprehensive assessment of frost heave as it affects chilled gas pipelines in the discontinuous permafrost zone, and at river crossings for the last 20 years of data collection is required. Particular attention should be paid to the efficacy of standard frost heave tests to predict the long-term behaviour of freezing soil; and, the relationship between the performance of laboratory tests and field behaviour of similar soils. These issues will be critical to the assessment of pipeline integrity beneath river channels, and at frozen/unfrozen interfaces in the discontinuous permafrost zone.

HYDROGEOLOGY AND GROUNDWATER

Baseline Gaps

1. Traditional knowledge specifically about hydrogeology and groundwater is virtually non-existent. An assessment of existing TK could be undertaken to find out whether any direct or indirect references to hydrogeology and groundwater have been recorded, and to determine if further recording of this type of TK is warranted.

2. Baseline data on hydrogeology and groundwater have been largely linked to development proposals. Considerable information seems to exist for mine sites, areas of reclamation, the Norman Wells to Zama pipeline and the previously proposed Mackenzie pipeline. It was not readily apparent that any effort has been made to document hydrogeology and groundwater in other oil and gas development areas, such as the Liard Plateau, Cameron Hills and Colville Hills.

3. In general, it would appear that a baseline assessment of hydrogeology and groundwater of the Mackenzie Valley is essential for accurately assessing impacts caused by hydrocarbon development activities. This assessment is especially important at future sites of intensive development – roads, compressor stations, well pads, borrow sites, camps, fuel storage areas – as groundwater contamination potential will be greatest at these sites. If this baseline assessment is not completed, it will be difficult to detect and quantify future impacts on groundwater sources (Kavik-Axys and LGL 2001; Halliwell 2003, pers. comm.).

4. An understanding of the interactions between groundwater and surface water is needed along the pipeline route. This baseline information is especially important for areas of future intensive development, such as roads, compressor stations, well pads, borrow sites, camps, and fuel storage areas. Often, groundwater wells are not entirely contained bodies of water. Links between these two sources provide pathways for contaminants within the groundwater to transmit to the surface water.

Impact Gaps

1. Permafrost acts as a partial or total barrier preventing interactions between surface and groundwater sources. At greater depths it acts as a barrier separating shallow and deep groundwater sources (which may have dramatically different water chemistry). Melting of permafrost may remove this barrier and allow for the interactions of previously separated water. Research is needed to assess the potential for this interaction resulting from permafrost melting in areas of shallow permafrost coverage (Pye 2002, pers. comm.)

2. Permafrost creation may impact area hydrogeology. In unfrozen ground a chilled pipeline would freeze water in the surrounding soil. Potentially, this would 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). Further study is required to understand the hydrological conditions along the pipeline route, as well as the impacts of permafrost degradation, and creation, on area hydrogeology.

SURFACE WATER

Baseline Gaps

1. Documented and available sources of traditional knowledge about surface water are limited, particularly for the oil and gas development areas. Further work to collect TK in these areas would be beneficial.

2. Hydrocarbon development processes can require large amounts of water. In many cases local surface water sources are used. Further study is required in order to assess the ecological in-stream flow requirements of lakes and tributaries within the study area before large scale water withdraw is permitted.

3. There is a need for further study of baseline water quality parameters, including baseline hydrocarbon, organic and bacteriological data. Sediment load data is needed for the Mackenzie River and its tributaries. Likewise, a better understanding of organic contaminant information is needed for the Mackenzie River its tributaries. Studies of fish livers have found hydrocarbons, toxophene and organochlorines but their origin has not been determined. This information is required in order to identify and determine effects caused by potential hydrocarbon development and activities (Halliwell 2003, pers. comm.).

4. An increase in the frequency of water quality sampling at established monitoring stations in the Mackenzie River basin is required. The development of a hydrocarbon water quality sampling program, which would operate during the development and operation of the pipeline, would allow the identification of project specific contamination, track quality changes and identify trends (Jasper 2003, pers. comm.).
5. Physically based hydrological models are essential for addressing water resource issues such as water supply and flooding, the transport of contaminants through northern ecosystems and the impact of climate change on northern ecosystems. Numerous hydrological models have been developed for use in southern Canada, but few, if any, are applicable for the north, and more importantly for permafrost regions, where the relative importance of hydrological processes are different (Reid 2003, pers. comm.).

6. The snow survey network is sparse and is focused on basins with hydroelectric developments and major communities. Data, where available, are for end-of-season snowpack only. No snow data has been collected in the Mackenzie Mountains and very little in the oil and gas development areas.

Impact Gaps

1. There is a need to fully understand the cumulative impacts of particular hydrocarbon development projects. An evaluation and classification of environmental contamination from 25 years of gas production in the Fort Liard area (i.e., lake and river sediment contaminant analysis) would provide a clearer understanding of the full impacts of gas production on the aquatic ecosystem (Jasper 2003, pers. comm.).

2. There is a need for the development of a hydraulic model, which would improve tracking of hydrocarbon spills (Jasper 2003 Per. comm.). Dispersion and travel time research is required for the Mackenzie River and its tributaries. As well, the identification of sensitive areas along the Mackenzie River is required. The hydraulic model would include dispersion/time, as well as sensitive areas data and would, in conjunction with the increased monitoring, result in the enhanced ability to deal with spill events by establishing clean-up and mitigation priorities.

FISH AND FISH HABITAT

Baseline Gaps

1. TK of fish spawning areas, and fish and fish habitat needs to be mapped at 1:250,000 and in some cases 1:50,000 in all areas. This should be done in conjunction with a literature review and map compilation of existing scientific information.

2. The Sahtu require fish and fisheries research and mapping (comment from Kim Horrocks, in Snortland and Veitch 2002). Similarly, studies on fish and fisheries in the Gwich'in are not region wide.

3. For anadromous species connectivity between the river and near-shore marine environments and the relative importance of each in determining population abundance must be better understood (Powers, 2003 pers. comm.). Arctic cisco migrate the length of the Mackenzie to spawn and return to the delta as juveniles. There are knowledge gaps pertaining to their life history, factors controlling population fluctuations, and the relative importance of in-river versus near-shore marine habitat (Powers 2003, pers. comm.).

4. Total exploitation rates from all fisheries should be estimated (i.e., domestic, commercial and sport for each species in each area, and summarized with respect to location of the fish/fishery) (CIMP 2002).

5. Long-term population monitoring is required in all areas to determine population changes over time.

6. Trophic structures important to fish and local aquatic ecosystem structure and function is basically unknown as are potential impacts of development on lower trophic levels relevant to fish populations. Understanding this is required to ensure that impacts on aquatic habitats are not transmitted through the trophic pathways to higher level predatory fish which are usually the commercially important species (Reist 2002, pers. comm.). Stable isotope analysis can be used to determine basic (trophic) ecological relationships. (Powers 2003, pers. comm.).

7. Little baseline information is known about non-harvested fish, other than presence/absence data (some collected in the 1970s). Non-harvested fish account for approximately 50 percent of all fish species, and are often used as forage for predatory species (Reist 2002, pers. comm.). Further data is required on the distribution and habitat use of these species. Acquiring this data would also be useful for biodiversity documentation.

8. Inland lake surveys were noted as a gap in the Norman Wells area (Sahtu Renewable Resource Board and RWED, 2002).

9. Rates of disease and parasites in fish are not regularly monitored in the NWT and changes in these rates are not available. Observations have been made by local fishermen on the condition of fish; however, these need to be systematically documented (CIMP 2002).

10. Monitoring benthic invertebrate communities has been recommended as an indicator of fish and water quality (CIMP, 2002) or overall biological integrity of rivers. An inventory of both baseline benthos and periphyton data (sites, taxon, chlorophyll a, biomass) would be beneficial (Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee, 2002).

11. A system to classify watercourses would be beneficial to determine areas of relative importance and allow for identification of any management or protected area for a species (Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee 2002).

Impact Gaps

1. The incorporation of TK into studies on fish populations or habitat use for comparison of past and present conditions is limited. Long-term studies of fish and fish habitat to compare to TK do not exist in the Gwich'in, Deh Cho or Sahtu regions and should be considered.

2. The major gap in managing potential impacts of development is the lack of clearly defined "sensitive areas" and clearly defined "sensitive timing windows". 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.

3. Removal of large volumes of water from small lakes and streams for winter roads, drilling, camp use (potable water) and pad construction can affect the survival of eggs of Arctic char, whitefish and cisco or overwintering char and grayling. The CAGPL pipeline proposal stated that no more than 10% of the total volume of water at a location would be removed and springs that support fish habitat would not be used (NEB 1977). Owing to an unclear understanding of exactly how water draw-downs may negatively affect Arctic lakes, there are fears from area inhabitants that any amount of draw-down may have a negative impact on fisheries resources. Therefore, water is currently drawn only from smaller lakes that lack any harvested fish resources. DFO is currently using a 1% guideline for water draw-down although this amount is considered too generous on some waterbodies while far short of the potential usable volume on others. The environmental impact associated with accessing a large number of small lakes instead of a lesser number of larger lakes may contribute to the overall "footprint" associated with oil and gas activity. Arctic tundra lakes are poorly understood and continuing requirements by the oil and gas industry, in both the exploratory and developmental periods, to access water for a variety of reasons suggests that some understanding of the potential impacts of water draw-down be made (Stevenson 2002).

4. Impacts on fish from seismic energy (including pressure and noise) sources are currently a focus of study by DFO. This is particularly pertinent for the seismic phase of hydrocarbon exploration. Seismic exploration studies over land (adjacent to fish-bearing watercourses) and in rivers are a source of vibrational energy. Information on the lethal or sub-lethal effects of seismic sound levels and frequencies on the Coregonids (whitefishes) that make most of the subsistence fisheries in the northern portion of the Mackenzie system is not known.

5. Toxicity and ecosystem studies looking at sediment characterization, fate, and biological impacts of natural hydrocarbons in the Mackenzie River have not been conducted. Therefore, research is required to better characterize sediment sources and composition in the Mackenzie River (and tributaries) and the transportation fate of this material as it passes through the Mackenzie Delta into the Beaufort Sea. Research is required to investigate the impacts of natural hydrocarbon sources on various toxicity responses by aquatic invertebrates and forage fish. Such data will form part of an important baseline data set and allow for better predictions of the consequences of accidental oil releases (CWS 2003).

6. A CIMP (2002) recommendation for the pipeline development included annual monitoring of selected representative streams along the Mackenzie to determine baseline water velocity, discharge, substrate composition and fish and invertebrate abundance/distribution. Representative small watersheds could be selected up and down the valley. This type of research may provide important information on changes over time and allow for monitoring of physical changes to fish habitats such as bank slumping.

7. Indicators for fish and aquatic ecosystem health over the long-term need to be developed for the project areas. The indicators need to provide the necessary trigger in order to respond to negative changes. Some fish indicators that have been recommended include maturity and fecundity, age distribution of fish stocks, aquatic habitat structure (substrate, spawning, rearing and cover) and quality (importance to species), over-wintering locations, fish abundance, size and distribution and water depth/velocity (CIMP, 2002). Arctic grayling growth rate has been noted as a potential indicator. Normal growth for the NWT is 1.5 to 4 grams per year (Macleod Institute 2002).

8. The potential impact of cumulative effects should also be considered. A review of the available information indicates that hydroelectric, mining, logging, and oil and gas developments in British Columbia have the highest potential to affect water uses in the Liard River within the NWT (Laird Plateau development area) (MacDonald Environmental Services 1993). Currently there is little data available for developing cumulative effects models that include the impacts of oil and gas, as well as other industrial development activities (e.g. forestry; mining etc.).

VEGETATION AND FORESTS

Baseline Gaps

1. An Ecological Lands Classification System is required to better predict potential impacts of development and to identify rare ecosystems based on area.

2. The Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee (2002) and Ducks Unlimited note the requirement for mapping and describing wetland functions to the Canadian Wetland Classification System. An understanding of the ground and surface water interaction within NWT wetland types is needed to assess impacts of developments (MacDonald 2002, pers. comm.).

3. Recommendations have been made to conduct development-specific surveys to capture rare plants and rare plant communities (Kavik-Axys and LGL 2001) and increase baseline vegetation monitoring programs to determine rare plant and medicinal plant locations in the NWT (CIMP Working Group 2002).

Impact Gaps

1. Traditional knowledge could be used to predict project effects with relation to burning (including forest fires), spills and leaks, and land clearing. Documentation of traditional knowledge of these effects (except forest fires in the Gwich'in Settlement Area) was not found during the scope of this project and should be examined further.

2. Currently there is no long-term data to determine the recovery rates of vegetation communities in the NWT after industrial disturbance. Surveys of older seismic lines to determine species presence and re-colonization rates may provide valuable data for predicting future impacts.
3. An ecological classification system is required within the NWT to allow for an assessment of the relative rarity of different vegetation communities. Without this information it will be very difficult to determine in what areas vegetation loss constitutes a major impact and in what areas vegetation loss constitutes a minor impact.

4. Steps should be taken toward developing a local seed and seedling bank for re-vegetation activities. Without available local, natural seed mixes it will not be possible to re-vegetate the disturbed areas in a manner that eliminates introduced species.

WILDLIFE AND WILDLIFE HABITAT

Baseline Gaps

1. Site-specific TK regarding wildlife habitat and ecology does not exist along portions of the proposed pipeline route that pass through areas that are difficult to access due to terrain (Benn 2003, pers. comm.).

2. Traditional hunting and trapping areas in the Deh Cho have been mapped and put into digital format for all communities except Fort Liard (Cizek 2003, pers. comm.).

3. Some traditional knowledge of wildlife habitat has been mapped for the Deh Cho, Gwich'in or Sahtu regions. Further mapping is required at 1:250,000 and in some cases 1:50,000 scales in conjunction with a literature review and map compilation of existing scientific information.

4. Traditional knowledge needs to be gathered according to clearly defined critical habitat categories, including:
    - Nesting,
    - Denning,
    - Whelping,
    - Calving,
    - Rutting,
    - Wintering areas, and
    - Movement corridors.

5. Workshops in the Sahtu concluded that continuous, long-term harvest studies are necessary in order to accurately identify changes in wildlife populations (Snortland and Veitch 2002). These studies should be conducted.

6. At a workshop in the Sahtu in the fall of 2002, TK gaps identified by both local people and researchers, included (Snortland and Veitch 2002):
    - Bluenose caribou eastern and western herds habitat use and population ecology,
    - Moose habitat use and population ecology,
    - Local trappers data, and
    - Studies on wildlife health.

7. The Northern Pipeline Environmental Impact Assessment and Regulator Chair's Committee (2002) identified the following information that require further assessment in order to be better prepared to assess a natural gas pipeline through the Mackenzie Valley:
    - wildlife seasonal occurrence;
    - relative or absolute abundance;
    - density;
    - distribution;
    - biodiversity;
    - population trends and importance;
    - wildlife species inventory, by area;
    - species of ecological, subsistence or spiritual importance; and,
    - the identification of rare, protected, designated or genetically distinct species.

8. At a 2002 workshop in the Deh Cho, Traditional Knowledge 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. However, no scientific monitoring has been conducted to confirm this or determine the cause. The concept of monitoring trap lines with GPS was considered favourable and monitoring the subsistence harvest considered important (RWED 2002).

9. A co-management plan and an estimate of survival rates for the Bluenose caribou herd are baseline data requirements and are identified gaps (Sahtu Renewable Resource Board and RWED 2002).

10. 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.

11. Woodland caribou require further study.

12. For woodland caribou monitoring of herd genetics, population size and recruitment (including adult female and calf survival), potential population effects due to increasing muskox populations, survival rates, migration routes, information on parasites and disease, and the possible impacts of climate change have been noted as data gaps (Sahtu Renewable Resource Board and RWED 2002 and CIMP 2002).

13. For moose there are no long-term monitoring programs on contaminants.

14. Baseline gaps noted by CIMP (2002) for moose include:
    - population size and trends in all regions of the NWT;
    - productivity and health of populations in the NWT;
    - harvest levels;
    - habitat inventory and status;
    - cow/calf ratios and;
    - monitoring for health and disease.

15. The Gwich'in have noted that information is needed on Dall's sheep population, habitat, health and human disturbance (Nagy et al. 2002).

16. Although not directly within an area considered for oil and gas development the mountain goats within the Mackenzie Mountains may be impacted by increased air traffic in the general area. As this species is at the northern limit of its range and numbers are believed to be relatively low a small negative impact from development could result in a rapid decline in the population. As a result accurate population estimates are required to ensure year-over-year changes in numbers can be monitored. In addition, depending on exactly where development occurs research into flight paths and noise impacts on the mountain goat population may be required.

17. The bison population levels of the Liard Valley are considered stable but low. A better understanding of habitat needs and bison distribution is required in order to determine the effect of oil and gas development in the area.

18. Further research on population size, range and other key ecological components required for muskox.

19. Further research on population size, range and other key ecological components required for grizzly and black bear.

20. Although contaminant levels have been assessed in some species of furbearers, there is little data regarding pathogens and parasites in fur-bearers and small mammals (Kutz, 2002, pers. comm.).

21. Information is needed to determine why some areas are highly productive for small mammals and furbearers so that development impacts can be predicted.

22. More accurate population estimate are required for small mammals and fur-bearers to allow for closer monitoring of potential development impacts.

23. The hydrocarbon development areas have a greater potential for impacting birds than the proposed pipeline through the Mackenzie Valley, due to habitat fragmentation. Baseline studies are required and should focus on these areas.

24. There is a lack of density estimates for forest birds north of the Liard Valley. Density estimates should be used to quantify the loss of migratory birds based on habitat loss to development. The CWS has recommended conducting two small-scale studies to assess bird density at two development locations farther north (Norman Wells, Peel Plateau or Colville Hills). The spot-mapping technique in a number of habitats or another accepted approach from published literature can be used to derive this information (CWS 2003).

25. The following gaps in bird data have been identified:
    - distribution, abundance, population size, breeding success and condition/health for most bird species;
    - lack of continuous annual monitoring;
    - lack of sufficient breeding bird survey routes for reliable population trend
    - analyses;
    - lack of data on distribution and population size of raptors for many regions
    - lack of species specific long-term monitoring of distribution, population size and breeding success, particularly for declining species;
    - lack of monitoring of bird communities in relation to possible climate-induced changes; and,
    - lack of a community-based program to monitor qualitative changes in bird condition, including body fat indices, parasites and diseases (mainly for game species – similar to harvest studies).

26. Lack of data on locations of staging and breeding areas for migratory birds along the proposed pipeline route.

27. Data from the Mackenzie Valley pipeline proposal in the 1970's provide valuable baseline information on migratory birds and important habitats in the Mackenzie Valley. However, much of this is currently available in a wide variety of "gray literature" in government libraries. There is a need to compile, summarize and synthesize this data (perhaps by GIS) (CWS 2003).

28. There is almost no information on shorebird distribution and abundance in the Peel Plateau, Colville Hills, Norman Wells, Liard Plateau and Cameron Hills development areas. Priorities noted by CWS include the establishment of species distribution and breeding densities and species breeding habitat requirements in these areas.

29. CIMP (2002) has recommended conducting an evaluation of baseline contaminant levels in aquatic bird species, to compare to results from late 1980s/early 1990s.

Impact Gaps

1. There is limited site-specific or project specific TK of the effects of oil and gas development impacts on wildlife and wildlife habitat. In the Gwich'in, Sahtu and Deh Cho regions, it was noted that accurate game harvest data to assess the impacts of development on wildlife (from seismic lines, access roads etc.) is not available (Nagy et al. 2002; Snortland and Veitch 2002; Deh Cho First Nations and RWED 2002).

2. The CWS has recommended that a study be conducted along the existing pipeline right-of-way 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 (CWS 2003).

3. Increased predation of woodland caribou and moose is expected from linear clearing (MVEIRB 2001). Changes in predator-prey dynamics may also result from the introduction of new species into an area (Sahtu Land and Water Board staff 2003, pers. comm.). For example, as forested areas are logged, moose are attracted and wolves follow. Linear corridors allow for easy wolf movement, and caribou predation increases (Applied Ecosystem Management Ltd. 2002). A major gap in the impact data includes information on development-induced changes in predator numbers, and movement patterns (CIMP, 2002). As well, there is no information on the potential impacts of intra-specific competition as a result of habitat alteration caused by industrial development.

4. Although a large number of mitigation measures have been proposed to deal with the potential impacts of oil and gas development, there is little data in the NWT or elsewhere that has examined the effectiveness of these mitigation techniques (e.g. how effective is flaring at reducing toxic gas emissions). A detailed literature review of existing data from other jurisdictions dealing with oil and gas development would be a useful exercise for determining which techniques are likely to be most effective.

5. Apart from direct impacts of oil and gas development, there has been little effort expended at examining the potential cumulative impacts of oil and gas and forestry (or other industrial activities) occurring in the same areas. While a single pipeline may have limited impacts, and a single cutblock may have limited impacts, the cumulative impact of both in the same area may be significant. Greater research into cumulative effects modeling would provide a valuable tool for predicting the impacts of future industrial activity.

BIODIVERSITY

Baseline Gaps

1. The potential for traditional knowledge to convey biodiversity information is substantial. The example in the Dogrib region is indicative of that. Additional analysis needs to be undertaken of the TK in the oil and gas development areas and the biodiversity information that it conveys.

2. An ecological land classification system is required to determine if developments will result in significant impacts on uncommon ecosystem features. From this classification system a ranking can be developed based on ecosystem rarity and species abundance within the ecosystem type.
3. Identifying genetically distinct sub-populations is an area that has seen little attention. Local genetic variation reflects local adaptation within a species is an important part of biodiversity that should be preserved (Reist 2003, pers. comm.).

Impact Gaps

1. The ability to incorporate TK relating to biodiversity into environmental assessment documents must be site and/or project specific (The NWT PAS Advisory Committee, 1999) and not theoretical but applied (Barnaby and Emery, 2002).

2. There is a need for biodiversity guideline to be used in conjunction with any environmental assessment.

3. There is a need to improve methodologies for evaluating impacts to the biodiversity of the NWT in light of the fact adequate baseline information is absent for many species and there is limited information on ecological processes.

AIR

Baseline Gaps

1. There is a need to upgrade existing air quality monitoring programs at Yellowknife, Snare Hydro, and Fort Liard monitoring sites to improve baseline data collection and data quality.

2. There is a need to evaluate cumulative effects of developments on air quality within the Mackenzie Valley.

3. Collection of baseline air quality data is necessary along the length of the proposed pipeline, in particular, for areas along the route especially where compressor stations, camp sites and storage facilities will be located. This baseline data is critical to assess air quality impacts from these developments.

4. There is a need for meteorological data sufficient to allow for point-source and multiple-source dispersion modeling studies of contaminant releases from oil and gas exploration and development sites.

5. It will be important to be able to differentiate and quantify air quality impacts from different sources in order to accurately determine the impacts from oil and gas activities. Ambient air quality samples may be affected by sources outside of hydrocarbon development (e.g. neighbouring communities, vehicle emissions and other industrial process emissions). This interference would prevent the accurate assessment of hydrocarbon development specific contaminants and the potential impacts on the sub-arctic ecosystem.

6. There is a need to increase ambient air monitoring at development sites in the north. However; expansion of current monitoring programs will not address all of the baseline needs since not all of the potential parameters of concern will be monitored (Draft Code of Practice 2002, Veale 2003, pers. comm.). Parameters of concern that should be monitored are:
    - total suspended particles (TSP);
    - Particulate matter (PM_{10} and $PM_{2.5}$);
    - ozone (O_3);
    - Nitrous oxides (NO_x);
    - Volatile organic compounds (VOC); and,
    - greenhouse gases.

Impact Gaps

1. Air quality monitoring in the north should focus on environmental impacts on sensitive vegetation species (Jasper 2003, pers. comm.). Species sensitive to hydrocarbon contamination may be used as environmental air quality indicators. Some lichens, mosses and other flora are sensitive to air quality changes, accumulating air pollutants and showing visible side effects. Further study is required on the effects of by-products of flaring and fugitive emissions on sensitive species and the northern environment, particularly at the oil and gas development sites where monitoring is ongoing. The results of these studies would assist in determining potential affects of increased air emissions fro other projects.

2. Expansion of air quality monitoring and dispersion modelling at well sites and gas production plants to define areas of impact for individual sources is required. A co-ordinated effort with all gas companies and government monitoring/research programs to evaluate cumulative effects and impacts is also necessary. The latter is important because of the need to characterize the larger regional air quality impacts of development over an extended period of time, not just on a project-by-project basis.

3. The RWED Code of Practice for air emissions will require developers to establish more monitoring stations near development sites. In the early stages of development, this will increase baseline information significantly, so that cumulative impacts can be properly monitored over time as development increases. The absence of large impacts as development begins should not cause monitoring programs to be delayed.

Appendix B

Presentation by S. Morison and H. Klein, Gartner Lee Limited: Research and Identifying the Gaps

Information and Research Gaps Workshop

Researching and Identifying the Gaps

Information and Research Gaps Workshop

- Purpose of Gap Analysis Project:
  - To identify key information areas that need to be addressed to facilitate future environmental assessment and regulatory processes.
  - To link where possible information gaps with key environmental issues.
  - Continuation of dialogue that will be crucial for future environmental assessment and regulatory requirements

Information and Research Gaps Workshop

- Information sources considered:
  - Traditional Knowledge
  - Scientific knowledge
  - Current research
    - talked to people
    - reviewed documents
    - looked at data bases

Information and Research Gaps Workshop

- Two areas of focus identified:
  - Baseline biophysical information associated with specific biophysical attributes
  - Environmental effects associated with the development scenarios, over a 5 to 15 year timeframe

Information and Research Gaps Workshop

- Baseline biophysical attributes:
  - terrain/soils/surficial geology
  - permafrost
  - water - surface and groundwater
  - air quality
  - fish and fish habitat
  - wildlife and wildlife habitat

Information and Research Gaps Workshop

- Baseline biophysical attributes (con't):
  - vegetation and forests
  - biodiversity
  - climate change
  - land use and resource use (protected areas)
  - cumulative effects

Information and Research Gaps Workshop

- Gap Analysis Approach, Environmental Effects:
  - Development scenarios for known Oil and Gas areas in the Mackenzie Valley
  - Development scenario for a potential natural gas transmission line through the Mackenzie Valley

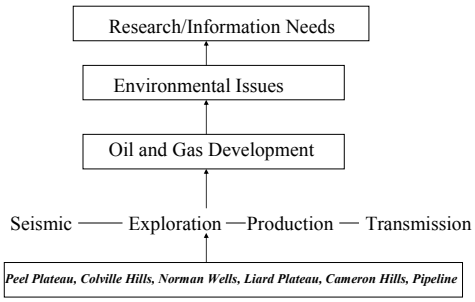
Information and Research Gaps Workshop

- Gap Analysis Approach, Environmental Effects:
  - Impact matrices prepared for oil and gas development areas and pipeline development scenarios
  - Used to identify potential environmental effects of development activities.

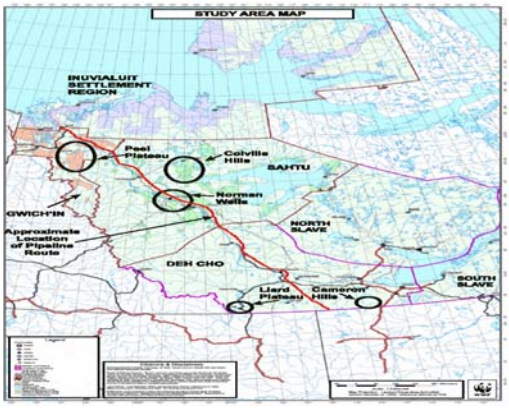
Information and Research Gaps Workshop

- Gap Analysis Approach, Environmental Effects:
  - Focused research efforts on those identified effects that are not mitigated by regulation, guideline, or engineering design.

Information and Research Gaps Workshop

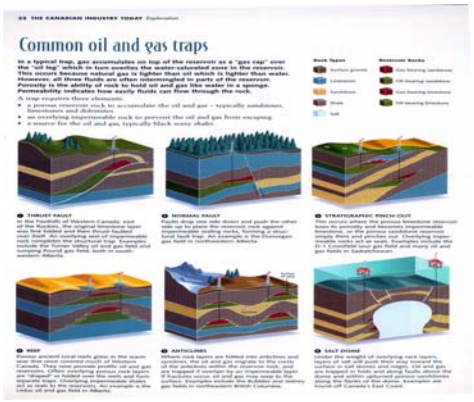


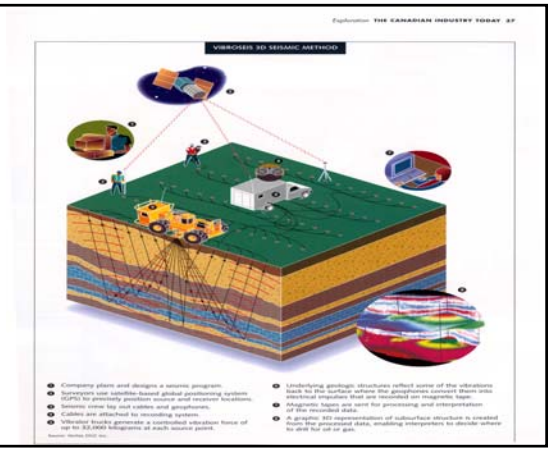
DEVELOPMENT SCENARIOS



OIL AND GAS EXPLORATION, DEVELOPMENT AND TRANSMISSION

- Exploration Phase
  - Seismic exploration
  - Exploration drilling
  - Abandonment
- Development Phase
  - Well preparation/ completion
  - Production
  - Direction wells
  - Development wells
  - Abandonment/ Reclamation
- Transmission
  - Project definition
  - Construction
  - Operations/ maintenance
  - Abandonment/ reclamation





SEISMIC EXPLORATION

- Where are seismic surveys done in the Mackenzie Valley?
  - 5 oil and gas development areas
  - Cameron Hills - 2 programs underway
  - Speculative seismic surveys done under Land Use Permit on Crown land
  - Many factors drive whether or not seismic is done:
    - Market conditions
    - Potential for finding hydrocarbons
    - Securing regulatory approvals

EXPLORATION DRILLING

- Why is it done?
  - To verify hydrocarbon reserves identified during seismic surveys
  - To quantify potential hydrocarbon reserves
- How is it done?
  - Set up and drill to target formation
  - Identify and test target formation
  - Flow back and flow test well

EXPLORATION DRILLING

- Where is exploration drilling done in the Mackenzie Valley?
  - Cameron Hills- 2 wells drilling
  - Liard Plateau- 2 wells drilling
  - Norman Wells- 1 well drilling
  - Colville Hills- 3 wells drilling
  - Peel Plateau- 3 wells drilling

Exploration Issues

Geophysics

Camp
Access Roads
Line Clearing
Water Courses
Water Supply
Off Shore Spill

Drilling

Camp
Fuel Storage
Access Road Alignment
Water Supply
Platform Construction

Solid Waste
Liquid Waste
Access Alignment
Cuts/Fills
Seismic Source(s)
Offshore Biota

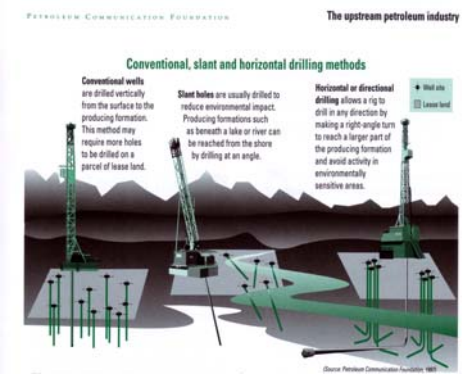
Sumps
Mud Storage
Mud Handling
Landing Strip
Offshore Spills

BGC

BGC

DEVELOPMENT / PRODUCTION

- Why is it done?
  - Petroleum reserves are not found in “underground lakes”, they are contained in the pores of certain sedimentary rock formations.
  - To supply markets for fuels, lubricants, plastics, etc.



DEVELOPMENT / PRODUCTION

- Where are the production wells in the Mackenzie Valley?
  - Cameron Hills- 3 wells producing gas & oil
  - Liard Plateau- 4 wells producing gas
  - Norman Wells- variable 8 production sites & ~ 325 wells contributing to producing oil
  - Colville Hills- 0 wells producing
  - Peel Plateau- 0 wells producing

Production Issues

Facilities

Camps
Batteries
Compressor Stations
Sumps
Flare Pits
Pumping Stations

Drill Pads
Tank Farms
Air Strips
Pipelines
Roads

Issues

Sumps
Flare Pits
Access Alignment
Cuts/Fills
Icings
Waste Disposal

Bridges
Culverts
Foundations
Groundwater Impact
Surface Water Impact
Hazard Assessment

BGC

Production Issues Continued

Typical Wastes – Potential Contaminants

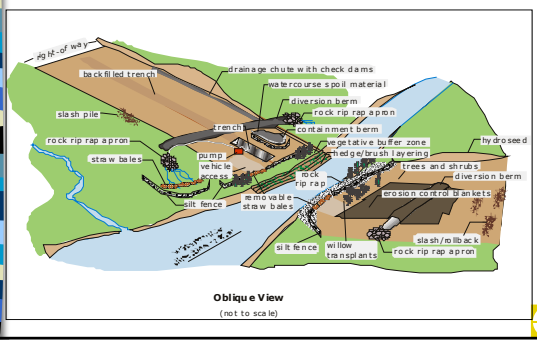
Hydrocarbons	Glycol
Metharcol	Condensate
Wax	De-emulsifies
Water Treatment	Frac Fluids
Acid	Drilling Muds
Produced Water	

BGC

TRANSMISSION

- Many factors contribute to the decision to construct a pipeline
  - Availability of proven hydrocarbon reserves
  - Market conditions and potential (supply and demand)
  - Securing regulatory approvals

Typical Erosion and Sediment Control Measures (CPWCC)



Oblique View

(not to scale)

TRANSMISSION

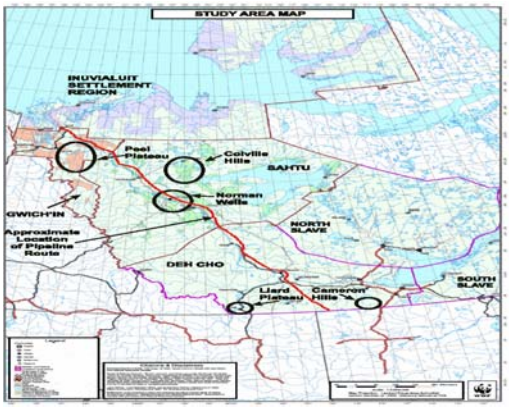
- Staging requirements
  - Accommodations
  - Helicopter / fixed wing landing sites
  - Fuel supply and storage
  - Equipment storage and maintenance

TRANSMISSION

- Resource requirements
  - Granular resources
  - Water
  - Survey, construction, engineering crews
  - Pipe material
  - Welding supplies

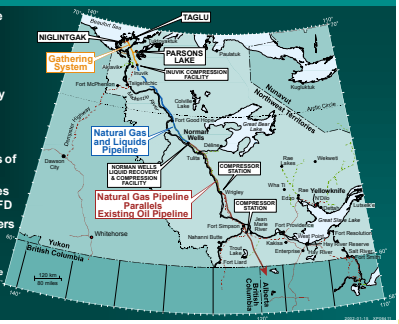
TRANSMISSION

- Pipelines in the Mackenzie Valley
  - Cameron Hills- late 2003 gas to Alberta
  - Pointed Mountain- 1972 gas to BC
  - Liard Plateau- 2000 gas to Pointed Mtn.
  - Liard Plateau- 2001 gas to BC
  - Norman Wells- 1986 oil to Alberta



Development Concept Overview

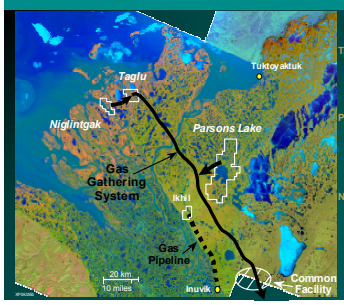
- Canadian onshore gas, three anchor fields
- Mackenzie Valley Pipeline
- Proven technology
- Minimize the environmental footprint
- Producer volumes of 800-1000 MCFD
- Aboriginal volumes up to 400-500 MCFD
- Accessible to others
- Utilizes ullage in existing pipelines
  - liquids to Enbridge
  - gas to TCPL



TRANSMISSION

- Mackenzie Valley Gas Pipeline
  - Twinned pipeline scenario - large dia. (30" - 36") gas, small dia. (10" - 12" - 14") liquids.
  - Liquids separation plant likely to be located in the vicinity of Inuvik.

Significant Discoveries - Onshore Gas



Taglu - 3 TCF
- Discovered 1971
- 100% Imperial Oil

Parsons Lake - 1.8 TCF
- Discovered 1972
- 75% ConocoPhillips Canada
- 25% ExxonMobil Canada

Niglintgak -1 TCF
- Discovered 1973
- 100% Shell Canada

- Provided by Mackenzie Gas Project, Imperial Oil - Resources Ventures Ltd.

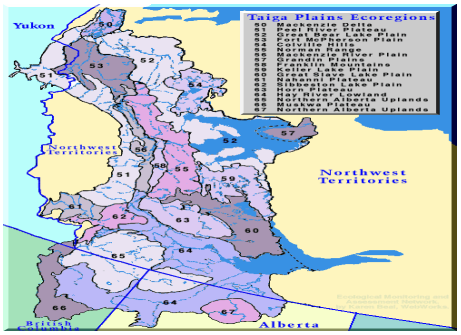
GAP ANALYSIS

Physical Components

Ecozones

- NWT has 6 ecozones
- Oil and gas development areas, and possible pipeline route all lie within the Taiga Plains
  - plateaus, lowlands, permafrost
  - black spruce, white spruce, jack pine, tamarack, paper birch, trembling aspen, balsam poplar
  - berries, mushrooms, roots, medicinal plants

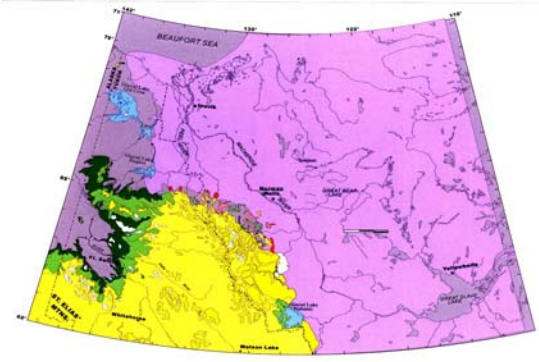
Taiga Plains Ecozone



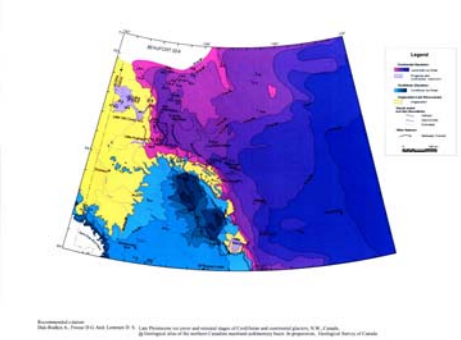
Terrain/Surficial Geology

- Mackenzie Valley landscapes were created by the last glaciation some 30,000 years ago.
- Glaciation re-directed preglacial drainage systems (including the Mackenzie River) to the Arctic Ocean
- Surficial geology is the study of terrain/landscapes
- What we know
  - Extensive surficial geology mapping terrain in NWT
  - Aggregate sources
  - Geotechnical engineering studies & evaluation of land sensitivity to disturbance.
  - Terrain influences the ecology of an area
  - Cultural sites are linked to surficial geology units (e.g. eskers)

Extent of Glaciation



Deglaciation History- NWT



Terrain/Surficial Geology

- Baseline- what we need to know:
  - A better understanding of the dynamics of slope movement to improve the accuracy of slope movement predictions.
  - Identify the location of locally significant soils, soils susceptible to compaction and terrain units that would modify drainage patterns.

Terrain/Surficial Geology

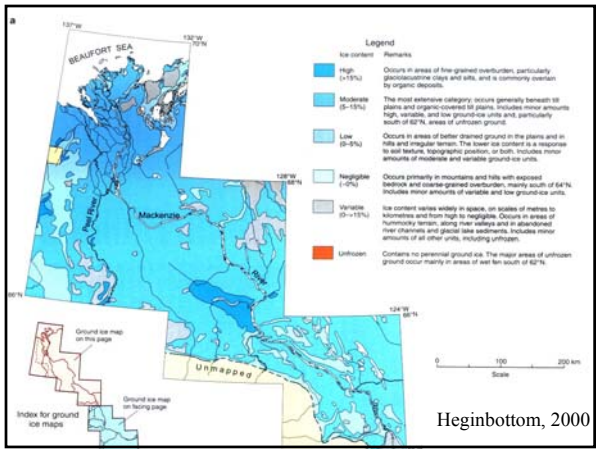
- Baseline- what we need to know (con't):
  - There is a need for geophysical and remote sensing technique development to improve interpretations and characterization of surface and subsurface terrain conditions.
  - Continued work to identify quality and quantity of granular resource supplies.

Terrain/Surficial Geology

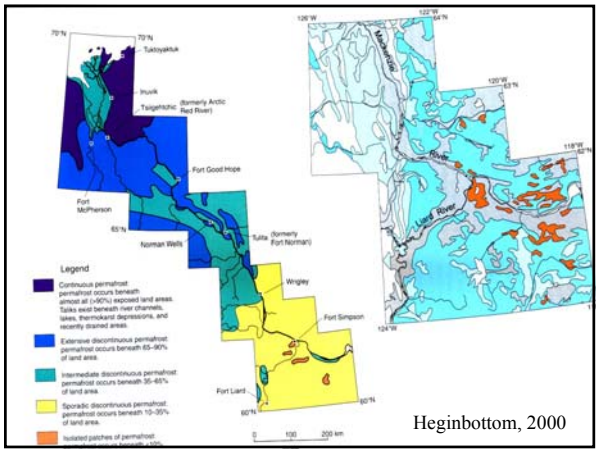
- Impact- what we need to know:
  - Continued research to fully understand the impacts of soil compaction and rutting if traffic is operating on partially thawed soil or soils which are susceptible to compaction.
  - Specific criteria by regulation to assess the trafficabilty of soil and terrain under varying conditions and mitigate these impacts (e.g. erosion control).

Permafrost

- Permafrost is defined as ground (soil or rock) that remains at or below 0 ° C for at least 2 years.
- Ground temperatures are a response to surface temperature regimes (microclimates) and the thermal properties of the soil materials (Burn, 1987).
- As a result micro-climate factors such as snow depth, slope aspect, surface wetness all impact permafrost, especially in discontinuous areas (Burn, 1987).
- Permafrost terrain has a surface active layer that thaws each summer underlain by frozen ground.
- Ground ice can be massive (ice wedges)or segregated (lenses).
- Long term indicator of climate change (ground subsidence)



Heginbottom, 2000



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Permafrost

- Baseline - what we need to know:
  - long term ground temperature monitoring across variety of permafrost terrain (climate change).
  - permafrost mapping and ground temperature monitoring around lakes/streams.
  - ground temperatures and near-surface ground ice conditions along a potential pipeline right-of-way (ROW) between Inuvik and Norman Wells.
  - ground temperatures and near-surface ground ice conditions for the five (5) developments areas.

Permafrost

- Baseline - what we need to know (con't):
  - Constraint mapping that would include information on the distribution of soil by type and permafrost proximity to water bodies.
  - Mapping thawed to frozen interface areas, and ice-poor to ice-rich interface areas is required.
  - Improved mapping of the spatial distribution of permafrost, ground ice, active layer and ground temperature data.
  - Research and analysis is required to assess the long-term effectiveness of drilling mud sumps in the study area.

Permafrost

- Baseline - what we need to know Enbridge Pipeline ROW:
  - A full analysis and assessment of the impact of the right-of-way on terrain conditions for the Enbridge pipeline.
  - Analyze data on near-surface ground temperatures and active-layer conditions.
  - Analyze data on slope movement and stability on the approaches to pipeline river crossings.
  - An assessment of soil-pipe interactions on hill slopes experiencing ground-ice creep is required.
  - The effect of chilled gas in the zone of transition between frozen and unfrozen ground needs to be studied. There is the possibility of frost aggradation and associated heave across the boundary .

Permafrost

- Impacts - what we need to know:
  - The impacts of permafrost degradation, and creation, on area hydrogeology.
  - The impacts of permafrost degradation, and creation, on slope stability.

Hydrogeology

- Baseline- what we need to know:
  - Baseline hydrogeology and groundwater research needed in other oil and gas development areas, such as the Liard Plateau, Cameron Hills and Colville Hills.
  - An understanding of the interactions between groundwater and surface water is needed along the proposed pipeline route in order to determine pathways for contaminants within the groundwater to transmit to the surface water.
  - Continued baseline information gathering of hydrogeology and groundwater in the Mackenzie Valley.

Hydrogeology

- Baseline- what we need to know:
  - Research into the potential impacts of surface and groundwater interactions resulting from permafrost melting in areas of shallow permafrost coverage.
  - In unfrozen ground a chilled pipeline would freeze water in the surrounding soil, potentially resulting in the formation of a frost bulb - an area of frozen soil in proximity to a pipeline - that may disrupt groundwater drainage patterns. Further study is required to understand the hydrological conditions along the pipeline route.
  - Groundwater contamination potential from areas of intensive activities (e.g., compressor stations, separation facilities).

Surface Water

- Baseline - what we need to know:
  - An increase in the frequency of water quality sampling at established monitoring stations in the Mackenzie River basin.
  - Develop a hydrocarbon water quality sampling program, which would operate during the development and operation of the pipeline.
  - Develop hydrological models that are applicable for the north, and more importantly for permafrost regions.
  - Snow survey network data is not complete for Mackenzie Valley or for oil and gas development areas.

Surface Water

- Baseline - what we need to know:
  - Further study is required in order to assess the ecological in-stream flow requirements of lakes and tributaries within the study area before large scale water withdraw is permitted.
  - There is a need for further study of baseline water quality parameters, including baseline hydrocarbon, organic and bacteriological data. Sediment load data is needed for the Mackenzie River and its tributaries.

Surface Water

- Baseline - what we need to know (con't):
  - An evaluation and classification of environmental contamination from 25 years of gas production in the Fort Liard area (i.e., lake and river sediment contaminant analysis) to provide a clearer understanding of the full impacts of gas production on the aquatic ecosystem .
  - Development of a hydraulic model to improve tracking of hydrocarbon spills.
  - Dispersion and travel time research is required for the Mackenzie River and its tributaries.
  - The identification of sensitive areas along the Mackenzie River is required.

Surface Water

- Impacts - what we need to know:
  - A better understanding of organic contaminant information is needed for the Mackenzie River its tributaries. Studies of fish livers have found hydrocarbons, toxophene and organochlorines but their origin has not been determined.
  - There is a need to fully understand the cumulative impacts of particular hydrocarbon development projects. An evaluation and classification of environmental contamination from 25 years of gas production in the Fort Liard area (i.e., lake and river sediment contaminant analysis) would provide a clearer understanding of the full impacts of gas production on the aquatic ecosystem.

Air

- What we need to know
  - need to expand the number of monitoring stations in the MV
  - need to establish baseline information in areas of potential oil and gas development
  - need to measure plant and animal sensitivity to changing air quality

Biological Components

Research requirements: General

- Site specific TK
- Traditional hunting and trapping areas
- Accurate wildlife population estimates for development areas
- Contaminant levels
- Abundance, biodiversity, species inventory

Research requirements: General

- direct mortality
- habitat loss and fragmentation
- barriers to wildlife
- sensory disturbance
- denning and nest site disturbance
- changes in competition, predation and health

Biodiversity

- TK research conveying biodiversity information
- Ecological land classification
- Comprehensive species listing
- Biodiversity guideline or standard

Vegetation and Forests

- Need for ecological land classification system
- Map locations of merchantable timber
- Map and describe wetlands
- Rare plant inventory
- Monitoring for forest health and biodiversity
- Incorporate TK into understanding of burning effects
- Need for local seed and seedling bank

Caribou: What we need to know

- Research required:
  - for calf/cow ratios; body weight/fat; parasites/diseases; levels of contaminants; number harvested; population size and trend; pregnancy rates; movements and distribution; migration routes; forage availability; habitat quality and suitability; wolf predation; and energetics
  - Change in predation - predator-prey dynamics
  - Impact of flaring
  - Cumulative impact of seismic and forestry activities on caribou habitat

Moose: What we need to know

- More comprehensive studies needed over a wider area
- Studies should include:
  - population size and trends
  - productivity
  - health
  - harvest levels and habitat inventory
  - traditional knowledge
  - Changes in predator-prey dynamics
  - Impact of habitat fragmentation

Dall's Sheep: What we need to know.

- Spot population estimates should be expanded to get a better idea of populations, health, and habitat needs
- Traditional knowledge

Bears: What we need to know

- More research required in oil and gas development areas and along potential pipeline route to determine population size, reproductive rates, habitat needs and harvest rates

Fur bearers: What we need to know

- Basic baseline information on all fur bearers, including:
  - population size
  - reproductive rates
  - age and sex structure
  - offspring survival rate
  - food and habitat availability
  - numbers harvested and trapped

Birds: What we need to know

- Need for population and density estimates of forest birds in areas where oil and gas development is expected
- Need to study how populations change as habitat disappears
- Need information on breeding habitat
- Need for many species data on population size, health, population trends, contaminant levels in tissues and response to climate change

Fish: What we need to know

- TK studies
- identification of critical and sensitive habitat in areas with oil and gas potential
- General mapping at 1:250:000 and detailed mapping at 1:50:000
- effect of climate change
- aquatic ecosystem studies
- more information on migrating fish
- Rates of disease
- Monitor benthic invertebrates as indicator of fish
- Impact of seismic energy on fish
- Toxicity and ecosystem studies looking at sediment characteristics and hydrocarbon impacts

Project impacts on fish

- impact of ice roads on fish and fish habitat
- removal of fish habitat
- change in water quality and quantity
- direct mortality
- contamination
- draw down

Impact of climate change

- What we know
  - climate change effects likely to be different in the southern MV versus the northern MV
  - changes in upper 4 m of permafrost expected this will affect sumps, pipeline construction, etc.
  - ice conditions
- What we need to know
  - climate change scenarios to understand how projects need to be designed
  - satellite imagery to track changes in vegetation over time
  - responsive mitigation measures suitable for oil and gas projects

Climate change

- Correlation studies linking climate change and changes in species distribution
- Ability to predict impact on fish from simple and complex climate events
- Impact of the loss of permafrost
- Impact of climate change on forest fire frequency, changes in ice thickness, changes in snow conditions

Appendix C

Presentation by R. McKechnie, DIAND: Environmental Studies and Research Funds (ESRF) - Overview and Northern Projects

Environmental Studies Research Funds

Overview &
Northern Projects

Profile

- The Environmental Studies Research Funds (ESRF) is a research program which sponsors environmental and social studies
- It is designed to assist in the decision-making process related to oil and gas exploration and development on Canada's frontier lands
- The ESRF program, initiated in 1983, receives its legislative mandate through the *Canada Petroleum Resources Act (CPRA)*
- Funding is provided through levies on frontier lands paid by oil and gas exploration companies that are permit holders

Profile (cont'd)

- The ESRF provides a forum for industry and government to develop a common knowledge base and to jointly design a focused study program which addresses the needs of both groups and avoids a repetition of effort and expense

Purpose

- To finance environmental and social studies pertaining to the manner in which, and the terms and conditions under which, petroleum exploration, development, and production activities on frontier lands should be conducted.

ESRF Management Board

The ESRF is directed by 12-member Management Board

- Bonnie Gray, Professional Leader of Environment at the NEB currently chairs the ESRF
  - Administration is provided by a small Secretariat within the NEB

Includes representation from:

- Federal government (4)
- Canada-Newfoundland Offshore Petroleum Board (1)
- Canada-Nova Scotia Offshore Petroleum Board (1)

ESRF Management Board (cont'd)

- Oil and Gas industry (4)
- General public (2) - *Chief Frank T'Seleie is the public member for the North*

Board's role is to:

- Set priorities for study topics
- Determine the program budget
- Facilitate the development of study proposals

Northern Study Areas for 2003

Priority Area: Studies in Response to Mackenzie Delta & Nearshore Beaufort Gap Analysis

- Assessing potential effects of near shore exploration activity on ringed and bearded seals in the near shore area of the eastern Beaufort Sea
  - Contract awarded to Tom Smith, EMC Eco Marine Corporation in association with Lois Harwood $100K ESRF
- Effects of seismic exploration on breeding migratory birds and their habitats in Kendall Island Migratory Bird Sanctuary, Mackenzie Delta
  - $90K ESRF to Canadian Wildlife Service, Environment Canada

Northern Study Areas for 2003 (cont'd)

- Analysis and mapping, in Geographical Information Systems format, the recent (1990-1998) aerial survey data on waterfowl and other aquatic birds in Mackenzie Delta Region $10K ESRF to CWS, EC
- Assessing The Impact Of Seismic Lines on Forest Songbirds $60K ESRF to CWS, EC

Priority Area: Discharges and Emissions

- Air monitoring in the Mackenzie Delta $80K - RFP to be prepared and issued:
  - Data collected to facilitate decision making by regulators and to allow proponents to manage air issues.

Northern Study Areas for 2003 (cont'd)

Priority Area: Discharges and Emissions (cont'd)

- Stage 1 Passive monitoring in Mackenzie Delta locations not monitored
- Stage 2 Continuous monitoring air emissions from specific events – e.g. well test flares

Priority Area: Waste

- Ongoing project: Development of Guidelines and Best Practices for Sumps in the Mackenzie Delta – support for an ongoing project initiated by industry

Northern Study Areas for 2003 (cont'd)

Priority Area: Seismic

- Assessing effectiveness of fish deterrents for use under ice, lakes and streams in the Mackenzie Delta -$100K- RFP to be prepared and issued:
  - evaluate the effectiveness of several fish deterrent devices on freshwater fish species of importance to residents in the delta. Data used to select mitigation measures.

First Draft of ESRF Priorities for 2004

Note: list of priorities will be pared down after a meeting of the Regional Advisory Team (ESRF Management Board Members with northern interests and stakeholders)

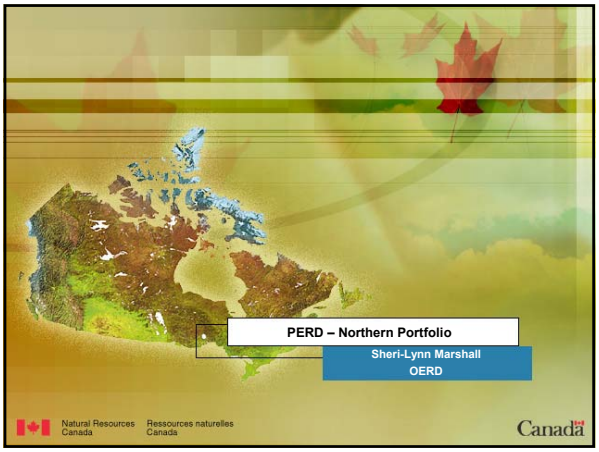
- seismic/acoustic effects onshore and offshore
- geo technical impacts and effects
  - (physical environment effects)
  - (terrain stability effects)
  - (Climate change)
- waste discharge/emissions (air and water) management and effects
- cumulative effects

First Draft of ESRF Priorities for 2004 (cont'd)

- critical fish and wildlife habitat disruption
- fish/wildlife/marine mammal disturbance
- heritage resources
- traditional knowledge
  - guidance on gathering
- resource mapping in the delta-GIS
- Information capture-support to Arctic Institute - ASTIS

Appendix D

Presentation by S. Marshall, NRCan: Program of Energy Research and Development (PERD)



Outline

- What is PERD?
- Participants
- Structure of the Program
- Northern activities in PERD

What is PERD?

- PERD = Program of Energy Research and Development
- a unique federal program focussed entirely on non-nuclear energy R&D
- a program at Natural Resources Canada that is delivered interdepartmentally through 12 federal departments and agencies
- funding provided to, and only through, the participating federal departments and agencies

Engaging PERD

PERD funds 12 federal departments and agencies, including:

- Agriculture and Agri-food Canada
- Canada Mortgage and Housing
- Environment Canada
- Fisheries and Oceans
- Health Canada
- Indian and Northern Affairs
- Industry Canada
- National Defense
- National Research Council
- Natural Resources Canada
- Public Works and Government Services Canada
- Transport Canada

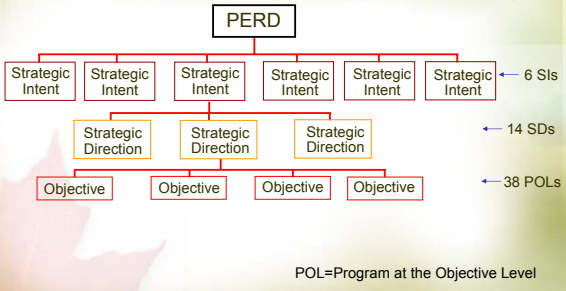
Features of PERD

- Strategic focus
- Collaborative approach
- Partnerships with recipients and industry
- Systematic evaluation
- Sound S&T expertise

Hierarchy of Priorities

1. To help the federal government fulfill its direct energy R&D responsibilities (standards, regulations, policy knowledge)
2. To conduct energy R&D for the public good
3. Reactive funding programs
4. Programs for demonstration, deployment, and engineering

Program Structure



POL=Program at the Objective Level

Features of a Program at Objective Level (POL)

- A POL may contain one or more activities
- The POL plan details the activities and their associated outputs, outcomes, and impacts, as well as accountabilities
- POL committees are composed of R&D performers, OERD Advisors, and representatives from regulatory agencies, industry associations and academia
- Lead by POL Leaders selected from the PERD community
- POL Committees are primary "point of contact"

S&T Strategic Intents

Strategic Intent 1: Fulfill federal government responsibilities while maximizing economic benefits and reducing environmental consequences from the expansion and diversification of Canada's oil and gas production

Strategic Intent 2: Foster cleaner sustainable transportation fuels and systems in order to improve the environment, reduce emissions, including GHGs, and to increase economic activity through development of domestic and export markets

S&T Strategic Intents

Strategic Intent 3: Reduce the overall energy intensity of Canada's buildings and community systems and, consequently, their associated GHG emissions while, at the same time, providing Canadian companies with potential economic opportunities

Strategic Intent 4: Reduce the overall energy intensity of Canada's resource sectors and, consequently, their associated GHG emissions while, at the same time, improving productivity and providing Canadian companies with potential economic opportunities

S&T Strategic Intents

Strategic Intent 5: Reduce the environmental impacts of Canada's electricity infrastructure, particularly greenhouse gases, through alternative electric power generation, increased efficiency of fossil-fueled plants and strategies to capture and manage emissions

Strategic Intent 6: Minimize the negative impacts of climate change on the Canadian energy sector

PERD Oil and Gas Portfolio (Strategic Intent 1)

3 Strategic Directions:

1.1 Onshore (mostly Oil Sands)

1.2 Offshore and northern

1.3 Cross-cutting environmental (on and offshore)

Strategic Direction 1.2

Offshore and northern oil and gas ($4.8M)

POLs

1.2.1. Offshore environmental factors
1.2.2. Oil & gas in the north
1.2.3. Marine Transportation and safety
1.2.4. Remediation of offshore drilling and production wastes, discharges & spills

Strategic Direction 1.3

Crosscutting Environmental Issues ($3M)

POLs

1.3.1. Regulate & reduce GHG emissions (primarily flaring)
1.3.2. Pipelines
1.3.3. Remediation of groundwater and soil

Northern components of PERD

- **(1.2.2) Northern POL focus - to provide knowledge to inform regulators and industry on the extent, severity, and mitigation of three types of factors:**
  - Geotechnical (ex. gas hydrates, coastal stability)
  - Environmental (ex. marine hazards, ecological sensitivities)
  - Engineering (ice-structure interation)
- **(1.3.2) Pipelines POL northern content – how is the pipe affected by its surrounding environment?**
  - Terrain characterization
  - Slope creep
  - Pipeline design modelling and guidelines
  - Risk-based hazard identification and mapping

Northern components of PERD (con't)

- **(1.2.1) Basin assessment – northern-related**
  - *Quantitative analysis of hydrocarbon systems of Northern Canada*
  - *Mapping the geographic distribution of undiscovered petroleum potential in Canada*
- **(3.2.2) Renewable energy and integrated systems in off-grid and remote communities**
- **(6.1.1) Climate change impacts of the energy sector**
  - Landfast ice
  - Ocean processes affecting ice cover

Approximate funding levels for FY 2003-04 (*northern components only)

- Northern POL: $624K
- Pipelines POL: $766K*
- Resource assessment: $263K*
- Estimates not available for remote communities and climate change work

Summary

- PERD has broad coverage in energy S&T, and is aligned with federal responsibilities and priorities
- PERD is contributing to northern R&D to the extent possible
- Although resources are limited, PERD is achieving significant outputs thanks to the collaborative nature of the program

Thank You!

Appendix E

Presentation by R. Tallman, DFO: Research Gaps on Aquatic Resources Related to the Development of Oil and Gas along the Mackenzie River Drainage.

RESEARCH GAPS ON AQUATIC RESOURCES RELATED TO THE DEVELOPMENT OF OIL AND GAS ALONG THE MACKENZIE RIVER DRAINAGE

R. Tallman

Research Gaps

- **General Points**
- **Fisheries/ Fish Populations**
- **Ecology/Life History/Environment**
- **Contaminants**
- **Distribution**
- **Ecosystem Understanding**
- **Species At Risk**

General Points

- DFO: Concerned with Conservation and Protection of Fish Stocks, Management of Fish Habitat, Aquatic Species at Risk, Management of the Oceans.

  Research to support "harvested stock' assessment in the Oceans and Territories, Habitat Requirements for fish, Aquatic Species at Risk, Oceanography & Limnology, Contaminants affecting fish.

General Points – The North

- Relatively little recent information
  - 1990s devolution expected – withdrawal from Freshwater Research
  - Unusual, environmentally sensitive ecosystem
  - Large Area – Little Resources for research
  - Limited Baseline Research describing fish and system
  - Recent Land Claims + Involvement of communities
  - = Uncertainty for resource use decisions

Fish Populations and Fisheries

- Dominated by a few species adapted to the north – Whitefishes and Charrs
  - Both groups – especially charrs (lake trout) very vulnerable to fishing pressure – Long lived, low productivity.
  - Data on abundance very spotty – poor time series or no data at all.
  - Models for species poor
  - Fisheries important to native people for food and culturally
  - Very low fishing pressure away from communities (< 1% exploitation rates)
  - Subsistence, Sport and Commercial Fishing
  - LAND CLAIM PROTECTION/ DFO Support
  - Species in rivers migratory or live in lakes

Fish Populations and Fisheries

- Expected Effects of Hydrocarbon Development
- MOST IMPORTANT: Greatly increased access for fishermen or short and long term. For example Travaillant Lake and area could increase fishing pressure 20 – 30 fold as a result of increased access
- Populations probably cannot sustain these new fishing levels

Fish Populations and Fisheries

- Research to determine the effects of hydrocarbon development
  - 1) Longer term studies of population abundance at key sites (Baseline)
  - 2) Studies designed to improve prediction of the value of the population and its response to increased fishing pressure
  - 3) General ecological studies – Spawning, Rearing, Overwintering sites, migratory patterns
  - 4) TEK studies related to fish production and migration.
  - 5) Development of good predictive models of northern fish populations – Mathematical models to estimate the extent of damage for mitigation questions.

Life Cycle of Fishes

- Many Species appear to have complex life cycles with both migratory and sedentary forms.

Many species life cycles are not described adequately.

- The key rearing, overwintering, and spawning habitats are undefined.
- Migratory routes and timings are not described.
- Basic environmental needs for maintenance not described (i.e. minimum and maximum temperature, dissolved oxygen requirements, pH, water clarity and sedimentation).
- Interactions with other species.

Life Cycle of Fishes

- Possible effects of hydrocarbon development
  - Loss of key rearing, overwintering, and spawning habitats.
  - Disruption of migration to spawn, rear or over-winter causing substantial loss of production.
  - Change in environmental parameters such as minimum and maximum temperature, dissolved oxygen requirements, pH, water clarity and sedimentation.
  - Disruption of other species that are Prey, Competitors, Predators or parasites.

Life Cycle of Fishes

- Research on the effect of development for
  - key rearing, overwintering, and spawning habitats.
  - Migratory routes.
  - Environmental parameters such as minimum and maximum temperature, dissolved oxygen requirements, pH, water clarity and sedimentation.
  - Disruption of other species that are Prey, Competitors, Predators or parasites.

Aquatic Contaminants

- The Arctic appears to be a sink for many contaminants
- Contaminants persist for long periods
- Fish species live long and hence bio-accumulation is a problem
- People rely on top predatory fishes such as lake trout and thus can absorb very high doses of contaminants

Aquatic Contaminants

- Possible effects of hydrocarbon development
  - Contaminants introduced during construction – Chemicals left on site, disruption of land causing unbinding of contaminants.
  - Spillage due to accidents.
  - Access effects so that others may bring in oil drums, gas and so on after in the course of fishing or trapping activities.

Aquatic Contaminants

- Research on the effect of development:
  - Need baseline (pre-development) levels in the harvested species such as lake trout and lake whitefish.
  - Short-term post development levels.
  - Long-term changes in contaminant levels in fish and aquatic environment.
  - Research into models of contaminant pathways within the ecosystem (food web studies – flux rates within the food web)
  - Studies to measure the background levels from other sources.

Distribution

- The range and distribution of species in the Arctic and sub-Arctic is poorly known (eg. Bull trout and short jaw cisco distribution – uncertain if at risk in the territories or just poorly described up until now.)
- It is undoubtedly changing due to recovery from glaciation but has been accelerated by rapid climate change.
- Riverine species and lake dwelling species have greatly different dispersal patterns and hence the underlying genetic variation will be quite different.

Distribution

- Possible effects of hydrocarbon development
  - Species distribution could be affected – species range reduced?
  - Effects obscured by climate change effects.

Distribution

- Research Needed
  - A GIS based inventory of the current geographical and temporal distribution of all Arctic and sub-Arctic species both adult and juvenile life stages.
  - Research on the effect of climate change on species distribution in the north.

Ecosystem Components

Much that has been said about fish applies to all aquatic species (including forage fishes). There is a lack of information about the ecology and the eco-system role of many species.

There is a need for research on the entire aquatic ecosystem from water chemistry through primary, secondary and tertiary trophic levels.

Species at Risk

The new species at risk act will place serious demands on the research community for informative studies in the Arctic. DFO has previously been mainly concerned with harvested species with a nod to the idea that “forage fishes” were important. With the species at risk act there will be a need for more research to determine which species are vulnerable regardless of their direct economic value.

Species at Risk

Hydro-carbon development may touch species that are listed under the SARA provisions.

It will be important to have detailed research on their ecological needs for rearing, spawning and over wintering.

TAKE HOME

The major point is that the lack of knowledge creates uncertainty regarding the effects of hydrocarbon development.

Research is required to address baseline information gaps in fish population abundance and diversity, other aspects of fish ecological requirements, on contaminants and distributional changes.

- Special efforts may be required in SARA cases.

Filename: DFO RESEARCH GAPS ON AQUATIC RESOURCES RELATED TO THE
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Author: gstewart
Keywords:
Comments:
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Appendix F

Presentation by K. McCormick, Environment Canada: Environment Canada's Information Needs Related to Hydrocarbon Development in the NWT.

Environment Canada's Information Needs Related to Hydrocarbon Development in the NWT

Science Gaps Workshop
Yellowknife, NT
April 8, 2003

Environment Canada Environnement Canada

Overview

- EC Mandate/Organization
- Development Scenarios
- Key Issues
- Information Gaps

EC Mandate/Organization

- Environmental Conservation Branch (ECB)
  - Migratory birds, species at risk, protected areas, water quality
- Environmental Protection Branch (EPB)
  - EA, contaminants, deleterious substances, environmental emergencies
- Meteorological Service of Canada (MSC)
  - Weather, air quality, climate, water quantity
- National Water Research Institute (NWRI)
  - Freshwater research

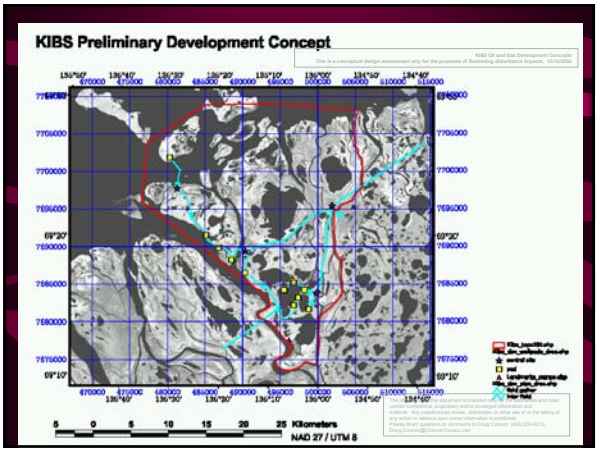
Development Scenario

- Mackenzie Valley Pipeline Route
- Mackenzie Valley Exploration Areas
- Mackenzie Delta Production
- Kendall Island Bird Sanctuary

Mackenzie Valley Pipeline Route

Map produced by Aboriginal Pipeline Group, provided as a public service by *NORTHERN GAS PIPELINES*: http://www.arcticgaspipeline.com/

Taken from: Cizek, P. and J. McCullum. 2002. Fort Liard Area Cumulative Impacts Mapping Project: Technical Report. Prepared for: Canadian Arcite Resources Committee and Canadian Parks and Wilderness



Key Issues

- Resource Management
- Environmental Assessment
- Cumulative Impacts
- Environmental Emergencies
- Climate Change

Resource Management

- Migratory Birds
  - Waterfowl/Waterbirds
  - Shorebirds
  - Forest Birds
- Water Quantity
- Aquatic Quality
- Key Habitats

Environmental Assessment

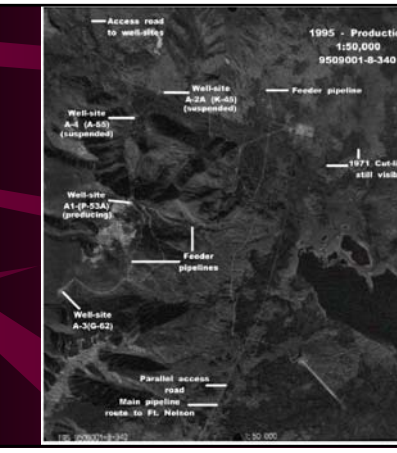
- CEAA
  - Responsible Authority for KIBS
  - Federal Authority everywhere else
  - Provide specialist advice
- Land Claim Legislation
  - Provide specialist advice

Cumulative Impacts

- Spatial and temporal impacts
- Regional land use planning
- Develop indicators and thresholds

Taken from: Cizek, P. and J. McCullum. 2002. Fort Liard Area Cumulative Impacts Mapping Project: Technical Report. Prepared for: Canadian Arcitc Resources Committee and Canadian Parks and Wilderness Society

Taken from: Cizek, P. and J. McCullum. 2002. Fort Liard Area Cumulative Impacts Mapping Project: Technical Report. Prepared for: Canadian Arcitc Resources Committee and Canadian Parks and Wilderness



Taken from: Cizek, P. and J. McCullum. 2002. Fort Liard Area Cumulative Impacts Mapping Project: Technical Report. Prepared for: Canadian Arcitc Resources Committee and Canadian Parks and Wilderness

Taken from: Cizek, P. and J. McCullum. 2002. Fort Liard Area Cumulative Impacts Mapping Project: Technical Report. Prepared for: Canadian Arcitc Resources Committee and Canadian Parks and Wilderness

Environmental Emergencies

- Risk of chronic/catastrophic hydrocarbon spills
- Identify sensitive areas/resources at risk

Climate Change

- Mackenzie Delta/Valley predicted to be most affected by climate change
- Terrain, water, ice, vegetation and habitat changes
- Change in species distribution
- Long-term integrity of development structures

Information Gaps

- Key Habitat Sites
- Kendall Island Bird Sanctuary
- Forest Birds
- Shorebirds
- Waterfowl & Waterbirds
- Aquatic Quality
- Water Quantity
- Environmental Emergencies
- Air Quality
- Climate Change

Key Habitat Sites

Existing Information:

- Occasional Paper (1991)
- Based on current information

Still Need:

- Updated Compendium

KIBS:


P. Latour

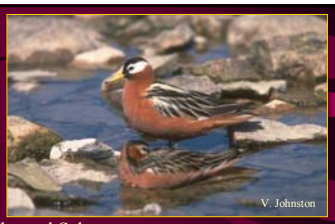
- Existing Information:
  - Distribution and abundance of Delta waterfowl
  - Impacts of seismic lines on vegetation and songbird communities
  - Sump thermal characteristics
- Still Need:
  - Impacts of sumps on soil chemistry and vegetation
  - Science-based regulation (eg. Ice-road thickness)
  - Updated habitat and wildlife inventory

Forest Birds


C. Machtans

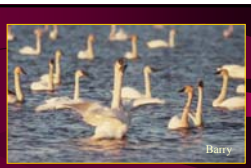
- Existing Information:
  - Baseline data in Fort Liard
  - Impacts of seismic lines on forest birds
  - NWT Bird Checklist Survey
- Still Need:
  - Baseline densities along pipeline route
  - Baseline densities in Peel Plateau, Cameron Hills, Colville Hills, Norman Wells
  - Does pipeline ROW affect predation on forest birds?
  - CI of habitat loss to forest birds in Fort Liard

Shorebirds


V. Johnston

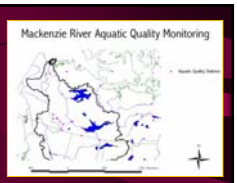
- Existing Information:
  - Limited surveys in Delta and Sahtu
  - Landsat data to ID priority habitat in outer Delta
- Still Need:
  - Baseline breeding dist'n and abundance in Delta, Peel Plateau, Colville Hills, Norman Wells, Liard, Cameron Hills and along pipeline route

Waterfowl & Waterbirds


Barry

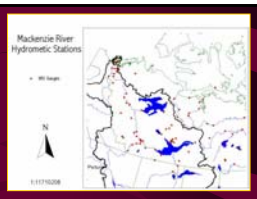
- Existing Information:
  - Broad-scale aerial surveys of Valley
  - Ongoing IFA implementation projects
  - GIS summary of current information
  - DU breeding pair surveys in ISR and Norman Wells
- Still Need:
  - Monitoring of Tundra Swans as indicator of CI in Mackenzie Delta
  - Updated estimates of numbers, distribution, and productivity of important "subsistence" species in the Mackenzie Delta

Water Quality



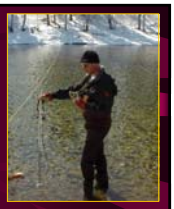
- Existing Information:
  - Stream sediment data in select areas
  - Background contaminants in Delta
  - Stream water quality data (inorganics), Mack & Liard Valleys (1960-)
- Still Need:
  - Expand contaminant info & baseline water quality data
  - Expand stream/pond/lake sediment quality data
  - Develop water quality index
  - Natural vs. anthropogenic sources of contaminants

Water Quantity



- Existing Information:
  - Water quantity data from hydrometric stations (Mack Valley 1938 -, Mack Delta 1970 -)
  - Sediment (quantity) monitoring in Mack Valley & Delta (1972-97)
  - Mackenzie River Basin Study (1978-81) - physical, biological, socio-economic evaluation for resource management
  - Water quantity, channel stability & erosion, & sediment regime monitoring & studies
  - Mackenzie Basin hydrologic process modeling (GEWEX: 1993-2005)

Water Quantity

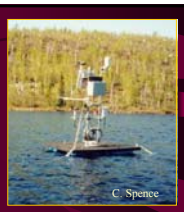


- Still Need:
  - Evaluate historic data to predict streamflow/floods for pipeline project design
  - Monitoring & modeling of Delta flows/levels: ice jams, channel erosion, spill dispersion
  - Hydrology & erosion studies on development impacts in sensitive terrain

Environmental Emergencies

- Existing Information:
  - Sensitivity mapping & spill dispersion model for 75 km reach of Mackenzie River @ N. Wells
- Still Need:
  - Updated sensitivity maps for entire Mackenzie River
  - Sensitivity maps for Liard River

Air Quality



- Existing Information:
  - Soon to have baseline monitoring in Inuvik, Norman Wells and Fort Liard (in partnership with RWED)
- Still Need:
  - Regional emissions inventory
  - Regional air quality monitoring & modeling for Delta and Sahtu

Climate Change

- Existing Information:
  - Mackenzie Basin Impact Study: Impacts of climate change/variability on environment (1990-96)
  - Reference Hydrometric Basin Network (1994-)
  - GEWEX - MAGS (1993-2005)
- Still Need:
  - Regional-scale Model
  - Analysis of baseline data
  - Sector-specific studies to define potential impacts of climate change

Summary

- Think Long Term
- Consider the Big Picture
- Proactive Approach
- Climate Change Impacts
- Monitoring vs. Research
- Partnerships
- Organizational Capacity

Appendix G

Presentation by R. DiLabio, NRCan: Science Gaps and Information needs in the Mackenzie Valley and Delta: NRCan's View.

Science Gaps and Information Needs in the Mackenzie Valley and Delta:
NRCan's View

Workshop at Yellowknife,
April 8-9, 2003

Outline

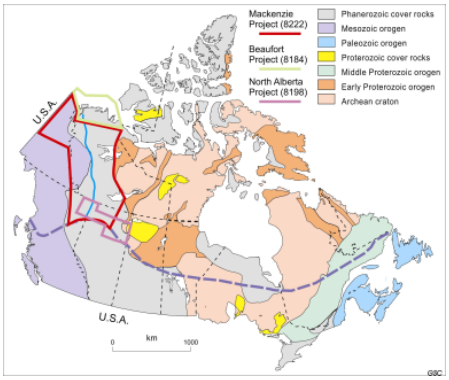
- Topographic Maps
- Geology
- Permafrost
- Coastline
- Pipelines
- Slope, Terrain and Pipeline Stability
- Databases
- Climate Change
- Budget 2003
- Gaps

Digital Topographic Maps at 1:50 000

- Size of gap in coverage depends on route selection and possible new fields, e.g., Colville Hills, Peel Plateau. Current gap is 15 to 20 map sheets
- NRCan can cover some costs if gaps identified early
- Cost for vectorization is $1400 per 1:50k sheet
- Areas of rapid change; e.g. delta and coast may need LIDAR surveys or satellite imagery

Northern Basins Geoscience Knowledge Around Pipeline Corridor

- Good knowledge of Beaufort-Mackenzie petroleum system
- Moderate knowledge of regional stratigraphy and facies relationships
- Variable map coverage (250K, 50K) across area
- Poor regional knowledge of basins' achitecture
- Poor knowledge of petroleum systems in southern and central areas
- Old (BF-MCK) or non-existent (Int Plains) Petroleum Resource Assessments



Mackenzie Corridor Project (8222) Highlights

- Digital atlas-based project
- Fulfils the need of communities near the proposed Mackenzie Pipeline route
- To stimulate investment by resource companies
- To encourage community to use geoscience information in their land use decisions

Mackenzie Corridor Project (8222) Highlights

- Surficial and bedrock mapping in the Norman Wells-Tulita area will provide permafrost and granular resource information
- Permafrost characterization studies will help northern communities and exploration companies in geotechnical risk assessment
- New aeromagnetic maps will stimulate further resource exploration.

Petroleum Resource Assessment

Beaufort-Mackenzie Delta Project (8184) Highlights

- Acquire, compile, and interpret extensive, multi-parameter geoscience data for the Beaufort-Mackenzie region
- Make information available to industry, government and other community stakeholders
- Design and delivery of nontraditional community outreach products and activities
- Geoscience basis for evaluating resource potential which will factor into community-based decisions on land use and attract global investment dollars

Beaufort-Mackenzie Delta Project (8184) Highlights

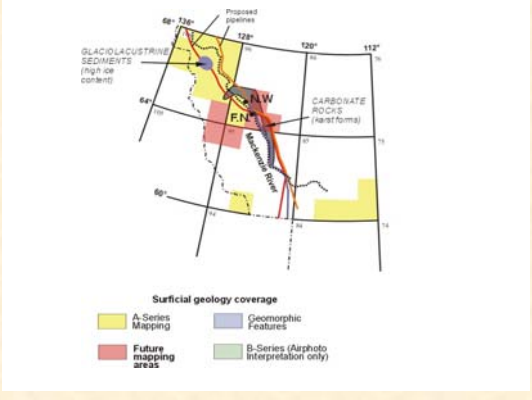
- Tertiary/pre-Tertiary biostratigraphy

Organic petrology

- Potential petroleum source rocks will be identified
- New bedrock map compilations
- Integration into models of hydrocarbon generation, expulsion, migration and entrapment

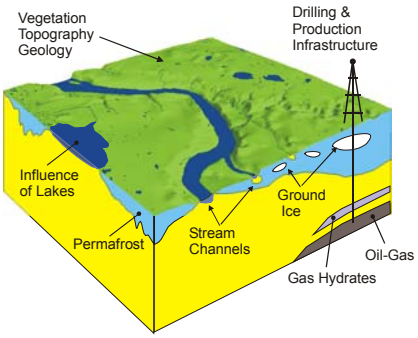
Northern Alberta and British Columbia Project (8198) Highlights

- Surficial geology maps in Alberta and British Columbia
- 3-D compilation of surficial geology for shallow gas reservoirs
- Stratigraphic drilling (TGI?)
- Permafrost, terrain sensitivity, and landslide assessments
- Kimberlite investigations
- Stream sediment surveys (TGI?)
- Glacial dispersal mapping

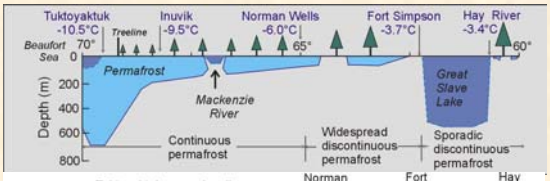


Norman Wells sinkhole.

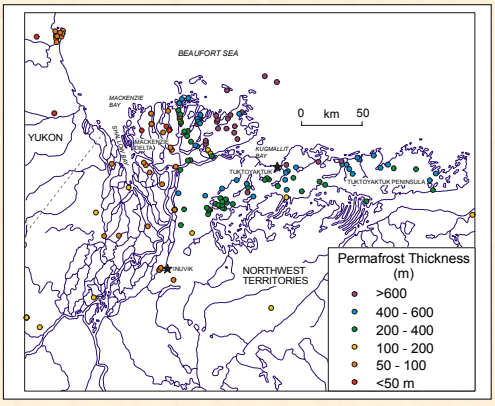
Geocomplexity of Terrestrial Permafrost Landscapes

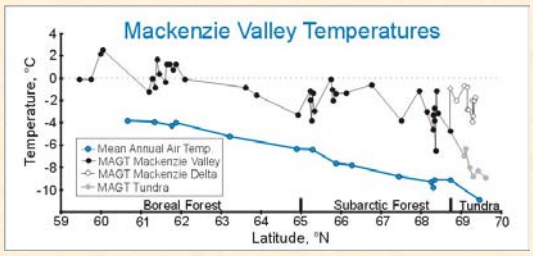


Permafrost in the Mackenzie Valley

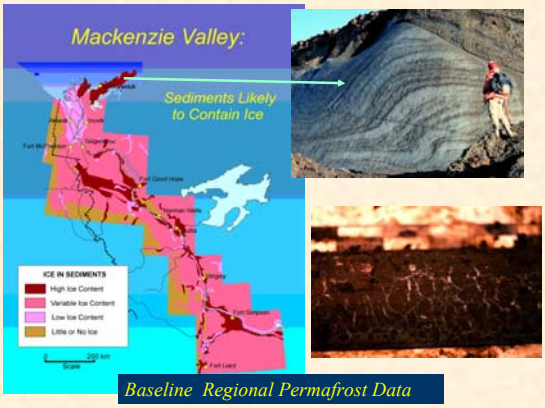


	Tuktoyaktuk	Inuvik	Norman Wells	Fort Simpson	Hay River
Active layer thickness	35 cm - >1.0 m	50 cm - >1.5 m	60 cm - >1.5 m	1.25 m - >2.0 m	?
Permafrost thickness	200 - >700 m	100 - ~200 m	0-60 m	0-10 m	0-5 ? m

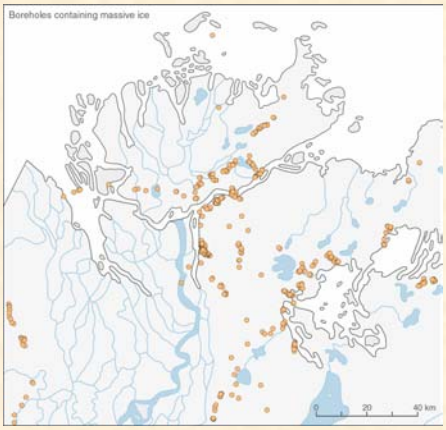




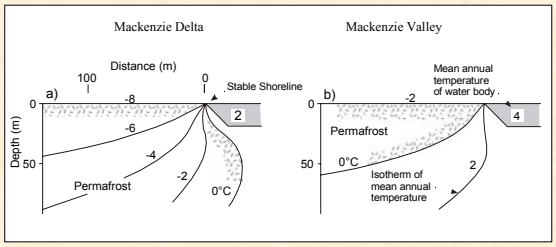
Baseline Regional Permafrost Data



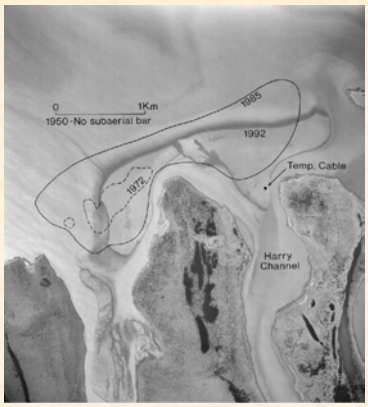
Baseline Regional Permafrost Data



Permafrost and stable shorelines



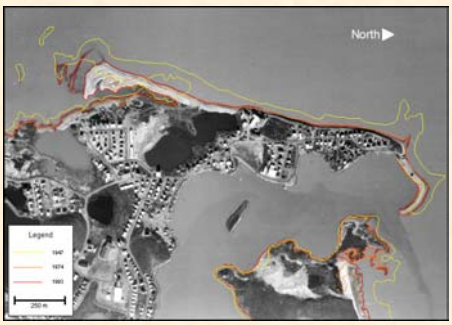
Isotherms of average annual ground temperatures adjacent to a laterally stable shore for the Mackenzie Delta and Valley



Development of a bar at the mouth of Harry Channel (east side of the Mackenzie Delta) with former outlines for 1985 and 1972 shown on a 1992 aerial photo. No bar is present on aerial photography for 1950.

Coastal erosion in Tuktoyaktuk

(data from Steve Solomon, GSC)



Coastal Issues

- **Definition of maximum flooding extent and return intervals under present climate and sea level**
- **Flooding extent in the future (30-50 years) due to changing rates of sea level rise and delta subsidence**
- **Safe and efficient routing of coastal feeder pipelines**

Pipeline Materials: Gaps - 1

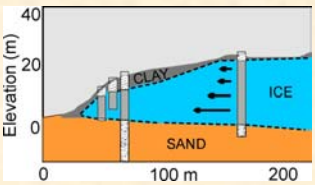
- Engineering Critical Assessment of Heavy-Wall, High-Strength Linepipe
- Low-Temperature Fracture Characteristics
- Stress-Corrosion Cracking of X80 and X100 Steels, and Coatings to Prevent Corrosion and SCC
- Welding of Heavy-Wall High-Strength Linepipe Steels
- Development of High-Strength Linepipe Steels

Pipeline Materials: Gaps - 2

- Intelligent Systems for Pipeline Infrastructure Reliability (ISPIR)
- Management of Microbiologically Influenced Corrosion (MIC)
- Internal Corrosion of Transmission Pipelines

Slope Stability and Deformations

Deep seated failures

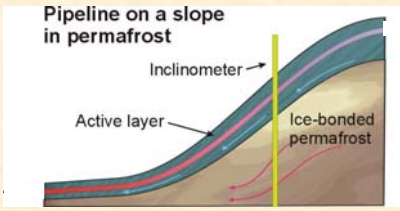


Slope Stability:

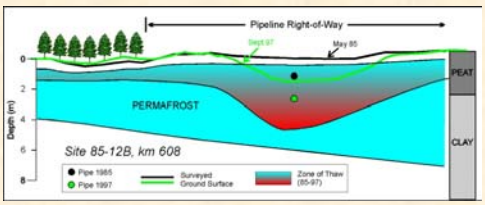
Creep

(gradual movements)

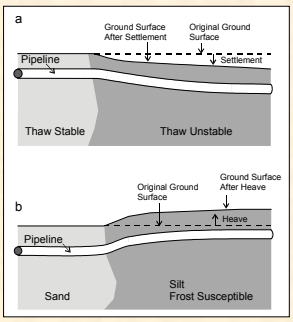
Arrows indicate direction of deformation (flow) of ground materials



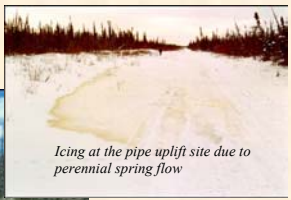
Terrain Stability & Technical Issues: Thaw bulb development and thaw settlement



Permafrost causing stress upon pipelines



Terrain Stability & Pipeline Integrity Issues: Upheaval Buckling



Icing at the pipe uplift site due to perennial spring flow

Pipe uplift in low density soils, at a location of perennial spring flow, due to freeze/thaw cycles

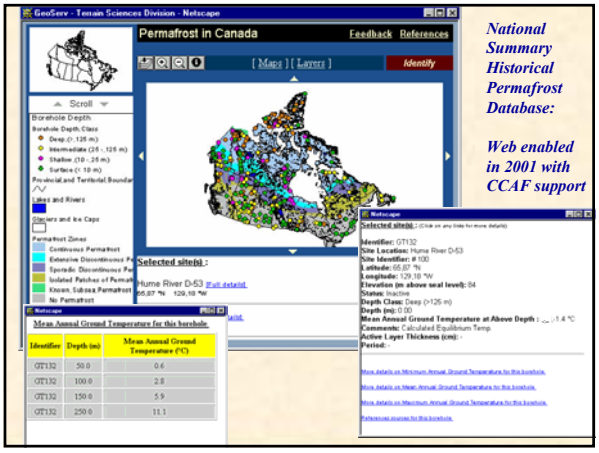
Key aspects, knowledge requirements

- Active layer
- Thickness
- Distribution, spatial and vertical; taliks
- Thermal regime
- Ground ice, occurrence and origin; degree of ice bonding
- Understanding of geologic history and complexity
- Understanding of active landscape altering processes – controls, rates of change and magnitudes
- Response to disturbances
- Climate change sensitivity, thresholds and impacts

Databases – Mackenzie

- compile, retrieve, upgrade, modernize
- digital formats, relational GIS

- Efforts begun/revived in last few years through CCAF, PERD

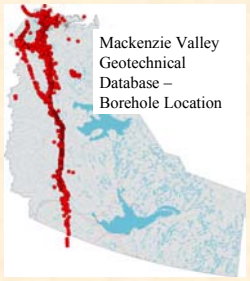


National Summary Historical Permafrost Database:

Web enabled in 2001 with CCAF support

Mackenzie Valley Geotechnical Database

Compilation of data from >12,000 boreholes describing the physical, geothermal and geotechnical properties of surficial materials along proposed aand existing transportation routes.

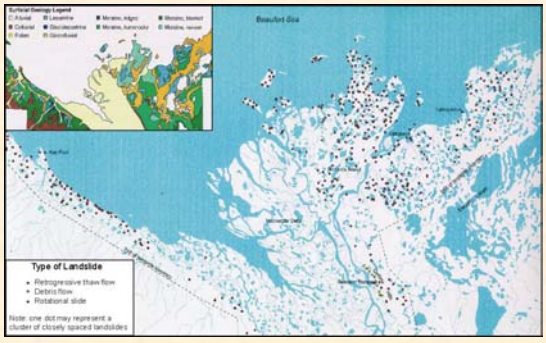


Mackenzie Valley Geotechnical Database – Borehole Location

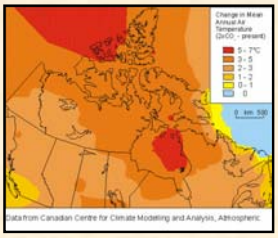
Attributes for boreholes include:

- soil type
- grain size
- moisture content
- density
- Atterberg limits
- permafrost/ground ice conditions

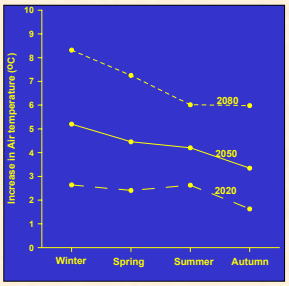
Landslide Database



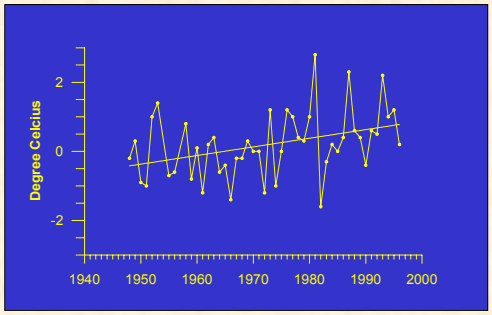
Climate change predictions



Northern Canada by 2050



Tuktoyaktuk

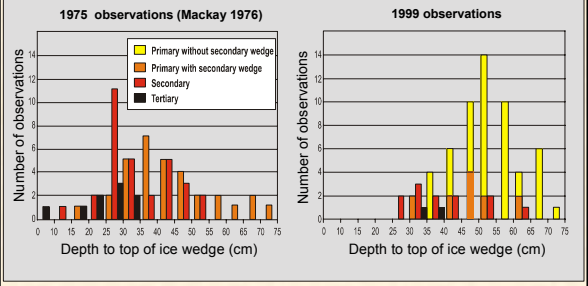


Temperature change in Tuktoyaktuk since 1948

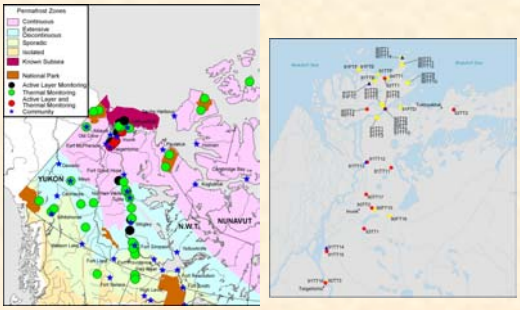
(approx. increase of 1.3°C)

DEPTH TO TOP OF ICE WEDGES

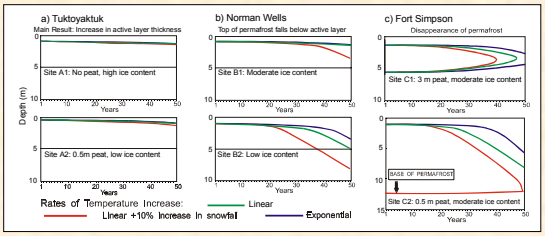
Richards Island and Tuktoyaktuk areas



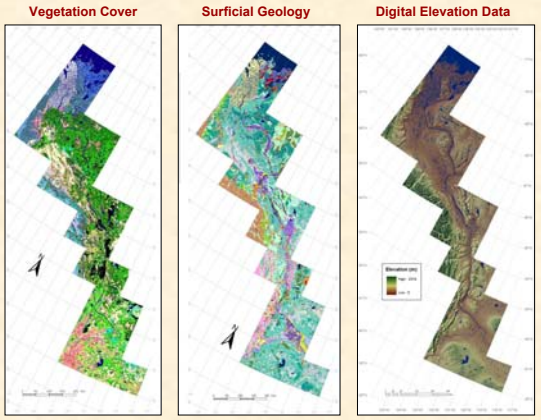
Permafrost and climate change - Existing permafrost thermal or active layer monitoring sites, western Arctic



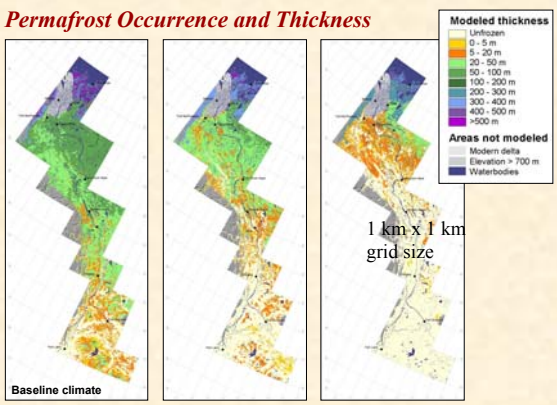
Modelling Permafrost Response to Climate Warming



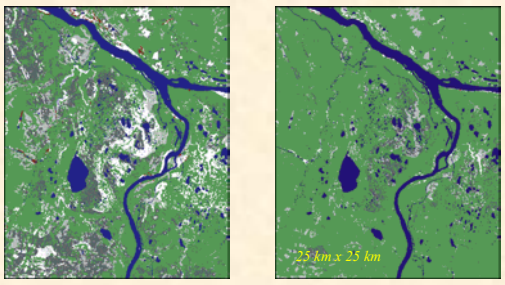
Predicted maximum annual thaw depth under 3 different climate warming scenarios at 3 locations in the Mackenzie Valley.



Permafrost Occurrence and Thickness



Permafrost distribution models implemented in GIS framework - mapping existing conditions and modeling future climate warming scenarios: Fort Simpson area



Present (- 4°C) *About 2030 (- 2°C)*

Permafrost / Geotechnical Issues (Report by D.E. Lawrence, February 2003)

- Data on soil thermal regimes
- Terrain stability; drainage and erosion
- Frost heave, thaw settlement
- Slope stability (landslides and creep)
- Coastal erosion and stability, stream crossings
- Channel, bar and island stability
- Pipe-soil interactions
- Movement, behaviour and containment of wastes in permafrost
- Effects of climate warming

Federal Budget 2003

- PCSP funding increase of $3M per year ongoing. Support available to all northern researchers
- TGI funded at $5M per year for two years. Significant support for energy-related GSC research along the likely pipeline route (four major projects can be augmented)
- Confirmed funding for research in the Beaufort Sea for the next two fiscal years

Operational Gaps

- Scientific and Systemic/structural
  - –Access to and sharing of information (old and new; lost; proprietary)
  - –Format/platform of data – update, digitize, modernize
  - –Limited funding; spread too thin (“workshop burnout”)
  - –Underestimation of resources requirements (financial/human)
  - –Logistical support
  - –Loss of corporate memory, continuity
  - –Short term perspective, loss of long term
  - –Requirement for preparedness on part of all stakeholders

Some Science Gaps and Information Needs

- Baseline data on permafrost, soil properties and terrain stability
- Updates of old databases
- Performance of existing pipeline and new pipeline materials
- Monitoring sites along existing and possible rights-of-way
- Digital topographic base maps
- Surficial geology maps
- Hydrocarbon assessments
- Coastal flooding models, delta subsidence vs. sea level
- Predictions of climate change impacts

Appendix H

Presentation by R. Hurst, DIAND: Research and Information Priorities

Department of Indian and Northern Affairs

Research Information and Priorities

DIAND Divisions Involved with Research Associated with Oil and Gas:

- Environment and Conservation;
- Water Resources;
- C.S. Lord Geoscience Centre;
- Lands Program; and
- Northern Affairs Program coordinating role and involvement in research funds (PERD) and programs (ESRF)

Water Resources – Research Priorities:

- Implement baseline water quality monitoring and site assessment for gathering system and pipeline stream crossings (will start in May 2003);
- Analysis of data collected by NRCan for the Norman Wells Pipeline;
- Data analysis of storm surge frequency and the effects of the changing open water period on storm surges;
- Probability model of ice jamming events in outer Mackenzie Delta;

Water Resources cont.

- Analysis of stream channel erosion and avulsions in the Mackenzie Delta to determine rates and frequency;
- Climate change predictions for the Mackenzie Delta and Valley and effects of ground warming on a chilled pipeline;
- Thermal monitoring of sumps in Mackenzie Delta (being conducted); and
- Drilling waste characterization (being conducted).

Environment & Conservation – Research Priorities:

1) **NWT Protected Areas Strategy:**

- Candidate Protected Area Evaluations – Priority;
- Mapping of ecologically representative areas in the Mackenzie Valley; and
- Non-renewable resource potential mapping in the Mackenzie Valley.

Environment and Conservation cont:

2) NWT Cumulative Impact Monitoring Program and Audit Monitoring Priorities

- NWT Cumulative Impact Monitoring Program will collect information **(both scientific data and traditional knowledge)** for monitoring the cumulative impact of land and water uses in the NWT. Program is community based and provides capacity building and training opportunities for community people.

A number of monitoring gaps and potential future monitoring programs have been identified for all of the following environmental valued components:

- Caribou;
- Moose;
- Land Mammals;
- Marine Life;

NWT CIMP cont.

- Birds (land and marine);
- Water and sediment quality;
- Water quantity;
- Air quality;
- Snow, Ground Ice and Permafrost;
- Fish Habitat, Population and Harvest;
- Fish Quality;
- Vegetation;
- Climate and climate change; and
- Human Health and Community Wellness.

NWT Cumulative Effects Assessment and Management (CEAM) Strategy and Framework:

Examples of CEAM Research Priorities

- Thresholds, carrying capacity, limits to changes, resilience, ecological cause and effect relationships;
- Best practices for managing CE;
- Tools for predicting impacts of linear and non-linear developments; and
- How to distinguish natural variability from effects of human activity.

C.S. Lord Geoscience Centre Research Priorities:

- NWT Petroleum Geology "Atlas" is a four year collaboration between CS Lord petroleum geology staff and the GSC (Calgary Office). Its primary objective is to provide a modern synthesis of subsurface geology for a corridor along the proposed Mackenzie Valley Natural Gas Pipeline.
- Conducting Resource appraisals of the Horn Plateau and Travaillant Lake in the Gwich'in Settlement Area.

Lands Program Research Priorities:

- Developing a regional granular resources management plan with the Inuvialuit for the ISR;
- Conducting research (under PERD) on Massive ice in granular resources;

Lands Program cont.:

Additional Research is required in the following areas:

- **On-going program of regional resources inventory; and**
- **Require re-evaluation of existing granular data based on revised surficial geology and current understanding of permafrost issues.**

Overall Gaps which need to be considered:

- A current view of industry practices (seismic, drilling and development) will assist in assessing possible impacts and identifying new research.
- A scan of GIS models could reveal areas where assumptions need more effective ground-truthing and refinement of models.
- Knowledge Management is an area which warrants attention.
- Availability of Funding.

Appendix I

Presentation by R. Case, GNWT (RWED): RWED Information and Research Priorities for the Mackenzie Valley.

RWED Information and Research Priorities for the Mackenzie Valley

Dr. Ray Case, Manager, Technical Support
Wildlife and Fisheries Division

Resources Wildlife and Economic Development
Government of the Northwest Territories

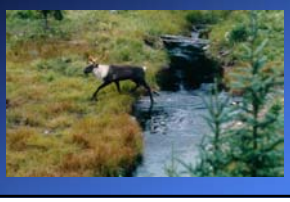
RWED Information and Research Needs

- Wildlife and Fisheries annual program reviews and Business Planning
- Western NWT Biophysical Study immediate needs review 2002
- Regional Research Needs Workshops - 2002
- The Non-Renewable Resource Development Strategy - 2000
- NWT Economic Strategy - 2000
- Cumulative Impact Monitoring Program – VEC Report - 2002

Geographic Scope

Information and Research Needs

- Status and trend in Boreal Caribou populations
- Status of the Grizzly Bear population in the Mackenzie Delta and Tuktoyuktuk Peninsula area



Information and Research Needs

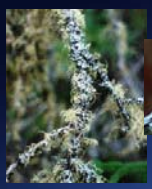
- Abundance, distribution and productivity of raptors
- Abundance, distribution and productivity of moose

Information and Research Needs

- Effects of sensory disturbance on terrestrial wildlife
- Impacts of displacement of grizzly bears from preferred habitats and dens

Information and Research Needs

- Baseline air quality data in areas of gas production and compressor stations
- Monitoring effects of emissions on sensitive plant species



Information and Research Needs

- Baseline information on abundance and location of rare plants and medicinal plants
- Locations of uncommon ecosystem features and areas of high bio-diversity


Information and Research Needs

- Vegetation classification and wildlife habitat mapping
- Standardized Ecological Land Classification
- Modeling options for obtaining ecosystem representation in protected areas

Information and Research Needs

- Forest inventory and forest health – baseline data and monitoring programs
- Wildlife health – incidence and prevalence of parasites and disease


Information and Research Needs

- Location and characteristics of important Boreal caribou habitats and calving areas
- Effects of habitat fragmentation and habitat change on key species
- Potential for interference with hunting and trapping

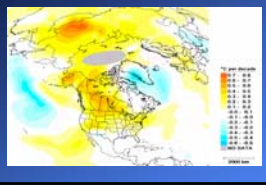

Information and Research Needs

- Information management
- Analytical tools/models for cumulative effects assessment and monitoring


Information and Research Needs

- Potential impacts of changes in climate

- Indicators and thresholds for monitoring



Appendix J

Presentation by D. Auriat, GRRB: The Gwich'in Renewable Resource Board's Panel Presentation for the Workshop on Science Gaps and Information Needs Associated with Hydrocarbon Exploration Development and a Potential Pipeline in the Mackenzie Delta and the Mackenzie Valley

The Gwich'in Renewable Resource Board's
Panel Presentation for the Workshop on Science Gaps and Information Needs Associated With Hydrocarbon Exploration, Development and a Potential Pipeline in the Mackenzie Delta and the Mackenzie Valley

Presented by:
Denise Auriat, Wildlife Biologist, GRRB

Research and/or Management Needs Not Within the GRRB Mandate

1. Status report on water quality and quantity in the GSA (Gwich'in Land Use Plan recommendation). Should be available in plain language for communities.

2. 'Best practices' for northern environments should be determined and implemented.
   - Some of the mitigative techniques implemented to reduce impacts of development activities are techniques which were developed in southern latitudes and may not be appropriate for northern ecosystems and permafrost terrain. For example, proponents frequently talk about planning their activities to avoid sensitive wetland areas and instead disturb higher ground. In the south this may be important given the loss of wetlands and the species associated with these environments however in this region most of the terrain is very wet. It is the drier terrain that is more scarce and therefore likely more important for some wildlife species. The Alaskans seem to have done a lot of work in this subject area and we should probably review and adopt some of their best practices guidelines.

3. Thresholds on development should be determined.
   - Continual exploration and development in the north creates cumulative impacts on wildlife and their habitat. Construction of a pipeline will lead to increased road construction, gravel extraction, and associated activities. A pipeline will also result in increased exploration near the line and, if more gas is found, construction of feeder lines. The sensitivity of different wildlife species that are at the northern extreme of their range to cumulative effects is unknown. We need to determine thresholds for development that will protect these species and their habitats.
   - Need solution to reduce use of and access to areas after development.

4. Appropriate disposal of drilling fluids
   - More research is needed to develop better solutions for the disposal of drilling fluids when drilling in permafrost terrain. From our understanding many of the sumps dug and filled with drilling fluids during the last oil and gas boom failed and their contents have seeped into the soils and into nearby waterbodies/watercourses.

Wildlife Research Gaps Identified by the Gwich'in Renewable Resource Board For the Arctic Science Workshop, Yellowknife, April 2003

General

Impacts of linear disturbance and habitat fragmentation to wildlife.

Seismic activity and road development has been shown to impact wildlife populations worldwide. In this region plant regrowth after disturbance is slow so the temporal footprint of linear disturbances will be long. However we do not understand the impact of linear disturbances to wildlife habitat quality. We have started a project with DRWED to look at the regrowth of old seismic lines and to try and 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 changes in vegetation on the lines. This research needs to be extended to include other wildlife, especially species used for subsistence harvest by the Gwich'in people.

Also, the effect of habitat fragmentation through roads and gravel extraction is not fully understood in this region. Gravel extraction, an increase in roads, and therefore access to areas not frequented previously, as well as a loss of high, dry ground for wildlife could all have negative effects on wildlife. Research should be conducted to determine any negative effects of these activities.

Species Specific

Boreal woodland caribou

Boreal woodland caribou have been identified as a threatened species in the NWT. It is believed that many of the southern populations have been extirpated due to the cumulative effects of oil and gas and forestry development. DRWED and the GRRB started looking at woodland caribou distribution, movements, and habitat use in the ISR and GSA, but more funding for satellite collars is needed to determine how human development affects this species.

Grizzly and Black Bear

More information on both black and grizzly bears is required to assist in proper management of bears in the GSA. There has been very little black bear research in the Northwest Territories, and none conducted in the GSA. Grizzly bears are now being managed by an agreement signed by all the RRCs in the GSA, but little is known about grizzly use of the proposed pipeline area. In order to properly manage both species in the pipeline corridor and surrounding area, necessary baseline information require includes bear presence, habitat use, movements, seasonal feeding areas, and denning locations.

Wolf

Wolves are commonly known to use human-created corridors for easier access to prey and new territories. The potential pipeline corridor could increase wolf travel routes and, therefore, have a potential impact on prey species such as moose and boreal woodland caribou. Research in the pipeline route should be conducted to determine potential wolf

use of the corridor and the possible impact on other wildlife of this use, to assist in determining the proper mitigation.

Furbearers (marten, lynx, muskrat, beaver, fox)
Very little scientific work has been done on furbearers in the area. Obvious gaps are population estimates and habitat use. Fur prices have increased in the last couple of years. Some populations of animals may be subjected to increased trapping pressure as previously remote areas are made more accessible by seismic line cutting and road development. Baseline research is needed to estimate population sizes and habitat use of furbearers in areas adjacent to the pipeline route.

Fisheries Research Gaps Identified by the Gwich'in Renewable Resource Board For the Arctic Science Workshop, Yellowknife, April 2003

Impacts to Upland Lakes and Watercourses Along Pipeline Route

The proposed pipeline route passes through an area of many interconnected lakes and watercourses from Caribou Lakes to Travaillant Lake. There is little scientific information about the populations of lake trout, lake whitefish, broad whitefish, inconnu, and other fish species that utilize these lake systems. Population data and information about fish movements within and between lakes, and location of critical habitats is needed. Similarly little work has been done to identify spawning sites and other important habitat for arctic grayling and other fish species that utilize Rengleng River, Tree River and Travaillant River.

Seismic Exploration

There is little information about the impact of 2D river seismic exploration on freshwater fish species.

Stream crossings

There is limited information about seasonal flow rates and other hydrological characteristics of most watercourses that will be crossed by the proposed pipeline. This information is needed to ensure that culverts are designed to not restrict fish movements during periods of high and low water flow.

Vegetation Research Gaps Identified by the Gwich'in Renewable Resource Board For the Arctic Science Workshop, Yellowknife, April 2003

Site Reclamation

Currently there is no source of local seed mixes for reclamation activities. Research is needed to develop appropriate seed mixes (native species only) for any active revegetation work that will occur of the pipeline route.

Natural Revegetation of Disturbed Sites

Past research has focused on the short-term revegetation of disturbed sites. Studies are needed to document natural vegetation succession on disturbed sites over longer time periods and to determine effective techniques that will promote natural revegetation following disturbance.

Current Distribution of Non-Native Plant Species

Pipeline and road construction may increase the introduction and establishment of non-native plant species. There has been little documentation of the current distribution and abundance of weed species.

Current and Completed Projects Attempting to Address Research Gaps

Cooperative and GRRB Projects

1. Ducks Unlimited Canada- Lower and Middle Mackenzie River projects (ongoing)
   - Provides baseline habitat data for waterfowl, and the LMRP developed excellent vegetation maps that can be used for other wildlife habitat projects.

2. DRWED and Environment Canada's HSP- Boreal Woodland Caribou TK and Habitat Projects (ongoing)
   - Provides baseline distribution and habitat selection/use information.
   - Forest re-growth following seismic line cutting.

3. Grad students (ongoing)
   - Waterfowl (scoter and scaup) and swan research

4. Gwich'in Land Use Planning Board- Gwich'in Land Use Plan (ongoing)
   - Provides background information and establishes land use zones in the GSA, based on existing traditional and scientific knowledge.

5. Peel River Fish Study (complete, 1998-2002)
   - Collected population and migration timing information on Coregonid species in the Peel River.

6. Dall's Sheep Habitat Study (new this year)
   - Will be collecting information on Dall's sheep habitat use (winter use, grazing pressure, vegetation classification) in the Mount Goodenough area of the Richardson Mountains. This will expand into a long term monitoring project.

Appendix K

Complete Biophysical Attribute Sheets

Gartner Lee

Terrain and Surficial Geology

		Is the gap vaild?	Why is it valid?	When is the information needed?					Where is the information needed?					What phase of development is the information needed for?							Priority	Who could do the research or science?							
Knowledge Gaps	What is the research/ science issue?	Yes or No	Not Available Information not current. Quality of info. in doubt Other	EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
TSG B 1	What information can be gathered to update and verify granular resource baseline data?	YES	Not Gathered	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X		ST/LLT			X	X				
TSG B 2	What information can be gathered to update and verify granular resource baseline data?	YES	Some Information	X	X	X	X	X	X	X		X				X	X	X	X		ST/SLT	X	X	X	X				
TSG B 3	What are the land form types and distribution in the Mackenzie Valley?	YES	Some Information	X	X	X	X	X	X	X		X				X	X	X	X		ST/SLT	X	X	X	X				
TSG B 4	What are the drainage patterns, deposit thickness, terrain hazards, and slope stability conditions in the Mackenzie Valley?	YES	Not Available	X		X	X	X	X	X	X	X	X		X	X	X	X	X		ST/SLT	X		X					
TSG B 5	What are the earthquake potentials in the oil and gas development areas in the Mackenzie Valley?	YES	Not Available	X		X	X	X	X	X	X	X	X		X	X	X	X	X		ST/SLT	X		X		X			
TSG B 6	DELTA - what are the sensativity of slopes and susceptibility to new drainage patterns?	YES	Not Available	X		X	X	X	X	X	X	X	X		X	X	X	X	X		ST/SLT	X		X					
TSG B 7	What are the slope movement mechanics in the oil and gas development areas and along the potential pipeline corridor?	YES	Not Available	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	ST/SLT	X - set context		X - get detail		X - NSERC			
TSG B 8	What are the locations of problem/sensitive soils in the oil and gas development areas and along the potential pipeline corridor?	YES	Not Available	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	ST/SLT/LLT	X - set context		X - get detail		X - NSERC			
																						X		X					
Impact																												
TSG I 1	What environmental impacts are caused by soil compaction and rutting?	YES	Some Information	X	X	X	X		X	X	X	X	X	X	X			X	X	X	ST/SLT/LLT	X		X		X			

Note:
ST - Short Term
LT - Long Term
SLT - Short Lead Time
LLT Long Lead Time

Permafrost

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current. Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
P B 1	Collection of ground temperature and ice conditions along pipeline corridor, especially NW to Inuvik, and in oil and gas development areas.	YES	Not Available	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	ST/SLT	X		X		X			
P B 2	What are the soil-pipeline interactions on hill slpoes experiencing ground-ice creep?	YES	Not Available	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	ST/SLT	X		X					
P B 3	What are the permafrost constraint/problem areas in the Mackenzie Valley?	YES	Some Available	X	X	X	X		X	X	X	X	X		X	X	X	X	X	X	ST/SLT/LLT	X		X					
P B 4	What are the effects of cleared pipeline right-of -ways on permafrost conditions?	YES	Not Available	X	X	X	X		X	X	X	X							X	X	ST/SLT/LLT	X		X					
Impact																												
P I 1	What are the effects of operating a chilled pipeline in permafrost? Do impacts accumulate over time?	YES	Not Available	X	X	X	X		X	X							X	X	X	X	ST/SLT/LLT	X		X					
P I 2	What are the long term success/stability of drilling mud sumps in the Mackenzie Valley?	YES	Not Available		X	X	X				X	X			X	X					ST/SLT/LLT	X							
(OLD 6)	linked to P I 2 above	see # 2	lumped with # 2																			X		X					
(OLD 7)	linked to P I 2 above	see # 2	lumped with # 2																			X		X					
P I 3	What are the effects of climate change on permafrost and resulting impacts on pipeline integrity?	YES	Not Available	X	X	X	X		X	X	X	X							X	X	ST/SLT/LLT	X		X		X	X		

Note:
ST - Short Term
LT - Long Term
SLT - Short Lead Time
LLT Long Lead Time

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Hydrogeology and Ground Water

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current. Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
HG B 1	What are the near surface groundwater flow characteristics along the potential pipline corridor?	Yes	Some available	X	X		X		X	X	X	X							X	X	ST/SLT	X		X				
Impact																												
HG I 1	What are the impacts of permafrost degradation and/or creation on hydrogeology along potential pipeline and at stream crossings?	Yes	Not available	X	X		X	X	X	X								X	X	ST/LT/SLT/LLT	X		X		X			

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Surface Water

		Is the gap vaild?	Why is it valid?	When is the information needed?					Where is the information needed?					What phase of development is the information needed for?							Priority	Who could do the research or science?							
Knowledge Gaps	What is the research/ science issue?	Yes or No	Not Available Information not current. Quality of info. in doubt Other	EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
SW B 1	How is stream and lake quality impacted by petroleum activity? How can this be resolved from natural biogeochemical background/cycling?	Yes	Not Available	X	X	X	X - EEM	X	X	X	X	X	X		X	X	X	X	X	X	ST/LT/LLT	X		X	X				
SW B 2	Adapt existing hydrometric models to northern context, particularly in permafrost regions.	Yes	Not Available	X	X	X	X - EEM	X	X	X	X	X	X								LT/SLT/LLT	X		X		X			
SW B 3	There is a need to expand the snow survey data collection program.	Yes	Some Available	X		X	X - EEM	X	X	X	X	X	X				X		X	X	ST/LT/LLT	X							
SW B 4	Baseline hydrometric data are required for tributaries of the Mackenzie River.	Yes	Not Available	X	X	X	X - EEM		X	X	X	X		X		X	X	X	X	X	ST/LT/SLT/LLT	X							
SW B 5	What causes rapid lake drainage and where are the most sensitive areas for this event to occur?	Yes	Not Available	X			X - EEM		X	X									X	X	ST/LLT	X							
SW B 6	What are the geomorphic conditions at stream crossings?	Yes	Not Available	X	X	X	X - EEM		X	X	X	X		X			X	X	X	X	ST/SLT/LLT	X		X					
Impact																												
SW I 1	What can be learned about surface water impacts that have occurred from long-term development in the Liard Plateau?	Yes	Not Available	X	X	X	X - EEM		X	X	X	X	X			X				X	ST/SLT	X	X	X	X				
SW I 2	What are the sensitive areas along the Mackenzie River and it tributaries north of Norman Wells?	Yes	Not Available	X	X	X	X - EEM	X	X	X									X		ST/SLT	X		X					X

Note:
EEM - Environmental Effects Monotirng
ST - Short Term
LT - Long Term
SLT - Short Lead Time
LLT Long Lead Time

Gartner Lee

Fish and Fish Habitat

		Is the gap vaild?	Why is it valid?	When is the information needed?					Where is the information needed?					What phase of development is the information needed for?							Priority	Who could do the research or science?							
Knowledge Gaps	What is the research/ science issue?	Yes or No	Not Available Information not current. Quality of info. in doubt Other	EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
1. A	What are the abundance and distribution of game fish, forage fish and invertebrates in the areas of interest?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	**L**		**P**	**P**				**P**
1. B	What is the distribution of contaminants in sediments and in harvested fish in the areas of interest?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	**L**		**P**	**P**				**P**
2. A	What are the important spawning, rearing and overwintering habitats for fish and invertebrates in the areas of interest?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**P**	**P**			
2. B	What are the key migration corridors and habitats for spawining, rearing and over-wintering activities of harvested and rare fish and invertebrates?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**P**	**P**			
2. C	What are the spatial and temporal (seasonal) patterns of migration in harvested and rare fishes and invertebrates?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**P**	**P**			
2. D	What are the factors that govern the abundance of economically important or rare species in the areas of interest?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**P**	**P**			
2. E	What are the critical trophic linkages that may be affected by developments in the areas of interest?	Yes	Limited information	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**P**	**P**			
3. A	What will be the short and long-term effects of oil and gas developments on the vital rates (reproduction, growth, mortality) of key harvested fish populations?	Yes	Limited information	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**L**				
3. B	What are the project related changes in abundance and species composition of invertebrates in the areas of interest over time?	Yes	Limited information	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**L**				
3. C	What are the spatial and temporal trends in contaminants as a result of projects in the areas of interest?	Yes	Limited information	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT	**L**		**P**	**L**				
4. A	In existing oil and gas development areas and along existing pipeline corridors, quantify what impacts have occurred as a result of development.	Yes	Limited information	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	**L**		**P**		**P**			**P**
4. B	In existing oil and gas development areas and along existing pipeline corridors, determine what mitigation measures have been implemented and determine their effectiveness.	Yes	Limited information	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	**L**		**P**		**P**			**P**
4. C	In existing oil and gas development areas and along existing pipeline corridors, quantify the effects of contaminants on biota.	Yes	Limited information	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	**L**		**P**		**P**			**P**
5. A	How do temperature changes and thermal shock caused by climate change affect fish species?	Yes	Not Available	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT/LLT	**L**		**P**	**P**				
5. B	What are the fish species and population changes that occur from temperature and water flow changes as a result of climate change?	Yes	Not Available	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT/LLT	**L**		**P**	**P**				

1. Survey in oil and gas development areas and along pipeline corridor.
2. Ecological knowledge gaps.
3. Monitoring programs.
4. Impact knowledge gaps.
5. Climate Change Effects

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Vegetation and Forests

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current . Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
VF B 1	Map and describe wetland types and distribution in the Mackenzie Valley.	Yes	Not Available	X	X	X	X		X	X	X	X	X				X	X	X	X	ST/SLT/LLT	X	X						
VF B 2	What are the locations of rare and medicinal plants in the Mackenzie Valley?	Yes	Limited Information	X		X	X		X	X	X	X	X	X	X		X	X	X		ST/SLT/LLT	X	X	X	X				
Impact																														
VF I 1	What Traditional Knowledge exists that relates to project effects on vegetation and forests?	Yes	Limited Information	X		X			X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT				X				
VF I 2	What are the long-term recovery rates of disturbed vegetation communities?	Yes	Not Available	X	X	X	X		X	X	X	X	X	X			X	X	X		ST/SLT/LLT	X	X			X			
VF I 3	Develop a local natural seed and seedling bank for re-vegetation. Map distribution of invasive species.	Yes	Not Available	X	X	X	X		X	X	X	X	X	X				X		X	ST/SLT/LLT		X		X	X			

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Wildlife-Mammals

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current . Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Muskox	Population numbers and trend data required. No information on resilience. Poor understanding of how respond to disturbances.	Yes	Little Information	X		X	X				X			X	X			X	X		ST/LLT		X		X				
WL Caribou	No population information - abundance, trends, resilience. Need to understand habitat needs, effects of habitat fragmentation, predator-prey relationships.	Yes	Little Information	X		X	X		X			X	X	X	X	X	X	X	X	X	ST/SLT/LLT		X		X				
Mtn Caribou	No population information, trend data. No impact data. Focus on Peel Plateau.	Yes	Not Available	X		X	X						X	X	X			X			ST/SLT/LLT		X		X				
BG Caribou	Have little information related to effects of displacement/disruption caused by development. No impact resilience information.	Yes	Some Information	X		X	X			X	X							X	X	X	ST/SLT/LLT		X		X				
Furbearers	Populaiton abundance, mapping of species specific habitat, responses to development impacts and harvest rates. Focus on lynx, marten and wolverine.	Yes	Little Information	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT/LLT		X		X				
Dalls Sheep	No information on effects of disturbance from development.	Yes	Some Information	X		X	X						X	X	X						ST/SLT/LLT		X		X				
Black Bear	No population information - abundance, trends, resilience. Need to understand habitat needs, effects of habitat fragmentation, displacement caused by developments.	Yes	Not Available	X		X	X		X	X	X	X	X		X	X	X	X	X	X	ST/SLT/LLT		X		X				
Grizzly Bear	Need better population data - status, trend, robustness	Yes	Some Information	X		X	X		X	X									X	X	ST/SLT/LLT		X		X				
Bison	Focus on effects caused by impacts.	Yes	Impact data poor	X		X	X					X			X	X			X	X	ST/SLT/LLT		X		X				
Moose	Little population data - abundance, trends, resilience. Need data on predation, food sources, and effects of access.	Yes	Little Information	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT/LLT		X		X				
Wolves	No information for population in treed areas. What are effects of development on wolf population? Effects of increased/improved access?	Yes	Not Available	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	LT/LLT		X		X				

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Wildlife-Migratory Birds

		Is the gap vaild?	Why is it valid?	When is the information needed?					Where is the information needed?					What phase of development is the information needed for?							Priority	Who could do the research or science?							
Knowledge Gaps	What is the research/ science issue?	Yes or No	Not Available Information not current . Quality of info. in doubt Other	EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
Forest Birds	Do right-of-ways affect predation rates of forest birds? No inventory data, presence/density data or association to habitat data.	Yes	Not Available	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	X			X				
Shore Birds	Very little habitat location and distribution information available. No information on above treeline staging. No data for boreal forest areas.	Yes	Not Available	X	KIBS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	X			X				
Waterfowl	Study habitat and breeding behaviour of waterfowl in oil and gas development areas.	Yes	Not Available	X	KIBS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	X			X				
Water Birds	Study habitat and breeding behaviour of water birds in oil and gas development areas.	Yes	Not Available	X	KIBS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT	X			X				
Raptors	Focus on perigrine falcon. How do oil and gas activities affect nest site abandonment?	Yes	More Information	X		X	X	X			X	X	X	X	X	X	X	X	X		ST/SLT	X			X				

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Biodiversity

		Is the gap vaild?	Why is it valid?	When is the information needed?					Where is the information needed?					What phase of development is the information needed for?							Priority	Who could do the research or science?							
Knowledge Gaps	What is the research/ science issue?	Yes or No	Not Available Information not current. Quality of info. in doubt Other	EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																													
B B 1	What Traditional Knowledge is available that conveys biodiversity information?	Yes	Not Collected	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT			X	X				
B B 2	Develop an ecological land classification system.	Yes	Not Available	X	X	X	X		X	X	X	X	X	X	X		X	X	X		ST/SLT	X	X	X	X				
B B 3	Identify genetically distinct species sub-populations.	Yes	Some Available	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/SLT/LLT	X	X	X	X	X			
Impact																								X	X				
B I 1	What site specific and project specific Traditional Knowledge about biodiversity is available?	Yes	Not Available	X		X			X	X	X	X	X	X	X		X		X		ST/SLT/LLT	X	X						
B I 2	Improve methodologies for biodiversity impact analysis by providing adequate baseline information on species diversity and ecological processes.	Yes	Not Available	X		X			X	X	X	X	X				X		X		ST/LLT								

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Air

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current. Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
A B 1	Upgrade facilities at Inuvik, Norman Wells, Fort Liard and Snare for TSP, particulates, NOx, VOCs, ground level O3 (parameters related to flaring and dehydration activities) to establish baseline.	Yes	More information	X	X	X	X		X	X	X	X	X		X	X		X		X	ST/SLT		X					
A B 2	There is a need to establish baseline air quality conditions at potential locations of flare stacks and compressor stations and to model these conditions..	Yes	More information	X	X	X	X		X	X	X	X				X	X	X		X	ST/SLT		X	X				
Impact																												
A I 1	What are the sensitive and indicator species of air quality, and the appropriate ambient air quality standards for wildlife?	Yes	Not Available	X		X	X		X	X	X	X				X				X	ST/LLT		X		X	X		

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Climate Change

Knowledge Gaps	What is the research/ science issue?	Is the gap vaild? Yes or No	Why is it valid? Not Available Information not current. Quality of info. in doubt Other	When is the information needed? EA of pipeline and gas wells	Regulation of pipeline and gas wells	EA of existing oil and gas activities	Monitoring and follow-up	Prerequisite for any of the foregoing?	Where is the information needed? Mackenzie Valley pipeline	Mackenzie Delta Dev.	Colville/ Norman Wells	Laird / Cameron Hills	Peel	What phase of development is the information needed for? sesmic	exploration drilling	production drilling	infrastructure	Field operations	pipeline construction	pipeline operations	Priority Two ratings 1. when is infor. needed? (Short Term, Long Term) 2. how long will it take to get it? (Short Lead Time, Long Lead Time)	Who could do the research or science? Federal Government	Territorial Government	Industry	Renewable Resource Boards / Community Org.	Universities	Research Institutes	NGOs	Private Sector
Baseline																												
CC B1	What are the long-term implications of climate change on species distribution and on species community structural changes?	Yes	Not Available	X	X	X	X		X	X	X	X	X			X	X	X	X	X	ST/LLT	X	X			X			
CC B2	What are the effects of climate change on fish populations?	Yes	Not Available	X	X	X	X		X	X	X	X	X				X	X	X		ST/LLT	X							
CC B3	What is the variability in permafrost regimes throughout the Mackenzie Valley caused by climate change?	Yes	Not Available	X	X	X	X		X	X	X	X	X			X	X	X	X	X	ST/LLT	X	X						
Impact																													
CC I 1	What are the climate change effects to snow conditions, fire, food quality, habitat fragmentation and species movement?	Yes	Not Available	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/LLT	X	X						
CC I 2	Do some climate change impacts affect some species more than others?	Yes	Not Available	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	ST/LLT	X	X						

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Appendix L

Biophysical Gaps Relevant to the Mackenzie Delta

Appendix L: Biophysical Gaps Relevant to the Mackenzie Delta

This project focused on biophysical gaps for the Mackenzie Valley between Inuvik south to the NWT/Alberta border and the five hydrocarbon development areas (Colville Hills, Peel Plateau, Norman Wells, Cameron Hills, and Liard Plateau). The scope of the project did not include the Mackenzie Delta (i.e., north of Inuvik). However, several of the information gaps identified for the purposes of this project were also deemed to be valid for the Mackenzie Delta, and these are listed in the following tables.

Table 1. Biophysical Gaps Relevant to the Mackenzie Delta - Identified at the Scientists' Workshop and during Community Visits

Biophysical Attribute	Gap Description
Traditional Knowledge	Increased capacity and tools in communities and regions for the collection, recording, archiving and use of traditional knowledge from all regions of the Mackenzie Valley.
Terrain and Surficial Geology	What traditional knowledge can be gathered about terrain and surficial geology that could be used for the environmental assessment, regulatory and management processes?
Terrain and Surficial Geology	What information can be gathered to update and verify granular resource baseline data?
Terrain and Surficial Geology	What are the landform types and their distribution in the Mackenzie Valley?
Terrain and Surficial Geology	What are the drainage patterns, surficial deposit thickness, terrain hazards and slope stability conditions in the Mackenzie Valley?
Terrain and Surficial Geology	What are the earthquake potentials in the oil and gas development areas in the Mackenzie Valley?
Terrain and Surficial Geology	What are the slope movement mechanics in the oil and gas development areas and along the potential pipeline corridor?
Terrain and Surficial Geology	What are the locations of problem/sensitive soils in the oil and gas development areas and along the potential pipeline corridor in the Mackenzie Valley?
Terrain and Surficial Geology	1. What are the locations and conditions of existing sumps? 2. What steps are being taken to clean-up leaking sumps and restore the environment? 3. What measures are being implemented for the proper disposal of drilling fluids for current and future projects?
Terrain and Surficial Geology	What are the locations of past and current seismic lines, seismic exploration activities and exploration drilling sites?

Biophysical Attribute	Gap Description
Terrain and Surficial Geology	Better mapping of traditional land use and cultural sites is required before large-scale developments are allowed to proceed.
Terrain and Surficial Geology	What environmental impacts are caused by soil compaction and rutting?
Permafrost	What are the ground temperature and ground ice conditions in the oil and gas development areas and along the potential pipeline corridor, especially north of Norman Wells?
Permafrost	What are the soil-pipeline interactions on hill slopes experiencing ground-ice creep?
Permafrost	What are the permafrost constraint/problem areas in the oil and gas development areas and along the potential pipeline corridor in the Mackenzie Valley?
Permafrost	What are the effects of cleared pipeline rights-of-way on permafrost conditions?
Permafrost	1. What are the effects of operating a chilled pipeline in permafrost? 2. Do impacts accumulate over time?
Permafrost	What is the long-term success/stability of drilling mud sumps in the Mackenzie Valley?
Permafrost	What are the effects of climate change on permafrost and resulting impacts on pipeline integrity?
Hydrogeology and Groundwater	What are the near surface groundwater flow characteristics along the potential pipeline corridor?
Hydrogeology and Groundwater	What are the impacts of permafrost degradation and/or creation on groundwater flow along the potential pipeline corridor sand at stream crossings?
Surface Water	1. How is stream and lake water quality impacted by natural hydrocarbon seeps? 2. What are the natural biogeochemical background levels? 3. How can background levels be distinguished from those resulting from exploration and development activities?
Surface Water	Existing hydrometric models to northern context, particularly in permafrost regions, need to be adapted.
Surface Water	Baseline hydrometric data are required for tributaries of the Mackenzie River.
Surface Water	There is a need to expand the snow survey data collection program.
Surface Water	1. What causes rapid lake drainage? 2. Where are the most sensitive areas for this event to occur?

Biophysical Attribute	Gap Description
Surface Water	What are the geomorphic conditions at stream crossings in the oil and gas development areas and along the potential pipeline corridor?
Surface Water	What are the environmentally sensitive areas along the Mackenzie River and its tributaries north of Norman Wells?
Surface Water	What are the water quality and quantity regimes in development areas?
Surface Water	What can be learned about surface water impacts that have occurred from long term oil and gas development activities in existing oil and gas development areas?
Air	Upgrade air monitoring facilities at Inuvik, Norman Wells, Fort Liard and Snare for TSP, particulates, NOx, VOCs, and ground level O_3 (parameters related to flaring and dehydration activities) to establish baseline.
Air	There is a need to establish baseline air quality conditions at potential locations of flare stacks and compressor stations and to model these conditions.
Air	1. What wildlife and vegetation species are sensitive to air quality changes? 2. What species would make good indicator species of poor air quality? 3. What are the appropriate ambient air quality standards for wildlife?
Vegetation and Forests	Wetland types and their distribution in the Mackenzie Valley need to be mapped and described.
Vegetation and Forests	What are the locations of rare and medicinal plants in the Mackenzie Valley?
Vegetation and Forests	Map and describe vegetation types and distribution in the Mackenzie Valley.
Vegetation and Forests	What traditional knowledge exists that relates to project effects on vegetation and forests?
Vegetation and Forests	What are the long-term recovery rates of disturbed vegetation communities?
Vegetation and Forests	Develop a local natural seed and seedling bank for re-vegetation.
Vegetation and Forests	1. Map the distribution of non-native species. 2. Develop measures to prevent the introduction of non-native species.
Biodiversity	What traditional knowledge is available that conveys information about biodiversity?
Biodiversity	An ecological land classification system needs to be developed.
Biodiversity	Genetically distinct species sub-populations of flora and fauna need to be identified.

Biophysical Attribute	Gap Description
Biodiversity	What site specific and project specific traditional knowledge about biodiversity is available?
Biodiversity	Methodologies for determining impacts to biodiversity need to be developed and improved.
Climate Change	What are the long-term implications of climate change on Terrestrial species distribution and on community structural changes?
Climate Change	What are the effects of climate change on fish populations.
Climate Change	What are the variability in permafrost conditions throughout the Mackenzie Valley cause` climate change?
Climate Change	What are the climate change effects to snow conditions, fire, food quality, habitat fragmentation and species movement?
Climate Change	Do some climate change impacts affect some species more than others?
Wildlife – Mammals – Barren Ground Caribou	1. Little information available regarding effects of displacement caused by development. 2. Little population resilience information.
Wildlife – Mammals – Furbearers	1. Information is required on population abundance and identification and mapping of species specific habitat type and use data, particularly in the oil and gas development areas and along the potential pipeline corridor. 2. Information is required on population responses to development effects and increased access and harvest rates. 3. Information is required for all furbearers, but can focus on key harvested species – lynx, Marten, wolverine, beaver and muskrat.
Wildlife – Mammals - Black Bear	1. Population abundance and trend data are required. 2. There is no information on population resilience or effects of displacement caused by development. 3. A better understanding of habitat needs and effects of habitat fragmentation is required.
Wildlife – Mammals – Grizzly Bear	Information on [population abundance, trend and robustness is required.
Wildlife – Mammals – Moose	1. Population abundance, trend and resilience data are required. 2. There is little information on predation, food sources and effects of increased access resulting from development.
Wildlife – Mammals – Wolves	1. There is no information on wolf populations in treed areas. 2. Information is required on effects of development and increased access on populations.

Biophysical Attribute	Gap Description
Wildlife – Migratory Birds / Raptors – Forest Birds	1. Information is required on population presence, density and inventory. 2. Information is required on population-habitat association data. 3. Information is required on effects of right-of-ways on predation rates. 4. What traditional knowledge is available about forest birds?
Wildlife – Migratory Birds / Raptors – Shore Birds	1. No information is available on population distribution and abundance in boreal forest. 2. No information is available on above tree line staging requirements (Mackenzie Delta, Kendall Island Bird Sanctuary (KIBS)).
Wildlife – Migratory Birds / Raptors – Waterfowl	1. Information on breeding behaviour and habitat use is required. 2. Information required for KIBS and Mackenzie Delta.
Wildlife – Migratory Birds / Raptors – Water Birds	1. Information is required on breeding behaviour and habitat use. 2. Information required for KIBS and Mackenzie Delta.
Fish and Fish Habitat	1. What are the abundance and distribution of game fish, forage fish and invertebrates in the areas of interest? 2. What is the distribution of contaminants in sediments and in harvested fish in the areas of interest? 3. What are the ecological characteristics of inland lakes and the biology and status of fish populations in these lakes?
Fish and Fish Habitat	1. What are the important spawning, rearing and over-wintering habitats for fish and invertebrates in the areas of interest? 2. What are the key migration (spatial/temporal) corridors and habitats for harvested fish and invertebrates in the areas of interest? 3. What are the factors that govern the abundance of economically important and rare species in the areas of interest? 4. What are the critical trophic linkages that may be affected by developments in the areas of interest?
Fish and Fish Habitat	1. What are the impacts of projects on vital rates (reproduction, growth, mortality) and abundance of populations, and in harvest rates? 2. What are the project related changes in abundance and species composition of invertebrates in the areas of interest? 3. What are the project related spatial and temporal trends in contaminants in the areas of interest?
Fish and Fish Habitat	1. In existing oil and gas development areas and along pipeline corridors, quantify what impacts have occurred as a result of development. 2. In existing oil and gas development areas and along existing pipeline corridors, determine what mitigation measures have been implemented and determine their effectiveness. 3. In existing oil and gas development areas and along existing pipeline corridors, quantify the effects of contaminants on biota.

Biophysical Attribute	Gap Description
Fish and Fish Habitat	1. How do temperature changes and thermal shock caused by climate change affect fish species? 2. What are the fish species and population changes that occur from temperature and water flow changes as a result of climate change?

Table 2. Specific Mackenzie Delta Gaps Identified from other Sources

Biophysical Attribute	Gap Description	Source
Surface Water	Need to know more about the channel migration rates in the Mackenzie Delta as this relates to location and construction of the feeder lines and other facilities/infrastructure requirements.	Scientists Workshop – Hydrogeology and Surface Water breakout group.
Surface Water	The current water quantity monitoring network is very sparse along the pipeline route down the East side of the Mackenzie River from the Delta to Alberta. The region from the Delta to Norman Wells lacks any data on river flows and levels.	Comments from Meteorological Service of Canada – Jesse Jasper, April 17, 2003.
Relative Sea level rise and Vertical Ground motion	Relative sea level rise refers to the net effects of rising oceans (eustatic SLR) and changes in the height of the land surface (isostatic and tectonic). Based on tide gauge records at Tuk relative sea level (the net result of the 2 components) is rising at a rate of about 3.5 mm per year, which is higher than the rate of global average eustatic sea level. This implies that the land surface is subsiding. This is likely the result of isostatic adjustment following deglaciation, thawing of permafrost and compaction of deltaic sediments. There may also be a tectonic component. The bottom line is that we do not know the magnitude of either component individually. Arctic sea levels (the eustatic part) are predicted to rise at a rate which exceeds the global average as a result of climate change. Production of oil and gas from beneath the delta will likely cause some subsidence which will be added to the natural rates of subsidence. This will impact engineering design of pipelines and infrastructure as well as migratory bird nesting sites. In order to predict the rate of submergence of the delta and adjacent lands and to measure the impacts of resource extraction we need to start to unravel the sea level story. At the present time there is a PERD-Funded (Climate Change POL) project lead by Don Forbes to measure rates of vertical motion	Comments from Natural Resources Canada – Steve Solomon, April 22, 2003.

Biophysical Attribute	Gap Description	Source
	across parts of the Arctic. This is done with very high resolution GPS measurements. The nearest monitoring location in the vicinity of the oil and gas activity is in Inuvik. A station at Tuktoyaktuk is scheduled to be established this year (funded by DFO) to control motion of the tide gauge station also scheduled to be installed this year. Additional information is required at the Delta front and probably at least one intermediate site. Efforts are underway to work with oil companies to establish a series of stations on benchmarks anchored at different depths in order to try to sort out the magnitude of the various subsidence mechanisms.	
Digital Elevation Models of the Delta using LIDAR	Existing information about elevations on the Delta are based on provisional topographic maps created based on 1972 air photography at scales of 1:50000 to 1:250000 (only the latter are available digitally). The first contour on the 1:50000 maps is 15 m; this elevation occurs about half way between Inuvik and the coast. This means that there is almost no information on the detailed morphology of the delta. LIDAR surveys would enable the development of a DEM with a vertical resolution of about 10 cm and a pixel size of 1-2 m. This is the required level of detail for flood mapping extent under different storm conditions and can be used to predict changes in recurrence intervals of different flood levels due to changing sea level. LIDAR surveys can also be used to develop detailed landcover and morphology maps which would be invaluable for pipeline route planning. Geotechnical and thermal conditions can be interpreted to some extent using these types of maps (with ground-truth) and the maps can be used as input to thermal models or to help set boundary conditions.	Comments from Natural Resources Canada – Steve Solomon, April 22, 2003.
Thermal, physical and geotechnical properties in the coastal zone	The coastal zone refers the area from about 5 m water depth to the maximum extent of storm surge influence on the land surface (about 2.5 m elevation). Within this zone ground conditions change drastically due to subtle changes in water depth which affect bottom fast ice conditions, and the spatial distribution of sediment properties. Initial ice content and sediment texture of terrestrial delta materials are modified they are transgressed by rising sea levels and exposed to an extreme range of energy and temperature conditions. Some thermal aspects of the changes are analogous to those experienced at the river and lake transitions, but are complicated by wave energy and salinity at the	Comments from Natural Resources Canada – Steve Solomon, April 22, 2003.

Biophysical Attribute	Gap Description	Source
	coastal interface. At the present time there is very little information on the surficial and subsurface sediment properties in this shallow water, nearshore zone or the adjacent terrestrial coastal areas; this represents gap in understanding which will affect feeder pipeline route selection and potential landing sites. Additional information on the detailed morphology of the coastal zone is necessary to improve our understanding of the spatial distribution of sediments and of the processes which affect them. These processes include wave/current/seabed interactions, sediment transport and landfast ice related properties such as seabed erosion from strudel scour (drainage through ice), sediment entrainment and removal by sea ice and sub-ice channelization and scour. Acquisition of subsurface information on ice content and sediment physical and thermal properties on both land and sea portions of the coastal zone will require the application of new geophysical tools in order to map the spatial distribution of material attributes. Detailed morphological information in the subaqueous portion of the coastal zone at a resolution similar to that of LIDAR is difficult to obtain in the nearshore shallow and extremely turbid waters of the Mackenzie Delta nearshore. The use of sweep bathymetry systems and/or interferrometry systems can acquire data in water depths as shallow as 1-2 m, but often water depths are less than 1.5 m at distances many km from the coast. Shallow water detailed bathymetry is another data gap, but one which may be very difficult to fill in the shallowest areas.	