NORTHWEST TERRITORIES ENVIRONMENTAL AUDIT 2005

Supplementary Report on the Status of the Environment

December 2005

EXECUTIVE SUMMARY

The Mackenzie Valley Resource Management Act (MVRMA), an outcome of the land claim agreements established between the First Nations and the Government of Canada, and the Gwich'in, Sahtu and Tlicho land claims agreements, require that an independent environmental audit be conducted at least once very five years. One component of the audit is an evaluation of information on the environment in order to determine trends in environmental quality, potential contributing factors to changes in the environment and the significance of those trends. The term "environment" is broadly defined as follows:

> "*The components of the Earth and includes:*
> *a) land, water and air, including all layers of the atmosphere;*
> *b) all organic and inorganic matter and living organisms; and,*
> *c) the interacting natural systems that include components referred to in paragraphs (a) and (b).*"

Given the above context, this first ever Status of the Environment report covers seven major components of the NWT environment:

- atmospheric environment (including air quality, climate and climate change);
- freshwater aquatic environment;
- marine environment;
- terrestrial environment;
- permafrost, ground ice and snow;
- human health; and,
- socio-economic and community wellness.

As a starting point in conducting the Status of the Environment assessment, the valued components (VCs) identified in the INAC report, *A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program* (NWT CIMP) *and Audit* were selected. Key indicators of change for the selected VCs were then identified and carried forward through the study. For these key indicators of change, trends in environmental quality were assessed for the Mackenzie Valley, the Inuvialuit Settlement Region and the NWT as a whole.

To assess current conditions and trends, previously completed studies were relied upon extensively, particularly where these studies had assessed trends in environmental quality. Where required, these studies were supplemented with original data analysis; however, conducting original research was not within the scope of the Status of the Environment reporting. For each of the key indicators, available data were analyzed and assessed to identify: trends; potential contributing factors to any changes in the environment; the significance of any trends identified; the likely impact of the trends; activities to mitigate the factors/emissions that are causing the observed trends, and, data gaps. Table ES.1 provides an overall summary of the results of the Status of the Environment assessment.

Overall, environmental quality in the NWT was found to be favourable for most components. In some cases it was difficult to determine the current condition of an environmental component or evaluate trends due to a lack of adequate baseline data for the NWT. However, where data were sufficient, several instances of unfavourable conditions and deteriorating trends were identified. The two most disturbing of these are: the recent large decreases recorded for the size of caribou herds that Aboriginal people living in the NWT rely on as a major source of subsistence; and, the need for action in the area of socio-economics and community wellness.

With changes to the environment from climate change and the potential for increasing development near calving grounds, the need for accurate data on the status of the individual herds and their habitat is becoming increasingly important.

With respect to socio-economics and community wellness, while traditional economic indicators show that the NWT population and economy are growing, there is no commensurate progress in community wellness with numerous measures of social well-being being found to be less favourable than national indicators. The social problems identified appear even more pronounced in the NWT smaller communities and are more associated with the Aboriginal population. This situation requires action by government agencies that have health and social service mandates.

Looking forward, climate change is expected to have a profound effect on the Canadian North. The potential effects extend to all components of the environment ranging from: loss of permafrost conditions in some parts of the NWT; increased erosion of river banks and shorelines; changes in the duration, extent, and quality of sea ice cover; changes in vegetation coverage and animal habitat; increased mobility of nutrients and organic and inorganic contaminants; and, changes in the quality and availability of traditional foods. Additional research is required in a number of areas to improve the understanding of the effects of climate change on all components of the environment.

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1.0 INTRODUCTION

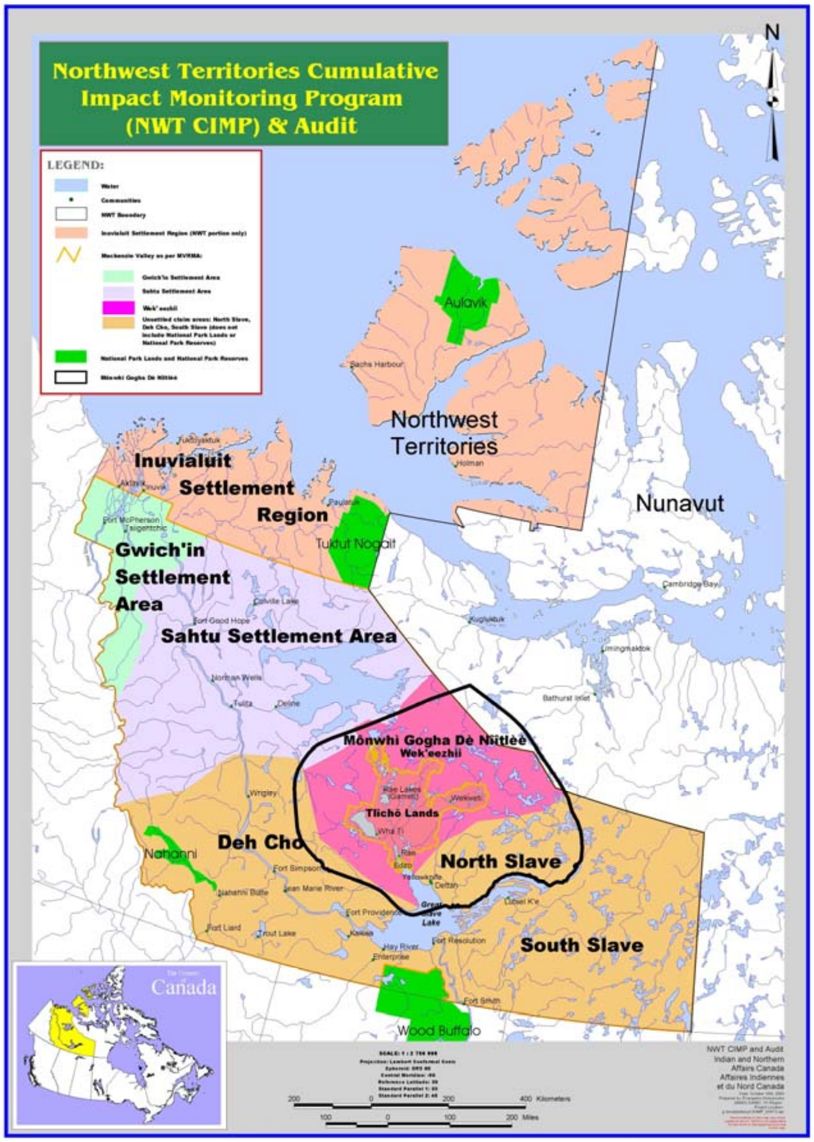
With a land mass of 1.3 million square kilometres, Canada's Northwest Territories (NWT) is roughly equivalent in size to Alberta and Saskatchewan combined. In contrast, the total population of these provinces is more than 100 times greater than that of the NWT. A map of the NWT and its regions is shown in Figure 1.1-1.

The vast geographic expanse of the NWT is accompanied by remarkable environmental and ecological diversity. From south to north, the boreal forest gradually transforms into the taiga, the tundra and ultimately the arctic coast. These environments are home to a tremendous variety and abundance of wildlife. Peary caribou, muskoxen, polar bears, arctic hares and beluga whales are among the mammals that inhabit the far north. Vast herds of caribou, including the 187,000-strong Bathurst caribou herd, traverse the barren lands on their annual migration. The Mackenzie Mountains are home to woodland caribou, Dahl's sheep, grizzly and black bears, lynx, martens, golden eagles and a variety of small birds and mammals. The Mackenzie River delta provides important habitat for muskrats and nesting waterfowl. In the southern boreal forest or taiga, moose, wolves, woodland caribou, lynx, red foxes and several types of weasel are found. Vast networks of lakes and rivers contain numerous fish species including trout, pike, whitefish and many others.

The NWT is also home to a diverse human population that originates from across Canada and around the World. While many residents of the NWT have made the north their home relatively recently, approximately half of the population has a connection to the NWT that is much older. Dispersed in communities across the NWT, the Aboriginal population is far from being a homogeneous group; instead, it represents a wide array of cultures and histories that are reflective of the varied environments their descendants have inhabited for thousands of years. Although differences do exist, the Aboriginal people of the NWT have one particularly important attribute in common: a profound connection to the land. Despite major lifestyle changes over the past 50 years, many Aboriginal households continue to spend part of each year on the land and "traditional foods" form a significant part of their diets. Not surprisingly, the land is at the centre of Aboriginal culture, spirituality, tradition and identity. The role of the environment in the lives of Aboriginal people cannot be overstated.

The modern economy of the NWT has been dominated by activities in the non-renewable resource sector. While some efforts are being made to diversify into other sectors, it is likely that non-renewable resources will continue to underpin the economy of the NWT for decades. Interest in the NWT's resources is substantial and current activity has all the hallmarks of a major resource boom. Two world-class diamond mines have come into production over the past eight years and a third will follow in the near future. Strong commodity markets are likely to

FIGURE 1.1-1
NORTHWEST TERRITORIES AND ITS REGIONS



stimulate ongoing interest in the development of other mining prospects throughout the NWT including diamonds, gold, uranium and base metals. The same can be said for the hydrocarbon reserves of the territory. Active oil and gas exploration is underway in several areas of the NWT and a pipeline to transport natural gas in the Mackenzie delta to southern markets is currently undergoing environmental assessment.

In the eyes of many Northerners and the rest of Canada, the NWT's natural resources can serve as a platform for northern "development". The need for change is undeniable, above all for Aboriginal people facing a daunting set of economic and social challenges. Within Aboriginal communities, levels of basic literacy and educational attainment are well below national averages. At the same time, unemployment levels and the incidence of drug and alcohol abuse, domestic violence and gambling are significantly higher than in non-Aboriginal populations.

Given the current context and the broad scope of the NWT environment, this Status of the Environment report covers seven major components of the NWT environment:

- atmospheric environment (including air quality, climate and climate change);
- freshwater aquatic environment;
- marine environment;
- terrestrial environment;
- permafrost, ground ice and snow;
- human health; and
- socio-economic and community wellness.

In conducting the Status of the Environment report, as a starting point we assessed environmental trends using valued components (VCs) identified in the INAC report, *A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program* (NWT CIMP) and Audit. Key VCs within each VC grouping and key indicators of change for the selected VCs were then identified and carried forward through the study. For these key indicators of change, trends in environmental quality were assessed for the Mackenzie Valley, the Inuvialuit Settlement Region and the NWT as a whole.

In assessing trends, previously completed studies were relied upon extensively, particularly where these studies had assessed trends in environmental quality. Where required, these studies were supplemented with original data analysis; however, conducting original research was not within the scope of the Status of the Environment reporting. In carrying out the review, the specialists used a range of information sources and contacted various individuals as appropriate for the Valued Component being assessed.

For each of the key indicators, available data were analyzed and assessed to identify: trends; potential contributing factors to any changes in the environment; the significance of any trends identified; the likely impact of the trends; activities to mitigate the factors/emissions that are causing the observed trends, and, data gaps. It should be noted that in several instances throughout the review it was difficult to determine the current condition of an environmental component or evaluate trends due to a lack of adequate baseline data for the NWT. It is receommended that the CIMP be used to fill these important data gaps.

Large scale resource development and economic activity can lead to significant social, cultural and environmental changes. With exploration and development intensifying, this Status of the Environment report provides an overview of the current conditions in the major components of the NWT environment and identifies areas where further research, monitoring, or action is required.

2.0 AIR QUALITY, CLIMATE AND CLIMATE CHANGE

2.1 INTRODUCTION TO AIR QUALITY AND CLIMATE CHANGE

The Arctic Climate Impact Assessment (ACIA) is a comprehensively researched, fully referenced and independently reviewed evaluation of climate change and its impacts for the region and for the world. The Overview Report entitled "Impacts of a Warming Arctic" (November 2004) concludes that:

"The Arctic is now experiencing some of the most rapid and severe climate change on Earth. Over the next 100 years, climate change is expected to accelerate, contributing to major physical, ecological, social and economic changes, many of which have already begun. Changes in arctic climate will also affect the rest of the world through increased global warming and rising sea levels."

The variability of the earth's climate has been the subject of much debate over the past decade as a result of the observation that emissions of air pollutants (greenhouse gases and ozone depleting substances) from human activity have had an observable effect on the chemical composition of the earth's atmosphere. It has been suggested that this change in chemical composition may have already produced simultaneous physical changes in the atmosphere with respect to meteorological variables such as temperature, precipitation and cloud cover, and that even greater changes can be expected over the next century as the atmospheric concentrations or loadings resulting from anthropogenic emissions continue to increase.

Air pollution is caused by both natural and anthropogenic (human-induced) emission sources. Pollution is defined as "the presence in the atmosphere of substances that are toxic, irritant, or otherwise harmful to people or damaging to vegetation, animals, or property." This pollution has a number of manifestations on various scales: regional and local – smog and acid rain; continental – transport of persistent toxics (e.g., mercury and PCBs) and global - climate change, ozone layer depletion.

A principal source of pollution is the combustion of fuels to produce heat and/or energy. Major sources of anthropogenic emission sources include:

- transportation;
- stationary fuel combustion (e.g., electrical utilities, industrial and residential heating);
- industrial processes (e.g., mining, oil and gas extraction, solvent use); and
- other (e.g., forest fires, agriculture).

Emission sources can have three different configurations, which have significantly different atmospheric dispersion characteristics:

- point sources (emissions from well-defined stacks/exhausts or vents within industrial plants and electric utilities);
- line sources (emissions from vehicles along a highway); and
- area or volume sources (emissions that come from a relatively large area such as wind-blown dust, emissions from furnaces in a residential area).

Factors that affect the concentration of air pollutants in the atmosphere include:

- the geometric configuration (e.g., point/line/area source), and geography in the vicinity of the emission site (e.g., lakes, valleys);
- the total amount of pollutant emitted;
- the meteorological conditions; and
- the amount of pollutant emitted.

Air quality is determined by the concentrations of pollutants in the atmosphere, which are, in turn, affected by the dispersion of pollutants from emission sources. Emission sources can be primary or secondary, where primary sources include stack emissions and volatilization from equipment, and secondary sources generally refer to the reemission of contaminants from large environmental reservoirs. Secondary sources are very important for legacy POPs, like PCBs, and help explain why they will be with us long after their production has ceased.

Weather plays an important role in the dispersion of air pollutants. Meteorology is a vital part of predicting both the current air quality as well as developing any strategies to improve the future situation. The parameters of particular importance are wind speed and direction, and atmospheric stability. The amount of sunshine also directly influences photochemical production of secondary pollutants.

Air quality issues such as regional scale smog, acid deposition, and the concentration of hazardous air pollutants in the lower levels of the atmosphere are linked to climate through temperature, precipitation, humidity, solar radiation, cloudiness and the large scale circulation of the atmosphere which acts to re-distribute air pollutants through long range transport.

The following sections describe the Air Quality, Climate and Climate Change in the Northwest Territories (NWT), with particular emphasis on:

- current monitoring/research programs and data;
- trends in the data and the significance of these trends; and
- information gaps and recommendations for additional monitoring/research.

2.2 AIR QUALITY

2.2.1 Introduction to Air Pollutants

Emissions of air pollutants result in environmental and health impacts through issues such as smog and acid rain. Smog refers to a noxious mixture of air pollutants - including vapours, gases and particles - that can often be seen as a haze in the air. The two main ingredients of smog that affect our health are ground-level ozone and fine airborne particles. Ground-level ozone is a colourless and highly irritating gas that forms in the lower atmosphere. It is called a "secondary" pollutant because it is produced when two primary pollutants - nitrogen oxides (NO_x) and volatile organic compounds (VOC) - react in sunlight through a process known as photochemistry.

Airborne particles are microscopic solid and liquid particles that remain suspended in the air for varying lengths of time. Primary particles are predominantly produced by fuel combustion, industrial processes, as well as natural processes such as wind blown dust. Secondary particles are formed in the atmosphere by gas-to-particle conversion processes of originally emitted gaseous compounds.

Sulphur dioxide (SO_2) is a colourless gas that can be chemically transformed into acidic pollutants such as sulphuric acid and sulphates (sulphates are a major component of fine particles). The main sources of airborne SO_2 are coal-fired power generating stations and non-ferrous ore smelters. Sulphur dioxide is also one of the main causes of acid rain, which can damage crops, forests and whole ecosystems.

Nitrogen oxides (NO_x) are nitrogen-oxygen compounds that include nitric oxide (NO) and nitrogen dioxide (NO_2). NO_2 is a toxic, irritating gas emitted by all combustion processes. It is both a separate component of smog and a pollutant that contributes to the formation of ground-level ozone and particulate matter. In combination with water, NO_2 can form the nitric acid component of acid rain.

Volatile Organic Compounds (VOCs) are carbon-containing gases and vapours such as gasoline fumes, with the major exceptions of carbon dioxide, carbon monoxide, methane and chlorofluorocarbons. Anthropogenic sources of VOCs are mainly fuel combustion and the evaporation of liquid fuels and solvents. Carbon monoxide (CO) is a colourless and odourless gas that is a product of incomplete combustion.

The Environmental Protection Service (EPS) of the Department of Resources, Wildlife and Economic Development (RWED; now Environment and Natural Resources (ENR)) monitors air quality in the NWT. The network consists of four monitoring stations located in Yellowknife, Fort Liard, Norman Wells and Inuvik. In 2003 the NWT air quality monitoring network was significantly upgraded and expanded. In Yellowknife and Fort Liard, the existing equipment was relocated to climate-controlled trailers, some aging monitors were replaced and additional monitors were added to measure other pollutants and meteorological parameters. New stations were installed in Norman Wells and Inuvik, using climate-controlled trailers, housing state-of-the-art continuous monitoring equipment. Pollutants monitored vary by station but include sulphur dioxide (SO_2), hydrogen sulphide (H_2S), fine particulate matter ($PM_{2.5}$), ground level ozone (O_3), carbon monoxide (CO) and nitrogen oxides (NO_x), as well as wind speed, wind direction and temperature (GNWT 2004).

The GNWT has adopted a number of ambient concentration limits for the protection of air quality in the NWT. The limits for SO_2, ground-level ozone, TSP and $PM_{2.5}$ are listed in the *Guideline for Ambient Air Quality Standards in the Northwest Territories* (RWED 2002). These standards are used in the assessment of air quality monitoring data as well as in determining the acceptability of emissions from proposed and existing developments. Where NWT standards are not available for a particular pollutant the Canadian National Ambient Air Quality Objectives (Environment Canada 1981) or limits established in other jurisdictions are used.

The "2002/2003 Northwest Territories Air Quality Report" (GNWT 2004) concludes that overall, the air quality in the NWT continues to be good. With increased development it is important to continue monitoring to ensure that there are no negative impacts on air quality. RWED is continuing to explore opportunities to upgrade and expand the existing air quality program.

2.2.2 Air Quality Indicators

The key indicators of air quality addressed in this initial SOE and the rationale for their selection are presented in the Table 2.2-1.

TABLE 2.2-1
RATIONALE FOR SELECTION OF INDICATORS
FOR AIR QUALITY VALUED COMPONENT

Valued Component	Key Indicators*	Rationale
Air Quality	• **Particulate Matter concentrations**	• Primary air quality contributor to local human health issues • Emitted from local sources • Monitored by GNWT and private companies at various locations
	• **SO_2/NO_x concentrations**	• Emitted and measured locally • Potential local health and ecosystem effects • Also transported from long-range sources • Chemically converted in the atmosphere to acid rain • Precursor to ground level ozone

*key indicators are in bold type.

2.2.2.1 Particulate Matter

Airborne particulate matter consists of particles ranging in size from 0.005 to 100 µm in diameter. For convenience in air quality assessment and regulation, the various size fractions are generally subdivided into several distinct size categories. These include total suspended particulate matter (TSP) consisting of all particles with a mean diameter less than 30 µm, inhalable particulate matter (PM_{10}) consisting of particles with a mean diameter less than 10 µm, and fine particles ($PM_{2.5}$) consisting of particles with a mean diameter less than 2.5 µm. In part, the distinctions between these size categories reflect the changing focus of regulations over the past three decades from coarser to finer size fractions of particulate matter.

Monitoring levels of inhalable particulate matter (PM_{10}) is important because inhaling particulates can aggravate asthma and other cardiac and respiratory disorders, damage plants and cause corrosion and soiling of buildings and cars. Fine particulate matter ($PM_{2.5}$) consists of solid or liquid particles with diameters less than or equal to 2.5 micrometres (1 micrometre = 1 millionth of a metre) in size. They can penetrate deep into the lungs and pose the highest risk to human health.

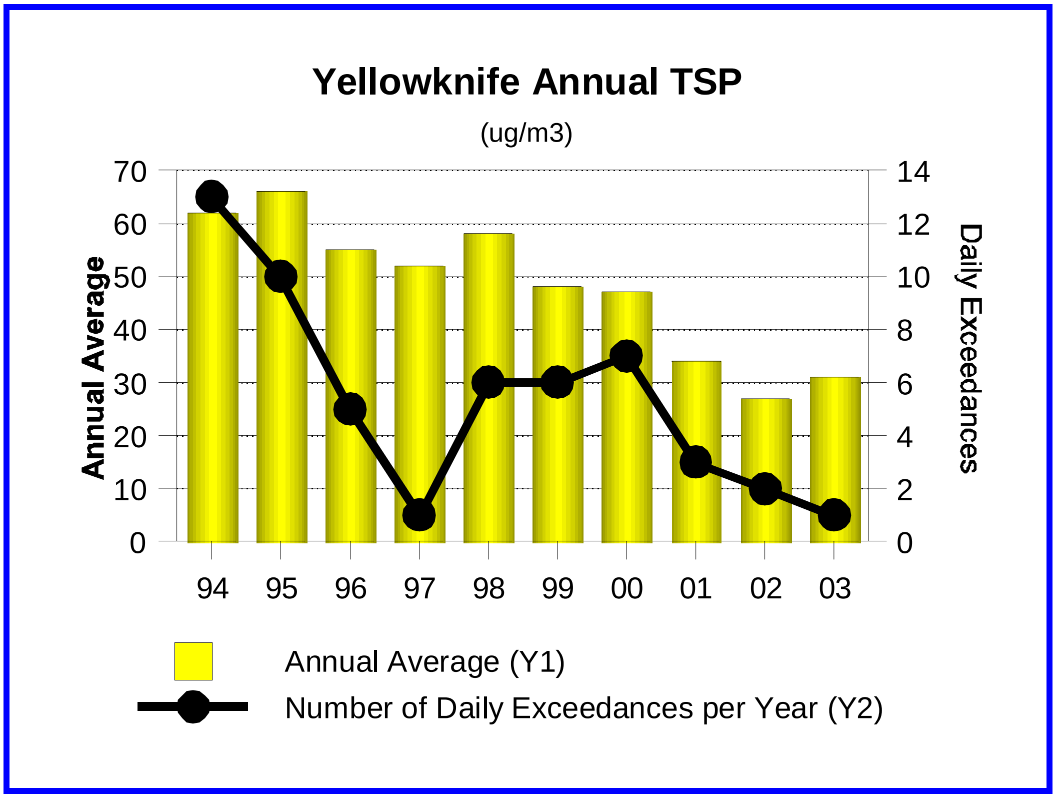
i) What is Being Measured?

TSP, PM_{10} (since 2000) and $PM_{2.5}$ (since 1999) are measured in Yellowknife. In mid-November 2003, a Beta Attenuation Monitor (BAM) was installed in Fort Liard to provide continuous monitoring of $PM_{2.5}$. A similar monitor was installed in Inuvik in December 2003.

ii) What is Happening?

Figure 2.2-1 shows the trend in annual average TSP levels in Yellowknife over the last decade. The graph shows a downward trend, with a slight increase in 2003, although the level of 31 µg/m^3 is well below the NWT annual standard of 60 µg/m^3. The line in Figure 2.2-1 shows the number of times during the year that the NWT 24-hour TSP standard (120 µg/m^3) was exceeded. The number of exceedances in 2003 continued the downward trend with only 1 of 52 samples exceeding the 24-hour standard.

FIGURE 2.2-1
ANNUAL AVERAGE TSP IN YELLOWKNIFE
AND NUMBER EXCEEDANCES OF DAILY STANDARD



Source: Figure 1 from 2002/2003 Northwest Territories Air Quality Report (Veale 2005).

Maximum 24-hour PM_{10} concentrations coincide with high April TSP values, confirming that PM_{10} concentrations are heavily influenced by the effects of road dust. Low PM_{10} concentrations are seen during the winter months when snow cover suppresses wind blown dust.

The annual average of $PM_{2.5}$ in Yellowknife has remained consistently low, ranging from 3 to 5 μg/m^3 since monitoring began in 1999. In 2003, the maximum 24-hour $PM_{2.5}$ values occurred between July 25 and August 6, and coincided with forest fires south of Great Slave Lake. Limited sampling in 2003 at Fort Liard and Inuvik showed very low concentrations of $PM_{2.5}$.

iii) Why is it happening?

Since the early 1990s, dust conditions in Yellowknife have improved, largely due to the City of Yellowknife's efforts to clean roads throughout the spring and summer, as well as ongoing paving of gravelled areas.

iv) What does it mean?

The greatest source of TSP in Yellowknife is dust from roads, especially in the spring. Forest fires, mining activities and combustion products from vehicles, heating and electricity generation also contribute to TSP levels. PM_{10} concentrations are also largely influenced by road dust. $PM_{2.5}$ concentrations are consistently low, with the greatest short-term influences being smoke from forest fires and extreme spring dust events.

v) What is being done about it?

The data emphasize the need for diligent and timely road sweeping by the City of Yellowknife during spring to minimize road dust sources. Ongoing road maintenance (e.g., sweeping and paving of dirt roads) and dust suppression activities on exposed areas throughout the summer are also important.

To address the health impacts of fine particulate matter, $PM_{2.5}$ monitors have been installed in Yellowknife, Fort Liard and Inuvik. A fourth monitor was installed in Norman Wells in 2004. PM_{10} concentrations are only measured at Yellowknife. It would be beneficial to complement the fine particulate monitoring being conducted at the other locations with PM_{10} monitors, in order to capture the coarser fraction of fine particles, which are associated with different sources and effects.

At the national level, the Canadian Council of Ministers of the Environment (CCME) endorsed Canada-Wide Standards (CWSs) for ground-level ozone and fine particulate matter ($PM_{2.5}$) in 2000. These standards set targets for ambient concentrations that have to be achieved by the year 2010. Slightly coarser particulate matter, particles with diameters less than or equal to 10 micrometres (PM_{10}), has been added to the Toxic Substances List under the *Canadian Environmental Protection Act, 1999.* (Environment Canada http://www.ec.gc.ca/soer-ree/English/Indicator_series/)

vi) What are the Information Gaps?

Current monitoring data (from the four operating stations) will provide a good baseline for air quality in the NWT, for future oil and gas and other industrial development projects. The four permanent stations have significant distances between them. A fifth station would be very valuable within the vicinity of Fort Simpson/Wrigley, to capture potential air quality impacts from pipelines/compressors in the area.

The mandate of GNWT's air quality monitoring network is the protection of community health. GNWT does not have jurisdiction over industrial developments that are not located on community lands, and therefore has no enforcement capability in the event of AQ impacts from such developments.

2.2.2.2 SO_2/NO_x Concentrations

Sulphur dioxide (SO_2) can cause breathing difficulties, is toxic to vegetation and is a precursor of acid rain causing acidification of natural ecosystems and damage to buildings. Measuring sulphur dioxide (SO_2) is important because of the health effects caused by exposure. SO_2 is linked to an increase in daily respiratory hospital admissions and an increase in cardiac and respiratory mortality.

Nitrogen oxides are toxic to plants and nitrogen dioxide can cause breathing difficulties in humans. Nitrogen oxides are one of the main precursors of ground level ozone, which can also affect breathing and damage crops and vegetation. Deposition of oxidized nitrogen causes acidification and eutrophication.

i) What is Being Measured?

Continuous monitoring of SO_2 has been conducted in Yellowknife since 1992. Significant oil and gas development in the Fort Liard region prompted the establishment of an air quality monitoring program in 2000. SO_2 and H_2S analysers were installed in March and October, respectively. In March 2003, both analysers were relocated to a climate-controlled trailer to provide improved operating conditions. In February 2003, a climate-controlled trailer housing continuous SO_2 and H_2S analysers was installed in Norman Wells. A similar station was brought on-line in September 2003 in Inuvik.

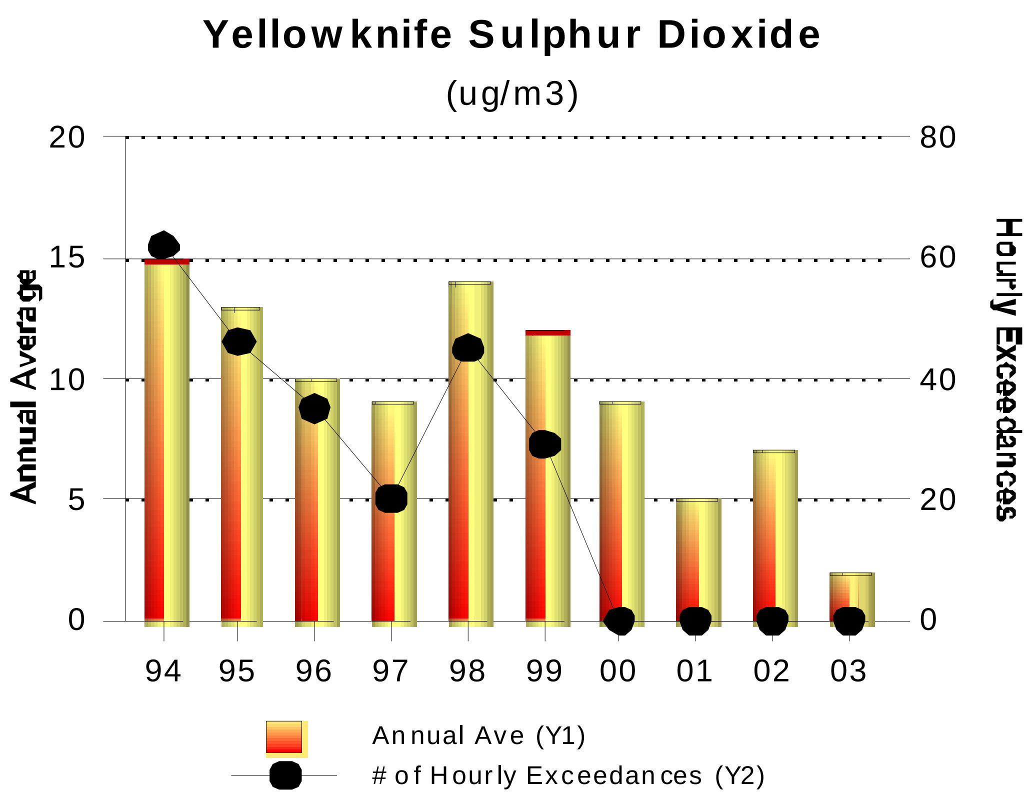
A NO_x analyser was installed in Yellowknife in November 2003. A NO_x analyser was added to the Inuvik station in mid-October 2003.

ii) What is happening?

Figure 2.2-2 shows the trend in annual SO_2 concentrations measured over a ten-year period in Yellowknife. The line shows the number of times in each year that the NWT 1-hour standard 450 $\mu g/m^3$) was exceeded. The number of exceedances have fallen to zero since the closure of Giant Mine in 1999. The annual averages indicate only background levels of SO_2 exist in ambient air in the Yellowknife region.

SO_2 concentrations measured in Fort Liard are within the expected range of background values and there appears to be no impact on community air quality from oil and gas development in the area, at the present time. SO_2 concentrations measured in Norman Wells and Inuvik in 2003, were also well below the NWT ambient standards.

FIGURE 2.2-2
ANNUAL AVERAGE SO_2 IN YELLOWKNIFE
AND NUMBER OF EXCEEDANCES OF HOURLY STANDARD



Source: Figure 10 from 2002/2003 Northwest Territories Air Quality Report (Veale 2005).

The limited NO_x data collected in 2003 indicate no exceedances of the 1-hour (400 $\mu g/m^3$) and 24-hour (400 $\mu g/m^3$) national acceptable limits for NO_2 More detailed information and analysis should be available in the 2003/2004 Air Quality Report, which is expected to be released in June 2005.

iii) Why is it Happening?

Following the closure of Giant Mine in late October 1999, SO_2 levels in Yellowknife have decreased significantly. The concentrations measured in 2003 reflect naturally occurring SO_2, usually in the range of 3 to 4 $\mu g/m^3$, and small amounts from the burning of fossil fuels. Similar background levels were noted in Fort Liard, Norman Wells and Inuvik.

iv) What does it mean?

Current SO_2 concentrations measured at four stations in the NWT indicated background (naturally occurring) levels of SO_2. Preliminary measurements from the recently established NOx analysers indicated similar background levels. Longer monitoring records are required to establish trends in these monitoring data. These stations will serve to monitor potential air quality impacts from proposed industrial developments that will be operating in the future.

v) What is being done about it?

The EPS has acquired a new computerized data management and warehousing system, which is intended to automatically download data from the monitoring network on an hourly basis, perform a series of validity checks, calculate the appropriate data averaging periods and store the data. The system also has the capability to post the calculated averages to a web page, providing public access to almost real time air quality data for each monitoring location (GNWT 2004).

Since the Acid Rain Annex was developed as part of the original Air Quality Agreement in 1991 to address SO_2 and NO_x emissions, the United States and Canada have taken significant actions to address acid rain. This Annex specifically targeted emissions from electric power generation, with the intention of protecting visibility, preventing air quality deterioration in clean areas, and monitoring emissions to ensure reductions. Both countries have established objectives for emission limitations or reductions, programs to implement these objectives, as well as timetables for implementation.

On June 23, 1999, the federal government passed regulations limiting the amount of sulphur in gasoline. In 2005, low-sulphur gasoline (that is gasoline with an average sulphur level of less than 30 mg/kg) is required throughout Canada. As an interim step, gasoline with an average sulphur level of not more than 150 mg/kg was required in 2002. The final level reduces the sulphur content of gasoline by more than 90% from current levels.
(http://www.ec.gc.ca/energ/fuels/regulations/sulreg_e.htm)

vi) What are the information gaps?

Current monitoring data (from the four operating stations) will provide a good baseline for air quality in the NWT, for future oil and gas development projects. The four permanent stations have significant distances between them. A fifth station would be very valuable within the vicinity of

Fort Simpson/Wrigley, to capture AQ impacts from pipelines/compressors in the area. The air quality monitoring infrastructure is established. Future improvements should include the monitoring of additional contaminants such as VOCs/methane for oil and gas developments (Veale 2005).

2.2.3 Other Air Quality Issues

The movement of air currents in the Northern Hemisphere is such that the air gravitates towards the Arctic and eventually carries pollutants into Northern Canada. Subsequently, these pollutants become trapped in the cold temperatures and can enter the food chain. Local sources of air pollution in the Northwest Territories include electrical power generation from diesel engines, residential emissions from home heating, motor vehicle emissions, and dust from gravel roads.

2.2.3.1 POPs and Heavy Metals

The Northern Contaminants Program (NCP) was established in response to studies that showed the presence of contaminants in the Arctic ecosystem. Many of these contaminants have no Arctic sources and yet some are found at high levels in animals at the top of the Arctic food chain and in humans. The three main contaminants groups of concern are persistent organic pollutants (POPs), heavy metals and radionuclides.

The NCP is managed by the Department of Indian Affairs and Northern Development in partnership with other federal departments (Health, Environment, Fisheries and Oceans), the three territorial government departments, Aboriginal organizations (Council of Yukon First Nations, Dene Nation, Inuit Tapiriit Kanatami, Inuit Circumpolar Conference) and university researchers.

Phase I of the NCP (1991-1997) focused on determining the main sources of contaminants and their transport pathways and fate in the Arctic, as well as their levels and spatial and temporal distribution within Arctic ecosystems and humans. The results were used in international negotiations to control contaminants. Education and communication of contaminants information with Northerners was a major emphasis of Phase I, led by the Aboriginal organizations. The NCP produced an extensive assessment in 1997, entitled Canadian Arctic Contaminants Assessment Report.

The NCP Phase II was a five-year program (1998-2003) that funded research on northern contaminants issues, in addition to supporting the Centre for Indigenous Peoples' Nutrition and Environment (CINE) and the participation of Aboriginal organizations in the NCP. The emphasis of Phase II was on expanding human health research, developing effective community dialogue, and continuing work on international agreements to control contaminants.

The NCP works closely with the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP). The goal of this cooperative program among the eight Arctic countries, Arctic Aboriginal organizations and a number of observer countries and organizations is to monitor and assess anthropogenic pollution in the circumpolar Arctic. The results of NCP projects represent the main Canadian contribution to AMAP, and those of NCP Phase I formed an integral part of the comprehensive AMAP Assessment Report: Arctic Pollution Issues, published in 1998.

In March 2003 the second Canadian Arctic Contaminants Assessment Report, reporting on research under phase 2 of the NCP, was published. Phase 2 results also made a substantial contribution to the second AMAP assessment reports published over the past three years.

NCP findings have provided substantiation for the calls for action on international controls of contaminants. POPs and Heavy Metals Protocols under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (CRTAP) have been signed by 36 countries, including Canada, since June 1998. Negotiations for a legally binding global instrument on POPs under the United Nations Environment Programme have now also been completed with the signing of the POPs Convention in Stockholm, Sweden on May 23, 2001. Both of these conventions entered into force in 2004.

i) Highlights of the Canadian Arctic Contaminants Assessment Report II

In general, the Canadian northern atmosphere contains lower levels of POPs and heavy metals than those found over most other circumpolar countries. Levels of most contaminants are declining slowly right across the circumpolar Arctic. However, it is still too early to tell whether mercury levels are increasing or decreasing. Most POPs are declining in the Canadian northern atmosphere, with the exception of dieldrin and endosulfan. Decreases in the hexachlorocyclohexanes (HCHs) and toxaphene are undoubtedly a result of international controls on their use. Lindane is expected to continue to be transported northward for some years from residues in Canada, France and China.

Several new contaminants not previously studied under the NCP are now being found in the Canadian northern atmosphere but it is still too early to tell whether levels are increasing. These include the brominated flame retardants, chlorinated paraffins and chlorinated phenols. The flame retardants are widely used and may be of concern in the future as they easily enter the food web. More research is required in this area.

The federal government now gives special attention to the ways in which northern Aboriginal children are exposed to contaminants, and to the levels and effects of these contaminants on their health. The NCP continues to provide direct input and direction to both the federal and NAFTA initiatives. NCP research played a significant role in the development of the domestic voluntary agreement to stop using lindane.

The Canadian Arctic Indigenous Peoples against POPs (CAIPAP) group was formed in 1997 to influence Canada's position in the UN/ECE LRTAP and UNEP Global POPs negotiations. The NCP Aboriginal Partners formed the members of (CAIPAP). CAIPAP participated actively and very successfully in the global POPs negotiations, due in part to the support of the NCP.

Summary of Recommendations

- It is important to monitor the levels of the new POPs in the physical environment, e.g., brominated flame retardants, chlorinated paraffins and chlorinated phenols.
- Continued research on the properties of contaminants will help identify which are more likely to travel to the Canadian North from southern sources.
- Older POPs should continue to be monitored in the atmosphere, as there is not enough data as yet to determine long-term trends.
- More work is needed on the routes taken by heavy metals (especially mercury) to the Canadian North.
- Continued research is required to assess the importance and nature of mercury depletion events.
- Studies on levels of contaminants in lake water and sediments should continue as these are very sensitive to changes in inputs from the atmosphere, runoff and rivers.
- Research is needed to increase understanding of the importance of microbes in removing contaminants from the physical environment.
- POPs in seawater should continue to be monitored, as ocean currents are now recognized as being more important transport routes than previously thought.
- The role of sea ice in moving contaminants from one part of the environment to another needs to be better understood – this is particularly important given climate change may change sea ice patterns.
- Research using radionuclides to "trace" ocean currents may provide information on the routes used by contaminants in seawater to reach the Arctic.
- More research on the properties of contaminants will provide useful information on what is likely to happen to them once they reach the Canadian North.
- Although snow is known to be important for bringing contaminants to the surface, more needs to be understood about how this happens, and what happens to the contaminants once they reach the surface.

- Climate change is expected to have a profound effect on the Canadian North and more research is needed to increase understanding of the effects of climate change on contaminants.
- Studies are needed on how melting permafrost will affect the flow of contaminants.
- It is important to look closely at the links between human behaviour worldwide (e.g., energy consumption, and international policies), and contaminants in northern Canada.

Global and regional gridded emissions inventories have been created for some OC pesticides such as HCH and toxaphene. Declines in the global use and emissions of technical HCH are consistent with observed declines of alpha- and gamma-HCH in Arctic air, results that are helping to refine global mass balance models. These results also provide strong evidence that international action to reduce global POPs use can have a direct impact on levels in the Arctic.

Decreasing atmospheric trends in most "legacy" persistent organic pollutants (POPs) over the last 5–10 years. The concentration of most POPs which were reviewed in the first CACAR and which have received international attention through the United Nations have been declining in Arctic air. Observations at Arctic monitoring stations, in particular at Alert, Nunavut, have confirmed this trend for POPs such as PCBs, DDT, chlordane, and HCH.

The observation of "new chemicals" in the Arctic abiotic environment. A new generation of POPs has been measured in Arctic air, seawater, and freshwater sediments that includes brominated flame retardants (in particular polybrominated diphenyl ethers, PBDEs), perfluorinated alkane compounds (PFA), short chain chlorinated paraffins (SCCPs) and polychlorinated naphthalenes (PCNs). Some pesticides currently used in the circumpolar countries were also identified: endosulfan, trifluralin and methoxychlor. PBDEs have concentrations that are rising. Unlike most other organochlorine pesticides, concentrations of endosulfan in Arctic air have not declined over the last 7 years.

Relatively stable atmospheric concentrations of anthropogenically derived heavy metals including copper, lead and zinc. Twenty-years of weekly mean concentrations of metals (not including mercury) in Arctic air reveal no significant increasing or decreasing trends for metals derived from anthropogenic sources.

ii) Mercury

Mercury is listed as a "toxic substance" under the Canadian Environmental Protection Act. It is a liquid heavy metal that can volatize into the air and be carried by the atmosphere all over the world. In Canada, airborne mercury emissions come mainly from coal-fired power plants in the United States and base metal smelting plants and incinerators in Canada.

Scientists have concluded that in Canada and the United States, mercury originates from both domestic and international sources and is deposited in sensitive ecosystems. Mercury is found in many lakes, streams, forests and fields. It can convert to a very toxic and bioaccumulative form known as methylmercury -- a substance that can affect both humans and wildlife. For example, methylmercury levels in traditional foods in northern Canada are rising above those established as acceptable by the World Health Organization.

Canada's actions on mercury include (http://www.ec.gc.ca/air/mercury_e.html):

a. The signing and ratification of an International United Nations Protocol, United Nations Economic Commission for Europe Convention on Long Range Transboundary Air Pollution, Heavy Metals Protocol, obliging Canada to control emissions of mercury, cadmium and lead from major stationary sources and some products.
b. The signing of the Phase II North American Regional Action Plan on Mercury by Canada, the United States and Mexico under the North American Commission for Environmental Cooperation on June 12, 2000. The Plan is an indication of North America's commitment to control mercury, and to demonstrate to other countries the need for global cooperation in dealing with long range transport of air pollutants.
c. The agreement by federal, provincial and territorial governments at the meeting of the Canadian Council of Ministers of the Environment in Quebec City on June 5 & 6, 2000 to ratify the Canada-wide Standard on Mercury, paralleling similar actions in the United States to minimize the risks from mercury in air emissions and products. Additional Canada-wide Standards were also accepted in principle to reduce emissions of mercury in fluorescent lamps and dental amalgam wastes.

Canada's continued implementation of mercury management options under the Canada/United States Great Lakes Bi-national Toxics Strategy in order to virtually eliminate mercury from human activities into the Great Lakes.

2.2.3.2 Stratospheric Ozone

The depletion of the stratospheric ozone layer in the past two decades has been mainly caused by the increase in emissions of chlorine- and bromine-bearing compounds such as chlorofluorocarbons (CFCs), bromofluorocarbons (halons), hydrochlorofluorocarbons (HCFCs), carbon tetrachloride, methyl chloroform and methyl bromide. In addition, however, emissions of gases such as methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) can have both direct and indirect effects on the ozone layer. Since the ozone layer is largely responsible for filtering out the solar UV-B radiation, projected long-term trends in decreasing concentrations of ozone in the atmosphere have led to concerns about potential future increases in skin cancers and cataracts, as well as concerns about ecological effects such as decreased primary production in terrestrial ecosystems, altered plant species composition, altered secondary chemistry with implications for herbivory, litter decomposition and biogeochemical cycles (Caldwell and Flint 1994)

In 2000, Canada signed the Ozone Annex under the 1991 Canada-U.S. Air Quality Agreement to reduce the flow of air pollutants across the Canada-U.S. border. Consequently, the Government of Canada announced a commitment of $120 million over 4 years as part of a 10-year program to invest in new measures to accelerate action on clean air by focusing on cleaner vehicles and fuels, initial measures to reduce smog-causing emissions from industrial sectors, improvements to the cross-country network of air pollution monitoring stations, and expansion of the public reporting on pollutant releases by industry.

2.2.3.3 Acid Deposition

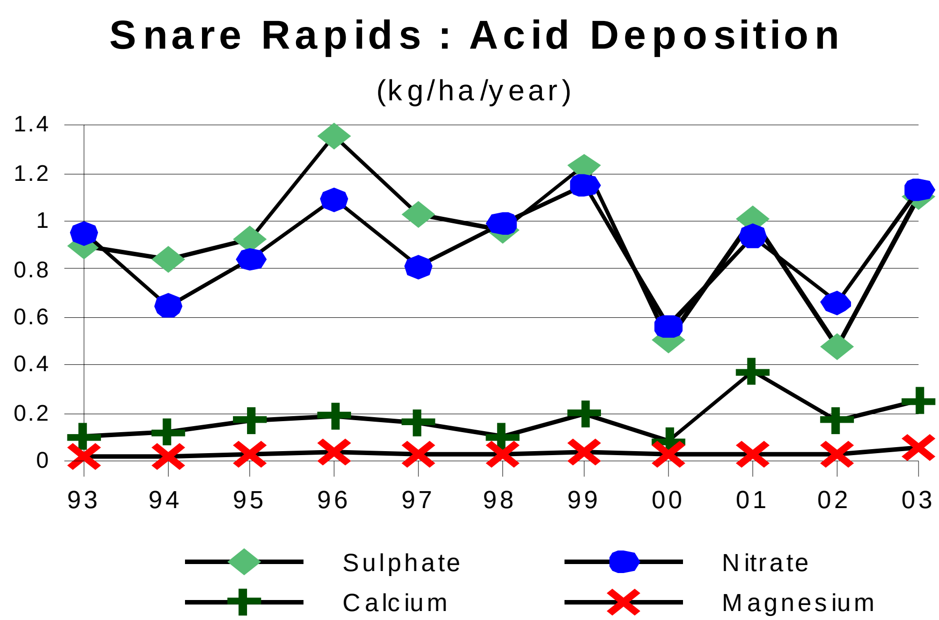
Acid deposition refers to the dry deposition of acidic compounds (in gaseous or particulate form), as well as the wet deposition of acidic compounds in rainwater, fogwater and snowfall. Since 1989, RWED has operated a Canadian Air and Precipitation Monitoring (CAPMoN) station at the NWT Power Corporation's Snare Rapids hydro site.

SO_2 and NO_x emissions can result in an increase in acidic compounds in the atmosphere, often in areas far removed from the original emission sources. The removal of these sulphur and nitrogen compounds through atmospheric washout is reflected in the increased activity (lower pH values) of precipitation. Calcium and magnesium ions, mostly from natural sources, act to neutralize acidity in precipitation. Assessment of acid precipitation is usually based on deposition to an area over a specified time period (e.g., kilograms per hectare per year, kg/ha/yr) (GNWT 2004).

Figure 2.2-3 shows the deposition rates of certain ions measured in Snare Rapids precipitation between 1993 and 2003. While calcium and magnesium deposition rates have remained relatively constant, both sulphate and nitrate deposition rates show an increase in 2003. However, these values are within the historical range for sulphate and nitrate, and reflect an annual variation noted in previous years. Sulphate and nitrate deposition rates remain well below levels that could cause an environmental effect in sensitive ecosystems (GNWT 2004).

GNWT's funding for this station may not be renewed in the new fiscal year due to budget constraints. This is the only acid precipitation station in Canada's North, and shutting it down will prevent detection of potential acid deposition effects from new oil and gas developments in the future (Veale 2005).

FIGURE 2.2-3
ANNUAL AVERAGE ACID DEPOSITION AT SNARE RAPIDS



Source: Figure 18 from 2002/2003 Northwest Territories Air Quality Report (Veale 2005).

2.3 CLIMATE

Climate is usually described in terms of the familiar elements that describe the weather. Temperature and precipitation are the essential indicators, but other parameters include sunshine, wind, cloud cover, atmospheric pressure, humidity and evaporation, to provide a more complete picture.

2.3.1 Climate Monitoring in Canada

Canada's national (atmospheric) Climate Network is, in practice, the composite of several rather distinct sub-networks:

- A Daily Temperature and Precipitation (T&P) Network, operated by cooperating agencies, volunteer and contract observers and including an increasing number of automatic stations;
- A Principal (Hourly) Network of automated and manned real-time reporting stations established primarily to support weather forecasting;
- An Upper Air (Radiosonde) Network, of manned stations to support weather forecasting;

- Supplementary Networks established to acquire observational data on variables such as:
    - Rate of Rainfall;
    - Wind Speed and Direction;
    - Ozone;
    - Evaporation (Pan);
    - Soil Temperature;
    - Sunshine;
    - Snow Cover/Depth;
    - Radiation;
- Air Quality and Precipitation Chemistry Networks.

2.3.2 Climate Indicators

The key indicators of climate that are addressed in this initial SOE and the rationale for their selection is presented in Table 2.3-1.

TABLE 2.3-1
RATIONALE FOR SELECTION OF INDICATORS
OF CLIMATE VALUED COMPONENT

Valued Component	Key Indicators*	Rationale
Climate	• **Temperature**	• *Long temperature record available in the North (50+ years)* • direct local impacts on humans and the ecosystem
	• **Precipitation**	• *reasonable precipitation record (not as reliable as temperature record)* • direct local impacts on humans and the ecosystem

*key indicators are in bold type.

2.3.2.1 Temperature

The near-surface temperature controls the reaction rate of contaminants as well as how fast the surface drys out. If the temperature is low, the moisture in the surface may stay there or it may even freeze, sealing the surface from the effects of wind erosion, thereby reducing wind-blown dust. Temperature near the surface also controls the buoyant component of turbulence (vertical motion). Heat from the earth's surface heats the air near the ground, causing it to rise. This mechanism reaches a maximum in the early afternoon, and a minimum near sunrise.

i) What is being measured?

Temperature records date back to about 1930 for most of the Canadian Arctic (some stations began in 19th century or early 20th century, e.g., Hay River, Fort Selkirk and Fort Simpson, Northwest Territories). Records from explorers, the Hudson's Bay company, and the gold rush are often sporadic, but offer information dating back several centuries (Kahl 1996). The stations in Canada's northern territories that have temperature records in the Historical Canadian Climate Database are widely and irregularly spaced (MSC 1999). Temperature records for the lower troposphere over the Arctic Ocean date back to 1950 (Kahl 1996). Climatic data is also measured at all Ecological Monitoring and Assessment Network (EMAN) sites in the NWT.

The Upper air monitoring program (conducted by Environment Canada since 1948) is comprised of instrumented weather balloons that are released twice daily from upper air stations at Fort Smith, Norman Wells and Inuvik to gather quantitative information about the vertical structure of the atmosphere over the NWT. The data include atmospheric pressure, temperature, moisture and winds from ground level to about 15 km.

The Global Energy and Water Cycle Experiment (GEWEX) is an international effort of the World Climate Research Programme aimed at improving our understanding and prediction of the water cycle and its relationship to climate. As a major contribution to GEWEX, the Mackenzie GEWEX Study (MAGS) focuses on understanding and modeling the flows of energy and water into and through the atmospheric and hydrological systems of the Mackenzie River Basin. The Mackenzie GEWEX study included a climate data-gathering phase which ended in 1999. However, several of the remote meteorological stations have been integrated into the surface weather monitoring network.

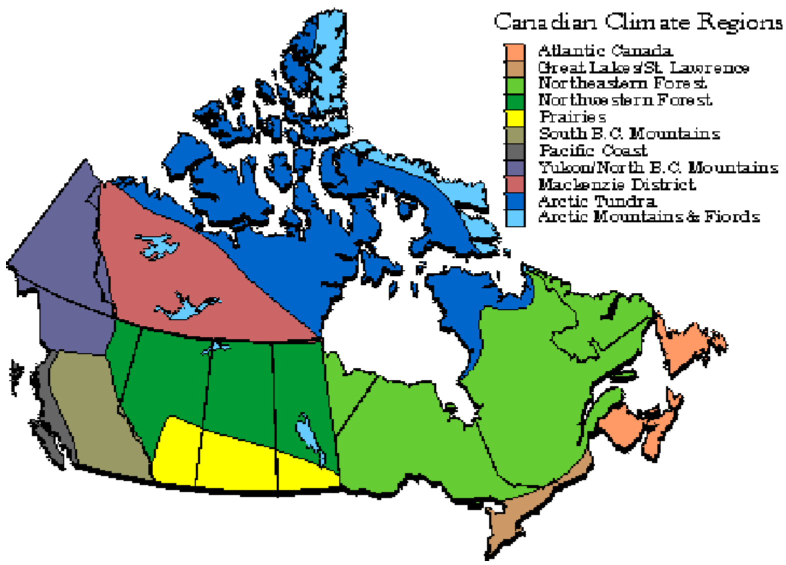
Lightning monitoring program (GNWT since 1987, Environment Canada since 1998) is comprised of a real-time lightning detection network that was established to detect the occurrence of lightning strikes as art of the forest fire management strategy. The current network of 14 stations operates continuously between May and September. The network senses the electromagnetic fields radiated from cloud-to-ground lightning flashes. There are varying degrees of uncertainty associated with the location accuracy of the lightning data and the detection efficiency of the network (DIAND 2002).

ii) What is happening?

The following information was adapted from an article by J.M. Bullas from Environment Canada's Prairie and Northern Region entitled : Recent Climate Trends in the Canadian Arctic" (http://yukon.taiga.net/knowledge/resources/yellow_bullas_07.html). Bullas described three Climate zones for the Arctic (Figure 2.3-1): a large tundra region, a somewhat smaller region bisected by the Mackenzie River, and the mountains and fjords of the far northeast. The results for the Mackenzie District and the Arctic Tundra district are applicable to the NWT.

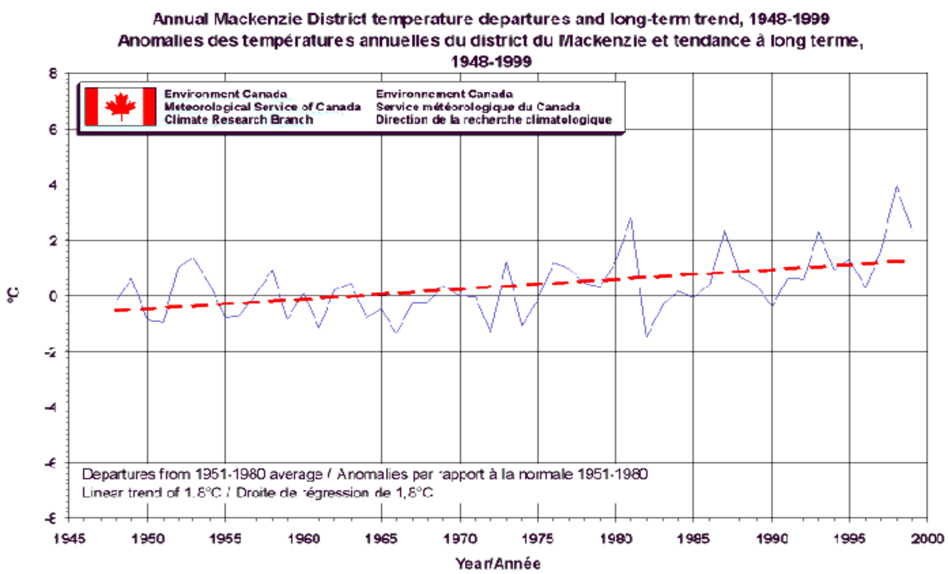
Figures 2.3-2 and 2.3-3 show the average trend in annual mean temperature for the Mackenzie District and the Arctic Tundra districts, respectively. The Mackenzie District (Figure 2.3-4) exhibits a clearly identifiable overall positive trend (about 1.5 degrees/century), comprised of a weak cooling trend into the seventies followed by a warming trend to 1999. The Arctic Tundra (Figure 2.3-5) shows a weak positive trend, but since the region is so large and variable in climatic influences, this trend probably does not apply to the whole district.

FIGURE 2.3-1
CANADIAN CLIMATE REGIONS



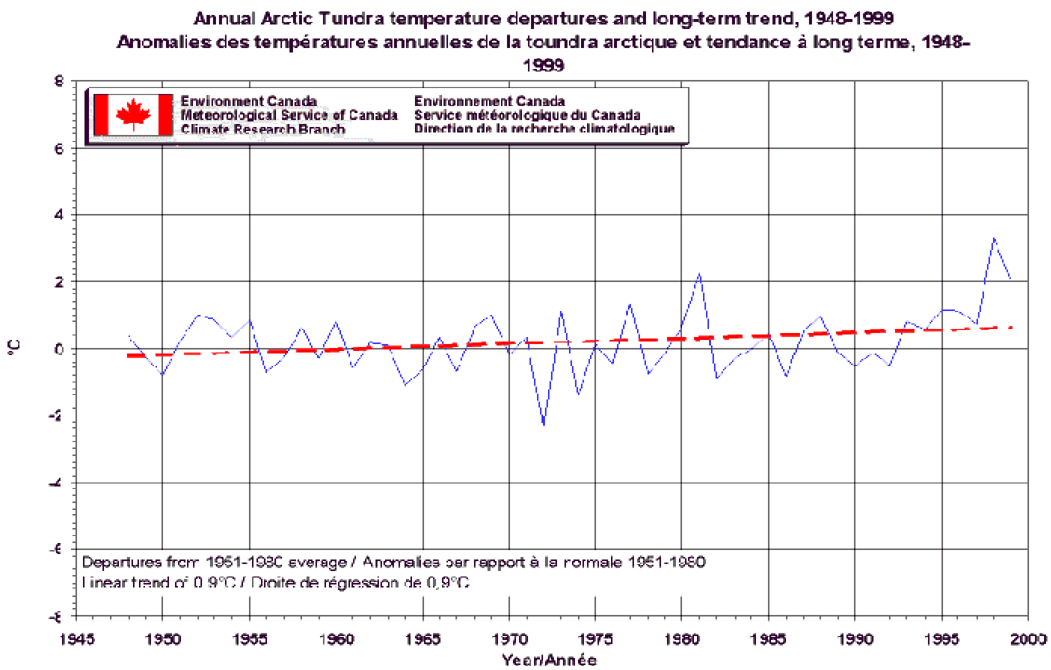
Source: Bullas 2000.

FIGURE 2.3-2
ANNUAL MACKENZIE DISTRICT TEMPERATURE TREND



Source: Bullas 2000.

FIGURE 2.3-3
ANNUAL ARCTIC TUNDRA TEMPERATURE TREND



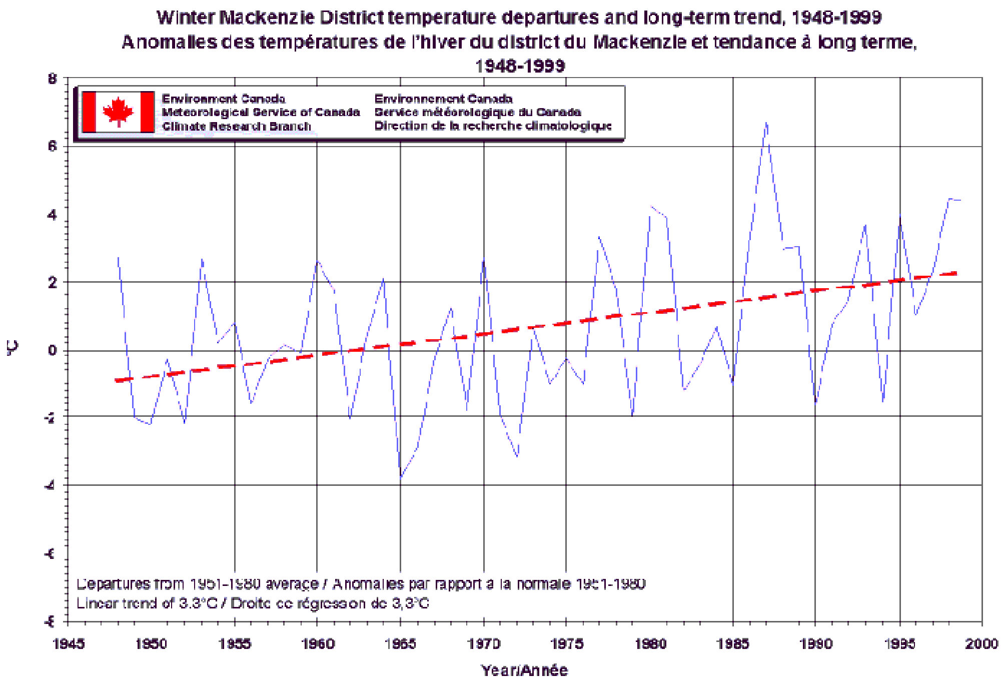
Source: Bullas 2000.

In the Mackenzie District, warming has occurred mainly in winter and spring. There is a very weak warming trend exhibited in the summer, and temperatures in autumn have been gradually decreasing. Elsewhere in the Territories, no significant seasonal variations are evident, although recent autumn seasons have been the warmest on record. Figures 2.3-6 to 2.3-7 show the seasonal trends for the Mackenzie District.

The warming in the winter in the Mackenzie District has been accompanied by a decrease in winter precipitation, while summer precipitation is somewhat higher and apparently more variable. The increase in precipitation over the Tundra region has been relatively evenly distributed throughout the year.

To summarize, prior to the mid-1940's, there were few observing sites in the Canadian Arctic. Since 1945, the western half of the Northwest Territories has exhibited a warming trend, mostly in the winter and spring. There is evidence to suggest that in the Mackenzie region, this trend may go back to the late 1900's or before. Precipitation has shown an increase in the Tundra portion of the Canadian Arctic since 1945.

FIGURE 2.3-4
MACKENZIE DISTRICT WINTER TEMPERATURE TREND



Source: Bullas 2000.

FIGURE 2.3-5
MACKENZIE DISTRICT SPRING TEMPERATURE TREND

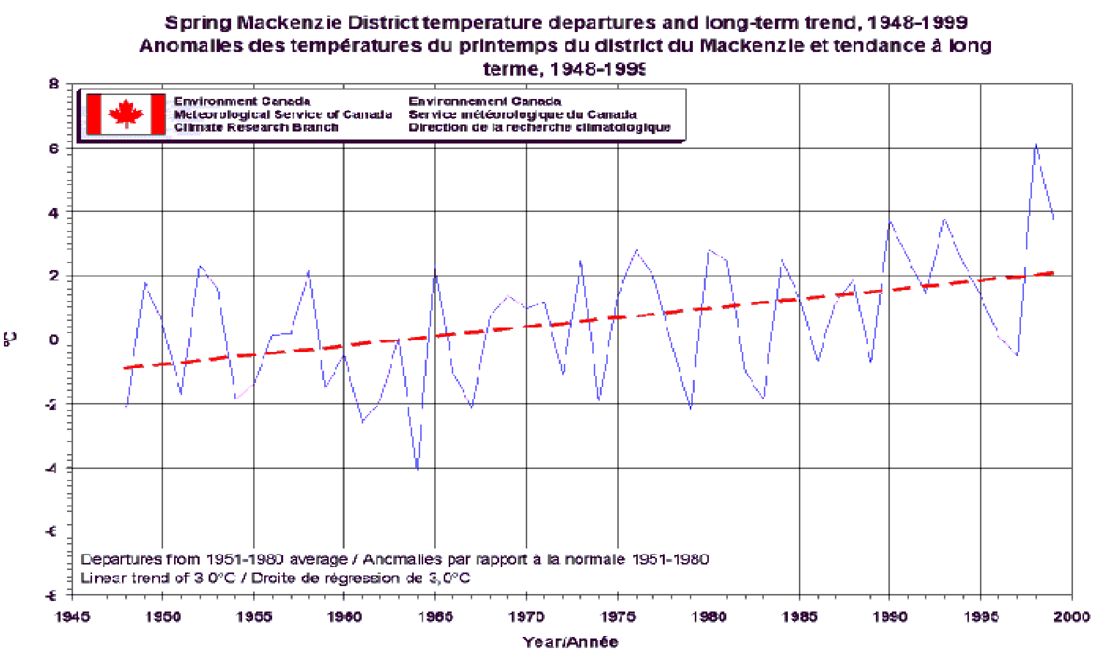
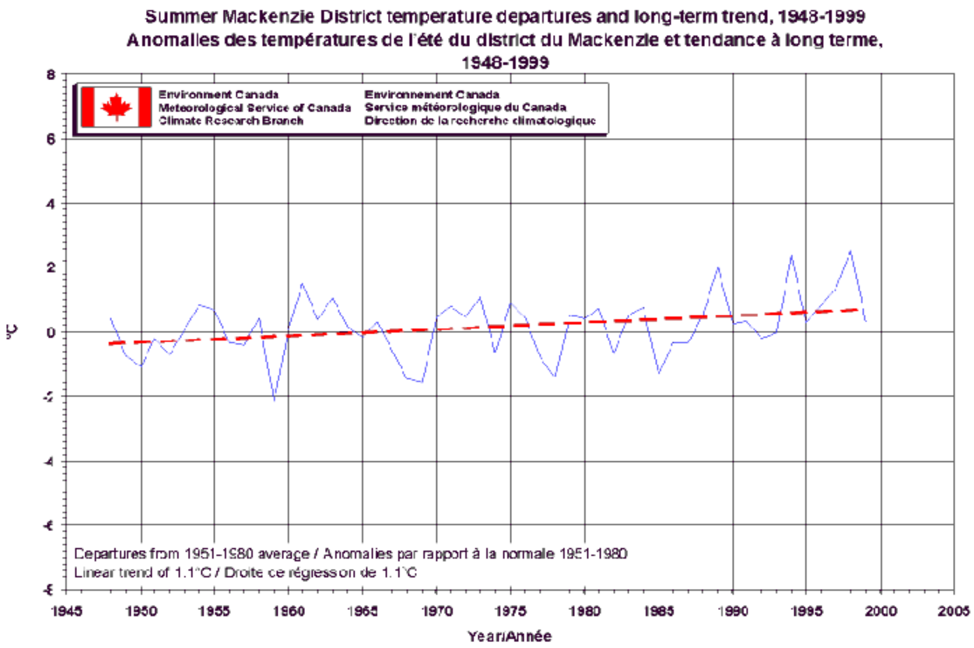
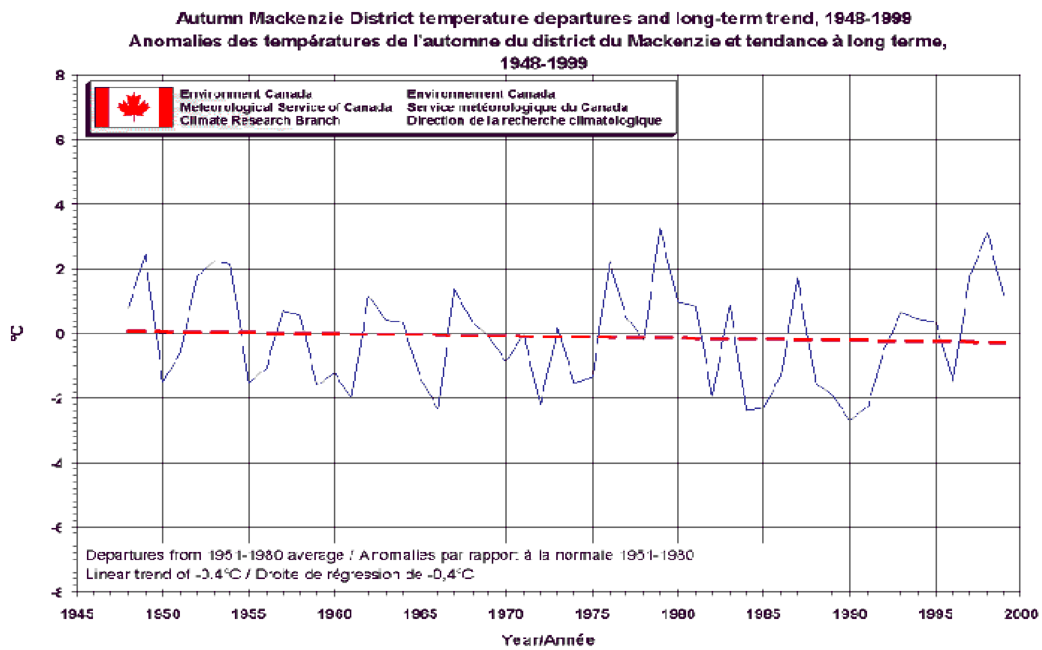


FIGURE 2.3-6
MACKENZIE DISTRICT SUMMER TEMPERATURE TREND



Source: Bullas 2000.

FIGURE 2.3-7
MACKENZIE DISTRICT AUTUMN TEMPERATURE TREND



Source: Bullas 2000.

ii) Why is it happening?

Increases in global mean temperatures have been predicted as a result of increases in atmospheric greenhouse gases generated by human activities. These changes have been predicted to be greatest in the polar region. Temperature changes may also result from natural climate variations, such as the decrease in temperatures that brought about the "Little Ice Age" cooling period in the 19th century for much of the northern hemisphere.

iii) What does it mean?

Changes in global and regional climate have important implications for many aspects of the environment. In the North, temperature warming may bring about changes in sea, lake and river ice, snow conditions, permafrost, habitat for plants and animals, and other changes. For human communities, this may mean changes in agricultural productivity, sustainable hunting levels, heating fuel consumption, and patterns of land use. These effects may be both positive and negative, and are likely to vary from region to region.

iv) What is being done about it?

Annual variability in mean temperatures is often large, and the detection of trends in climate generally requires long-term data sets. Reliable, consistently measured long-term climate records are required for the analysis of climate trends and for the validation of climate change models. In addition to the restoration of instrumental records, researchers are re-constructing historical climate records in the Arctic using lake sediments, ice cores and tree-ring analysis.

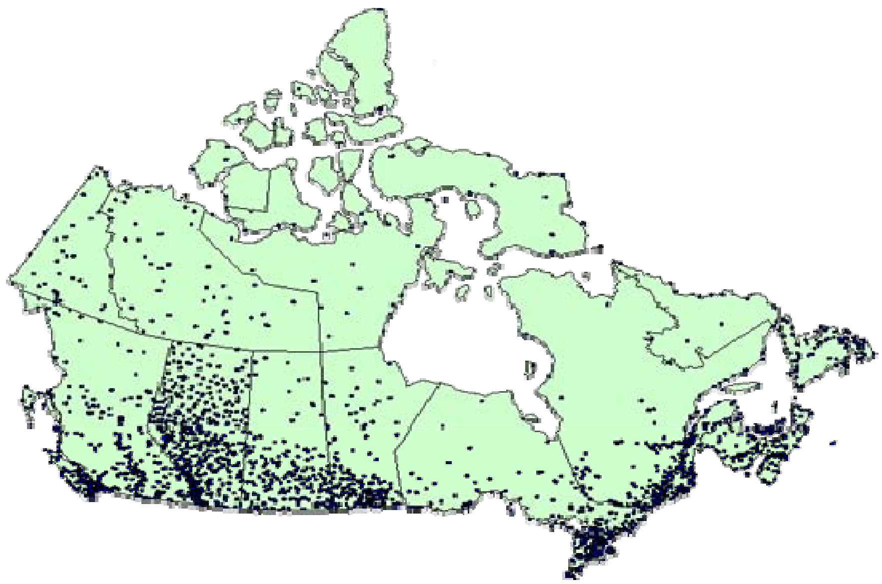
v) What are the information gaps?

Several stations have been closed recently due to budget cuts, and automated stations are replacing manual stations. Automatic stations can never be as accurate as manual stations, for example when mixed precipitation occurs (total precipitation is recorded but the breakdown of liquid versus solid precipitation is unknown) or when blowing snow is measured as false accumulation.

The CIMP VC report (DIAND 2005) identified particular areas with data gaps: the Mackenzie Mountains, Mackenzie River east bank, north of Great Bear Lake, Coppermine River basin, North Slave and South Slave.

The extensive national climatological network of temperature and precipitation stations has undergone significant, budget driven, reductions over the past decade and now totals 2147 stations. Station distribution is illustrated in Figure 2.3-8, reflecting a bias towards lower and more populated latitudes and elevations.

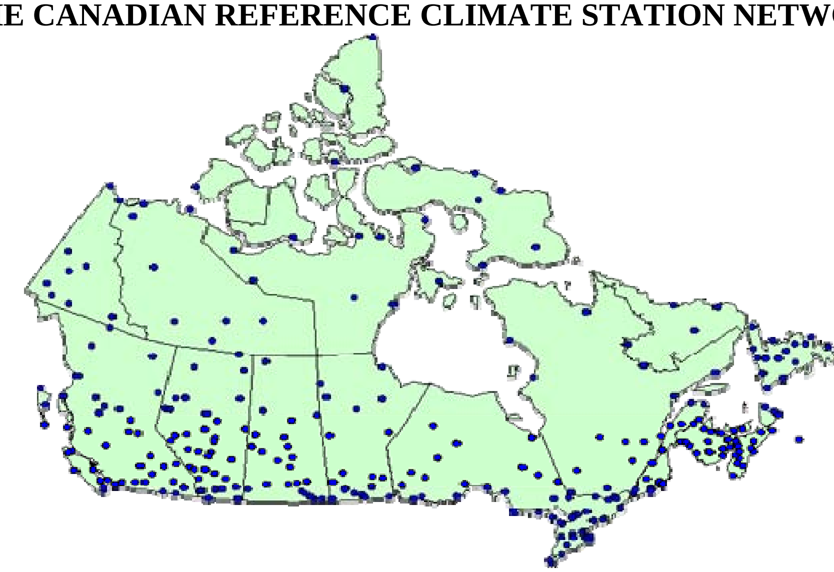
FIGURE 2.3-8
THE CANADIAN TEMPERATURE AND PRECIPITATION NETWORK



Source: http://www.ec.gc.ca/climate/CCAF-FACC/Science/nat2002/toc_e.htm.

Recent efforts to address the attrition in this network and its uneven distribution have focussed on the identification of a Reference Climate Station (RCS) Network of about 300 of the best stations and targeting these for long-term maintenance and enhancement through automation, addition of variables and other measures. These efforts will continue to be a priority during the coming decade. Figure 2.3-9 illustrates the RCS Network.

FIGURE 2.3-9
THE CANADIAN REFERENCE CLIMATE STATION NETWORK



Source: http://www.ec.gc.ca/climate/CCAF-FACC/Science/nat2002/toc_e.htm.

2.3.2.2 Precipitation

Precipitation plays a role in both control of emissions, and removal of pollutants from the air. For example, low precipitation will leave a soil surface mostly dry, and susceptible to wind erosion, whereas a lot of precipitation effectively seals the surface. Dew will effectively hold dust on the ground in the early morning. The contaminants in the air are washed out by precipitation - more precipitation produces more washout.

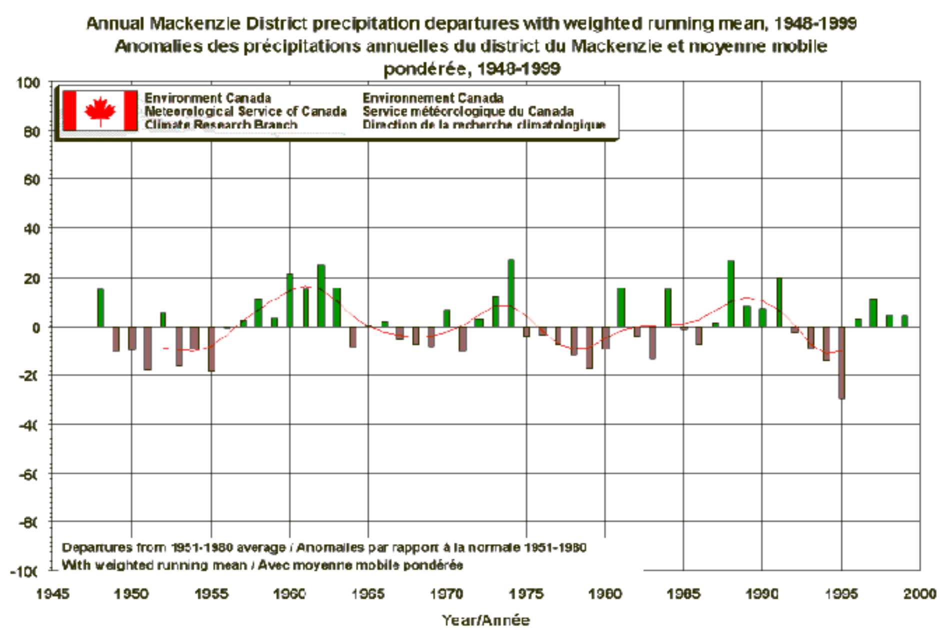
i) What is being measured?

About 65 precipitation gauges throughout Northwest Territories and Nunavut are monitored by Environment Canada (Isaac 1998); precipitation records go back to 1893 for Hay River, Northwest Territories.

ii) What is happening?

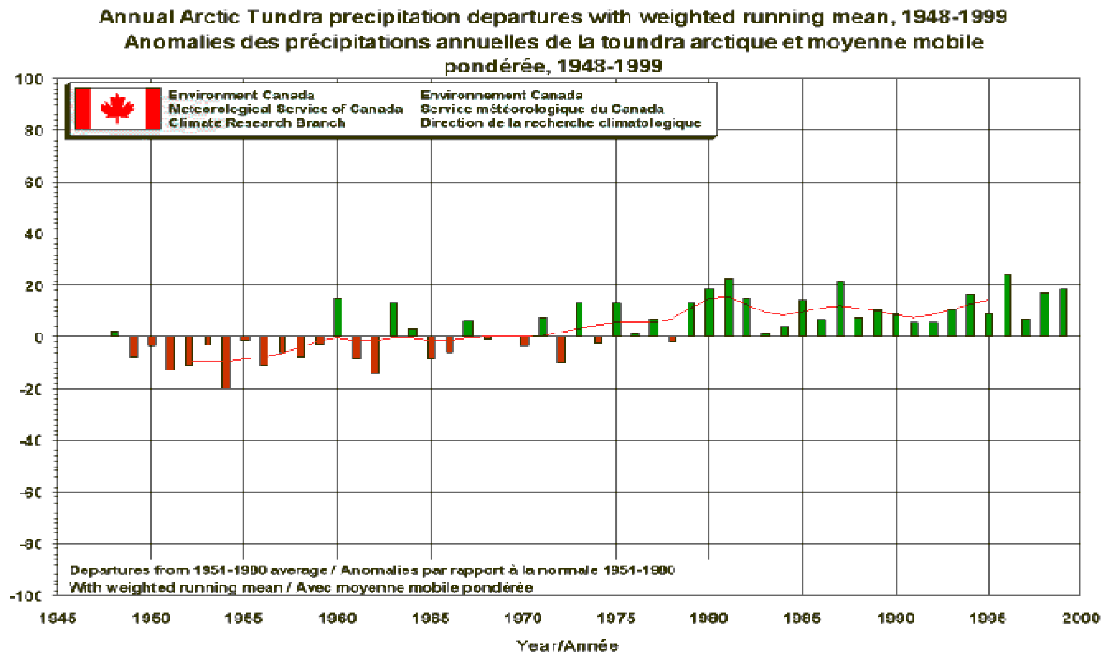
Because of the year-to-year variability, precipitation trends are more difficult to discern. Figures 2.3-10 and 2.3-11 show the trend in precipitation for the Mackenzie and Arctic Tundra districts. Mean annual precipitation has increased somewhat in the Arctic tundra region since 1945. There is no clear trend on an annual basis in other regions of the NWT.

FIGURE 2.3-10
MACKENZIE DISTRICT PRECIPITATION TREND



Source: Bullas 2000.

FIGURE 2.3-11
ARCTIC TUNDRA ANNUAL PRECIPITATION TREND



Source: Bullas 2000.

iii) Why is it happening?

Detecting changes in precipitation trends is difficult because precipitation varies widely across even small geographic areas. Although most of the changes are not statistically significant, an increasing precipitation trend has been measured for some areas of the NWT.

iv) What does it mean?

Human activity aside, surface and groundwater quantity is driven by the balance between atmospheric input from precipitation, and losses due to evapotranspiration. The impacts of changes in precipitation are described in other sections of this report.

v) What is being done about it?

Significant errors have been recognized in the measurement of cold season precipitation. The inherent nature of snow (e.g., varying density and wind effects) and snow cover (sublimation, the effects of land cover, temporal metamorphosis and redistribution by the wind) makes snow very difficult to measure. Snow makes up 60% to 70% of total annual precipitation in the NWT, with a chance of snowfall every month of the year. Because of this, accurate measurements of snowfall are very important for quantifying the water resource.

Both municipal and industrial demands for water are tempered by the ability of water managers to quantify water supply. Also, international research programs such as GEWEX (Global Energy and Water Experiment), WCRP (World Climate Research Program) and ACSYS (Arctic Climate System Study) require accurate long term precipitation measurements. In response to these needs, the Atmospheric Environment Service (AES) and Water Resources, Department of Indian and Northern Affairs (DIAND), developed a corrected historical precipitation archive for selected NWT climate stations. Methods used to correct the precipitation archive accounted for wind, wetting effects and trace measurement errors. As well, more accurate assumptions of snow density and snow ruler precision were applied. Research into precipitation measurement correction is still on-going. Known biases have been accounted for. However, verification of these corrections is needed in order to confirm the accuracy of the new archive (Spence 1997).

vi) What are the information gaps?

The Northern Climate Exchange Knowledge Site (http://yukon.taiga.net/matrix/) notes there is a marked lack of precipitation recording stations in the north relative to southern Canada (e.g.: 1 station per 50,000 km^2 in NWT, versus 12.5 stations per 50,000 km^2 in the rest of Canada) (Lukawesky 1994). There are often significant errors in measuring precipitation, particularly when snow falls in trace amounts, due to factors such as wind and wetting.

2.4 CLIMATE CHANGE

2.4.1 Introduction to Climate Change

The meaning of the term “climate change” within this report is consistent with its definition by the United Nations Framework Convention on Climate Change:

> *“a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.”*

Within the context of this definition, climate change refers to any human-induced changes that are superimposed onto a background of natural climate variability that results from either internal instabilities in the ocean-atmosphere system, or triggering influences such as the El Niño -Southern Oscillation phenomenon, major volcanic eruptions or solar variability. Human-induced changes in climate are assumed to occur over time scales ranging from several decades to centuries.

The Arctic has some special features that make it an important focus for climate research. Physically, the Arctic islands are entirely snow-covered for more than half the year, and the region contains mountain glaciers, ice caps and extensive areas of permafrost. Arctic waters are also covered with sea ice for most of the year. Changes in the amount of sunshine are extreme since the Arctic experiences periods of 24-hour sunlight and 24-hour darkness at different times of year. Also, while large parts of the Arctic are essentially desert-like, large expanses of open water do occur during the short summer, making the Arctic a significant source for moisture and clouds. Northward-flowing rivers such as the Mackenzie empty their waters into the Arctic Ocean, influencing the ocean's physical characteristics. There are also important large-scale climate patterns, such as the Arctic Oscillation, where atmospheric pressure in the Arctic switches between high and low, causing shifts in climate and weather patterns in the Northern Hemisphere. These factors produce a complex interplay among climate processes in the Arctic.

The Intergovernmental Panel on Climate Change (IPCC) has been established by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation.

To determine how the composition of the atmosphere, and consequently how climate may change in the future, it is necessary to construct scenarios of greenhouse gas and sulphate aerosol emissions for the next 100 years and beyond. This requires assumptions to be made about how society will evolve in the future. These emissions scenarios are then used in global climate models to simulate the evolution of climate over time. The IPCC has recommended a series of emissions scenarios, which describe plausible future changes in atmospheric composition. These are known as the SRES emissions scenarios after the IPCC’s Special Report on Emissions Scenarios (IPCC 2000).

General Circulation Models (GCMs), and in particular, coupled Atmosphere-Ocean GCMs are the primary tools used to generate global-scale scenarios of climate change at broad spatial and temporal scales. Although there has been much progress in the refinement of GCM projections in recent years, the accuracy of GCM predictions is still uncertain, even with respect to representations of current climate conditions. Moreover, GCMs differ in their internal parameterizations so that, for any given scenario, there exist a range of possible outcomes depending on which model is used. Nevertheless, data from currently available GCMs project increasing global average temperatures in response to increases in greenhouse gas concentrations.

The lives of many Canadians are closely tied to the land. This is especially true for aboriginal communities, who get much of their food from hunting and fishing and the harvesting of edible plants and berries. These traditional activities are also an important part of aboriginal culture, which contains a large amount of knowledge about climate and how it affects these activities and the environment that it supports (CCME 2003).

Climate change is a major concern throughout Canada's arctic and sub-arctic regions, and many communities have begun to record their observations of how climate change is affecting their environments and their lives. These observations generally agree with the scientifically measured trends, although the scientific record gives a stronger impression of cooling in the eastern Arctic than the reports of local observers. This may be because local observers have given more emphasis to recent years, which have been unusually warm. The scientifically measured trends, on the other hand, cover a span of 50 years and include a greater number of cold years (CCME 2003).

Changes in Northern Canada's climate are affecting many aspects of the environment, such as ice and terrain conditions and the supply of game, wild plants and fresh water. As a result, native peoples are finding it harder to rely on the traditional knowledge and practices they have used for so long to survive in a region that is usually frozen for more than half the year (CCME 2003).

In recent years the Kitikmeot Inuit have noticed dramatic changes in the local climate and environment. Winters and summers have become warmer, and sea and lake ice have been melting earlier in the spring. Fall freeze-up, which occurred in August or September a few decades ago, now happens mostly in October or November. The weather has also become more variable, and short-term temperature swings that cause repeated thawing and freezing have become more common. With a more variable climate, weather and ice conditions have become harder to predict, and that has made it more difficult and dangerous for hunters and others traveling on the land and ice (CCME 2003).

People in most parts of the North are noticing the arrival of birds, fish and animals that have not been seen in their regions before. They are also noticing more unusual weather and more storms. Thunder and lightning, once very rare in the Arctic, are now being experienced more often, and in 2001, the Mackenzie Delta got its first tornado warning (CCME 2003). Most communities in the Mackenzie River Basin reported an overall increase in temperature and some comment that elders have a difficult time dealing with extreme summer heat (MRBB 2004).

Traditional knowledge has provided a broad perspective on the issue of climate change. Not only has it reported warmer temperatures, a more variable climate and unpredictable weather, but it has also indicated that the environment has changed in response to these changes in climate.

Some of the environmental changes could threaten or impose upon subsistence lifestyles (MRBB 2004).

2.4.2 Climate Change Indicators

The earth's climate has always changed. During the last ice age, glaciers covered much of Canada and temperatures were much colder than today in the Arctic. Rapid warming followed the ice age and global temperatures were 2°C warmer than in the early 20th century. The key indicators of climate change and the rationale for their selection are presented in Table 2.4-1.

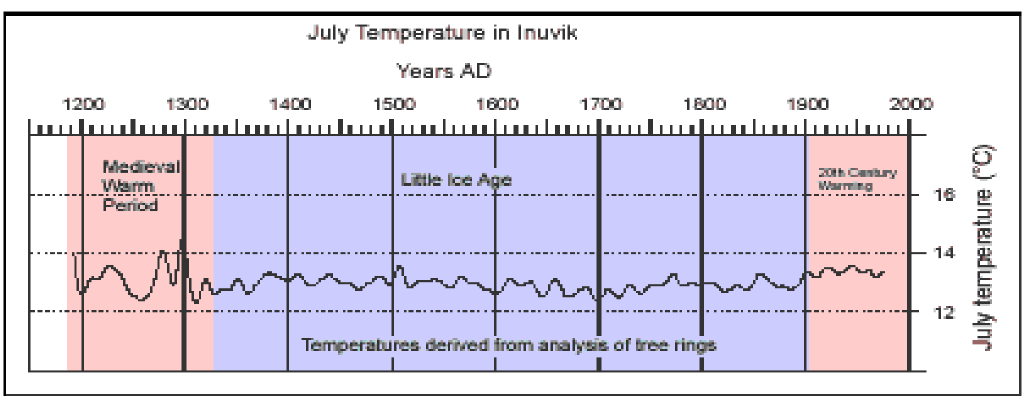
TABLE 2.4-1
RATIONALE FOR SELECTION OF INDICATORS OF CLIMATE CHANGE

Valued Component	Key Indicators	Rationale
Climate Change	• **Changes in Temperature and Precipitation**	• demonstrated changes in the North due to climate change • directly linked to climate change predictions in Global Climate Models • direct local impacts on humans and the ecosystem
	• **Atmospheric CO_2 Concentrations**	• measured in Alert, NWT since 1976 • strongly linked to increasing greenhouse gas emissions and hence the greenhouse effect • concentrations have increased dramatically since industrialization

2.4.2.1 Temperature and Precipitation

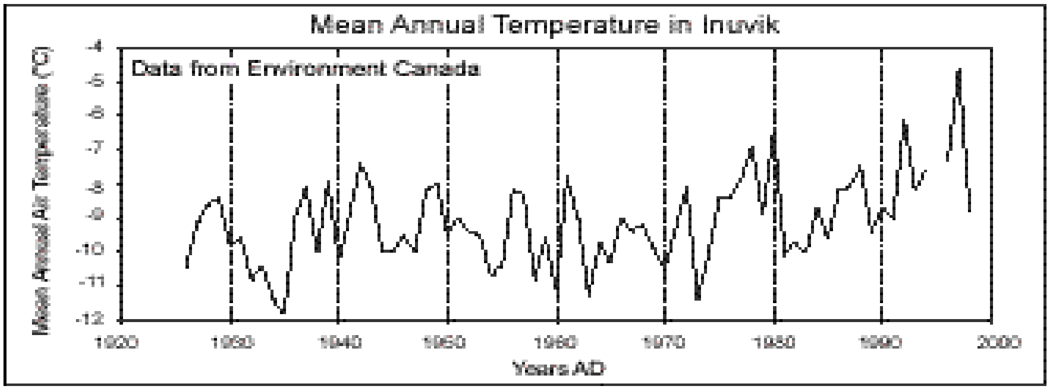
Data from Inuvik shows that air temperatures have changed over the last 800 years (Figure 2.4-1). During the Medieval Warm Period (1200 to 1300 AD), temperatures were higher than today. A cool period called the Little Ice Age followed this, ending only about 100 years ago. Warming has generally occurred over the last 100 years with average annual air temperatures for the western Arctic increasing by 1.5°C (Figure 2.4-2).

FIGURE 2.4-1
HISTORIC RECORD OF JULY TEMPERATURES IN INUVIK



Source: http://adaptation.nrcan.gc.ca/posters/articles/wa_02_en.asp?Region=wa&Language=en.
Adapted from: Begin, C., Michaud, Y. and Archambault, S. 2000.

FIGURE 2.4-2
MEAN ANNUAL TEMPERATURE IN INUVIK



Source: http://adaptation.nrcan.gc.ca/posters/articles/wa_02_en.asp?Region=wa&Language=en.

i) What is being measured?

Atmospheric observations are needed to monitor climate, detect and attribute change, improve understanding of the dynamics of the climate system and its natural variability and provide input for climate models. Several global observational networks have already been identified for the atmospheric component of the GCOS (Global Climate Observing System) Initial Observing System (IOS). In particular, a geographically representative GCOS Global Upper Air Network (GUAN) has been specified, a GCOS Global Surface Network (GSN) has been defined and the Global Atmosphere Watch (GAW) network is now considered a component of the GCOS. It is also recognized that other networks will be needed to address additional variables and that satellite observations of the atmosphere can make an important contribution to GCOS. (Source: http://www.ec.gc.ca/climate/CCAF-FACC/Science/nat2002/toc_e.htm).

Systematic observations of atmospheric constituents are needed to simulate the climate system, initialize and evaluate models and monitor the effectiveness of emission controls. The Global Atmosphere Watch (GAW) system, established in 1989, addresses this requirement and is a coordinated network of global and regional stations, along with associated infrastructure. Canada currently operates 43 GAW stations. Notably, the station at Alert (Nunavut) has been designated as a primary global background GAW station. Alert's baseline measurement program includes trace gas measurements of the greenhouse gases (CO_2, CH_4, CFC-11 and I_2, O_3, N_2O), along with aerosol measurements of black carbon, condensation nuclei and aerosol chemistry.

Additional measurements of atmospheric constituents are provided by two Canadian programs - CORE and CAPMoN. The "CORE" network of 6 stations has been developed to provide long-term, high quality, observations of atmospheric composition and radiation at locations representative of major atmospheric regimes and geopolitical regions. The Canadian Air and Precipitation Monitoring Network (CAPMoN), consisting of 22 stations, was created to study the regional patterns and trends of acid deposition in Canada and is an integral component of the GAW network.

The historical Climate Information and Monitoring Network in Canada's North is comprised of:

- The longest running climate stations, which have recorded basic information since the late 19th century;
- The large Beaufort Sea and Mackenzie Valley climate database that dates back to the 1940s;
- Coastal Distant Early Warning (DEW) line stations that have monitored temperature, wind and precipitation since late 1950s;
- Central Northwest Territories monitoring stations that were installed with mineral exploration activity in the 1970s (Lukawesky 1994); and
- A few eastern stations that began monitoring as early as 1920s and 30s (Fox 2000).

Documentation of local observations of climate change is increasing throughout northern Canada. Examples include:

- A video of Inuit observations of climate change and its impacts (Banks Island, Northwest Territories) (Riedlinger 1999);
- Collection/documentation of traditional knowledge of climate change impacts in Baffin Island (Fox 2000); and
- Other projects such as the Mackenzie Basin Impact Study or the Hudson's Bay and Northern Basins Study incorporate traditional knowledge (GeoNorth Ltd. 2000).

There are four EMAN-North sites in the NWT: Yellowknife, Daring Lake, Mackenzie Delta and Nahanni National Park. The Arctic Borderlands Ecological Knowledge Co-op is also partially located in the NWT. Long-term ecological monitoring of avian and terrestrial wildlife, vegetation, water quality and quantity, snow, permafrost and climate occurs to varying degrees at one or more of these sites.

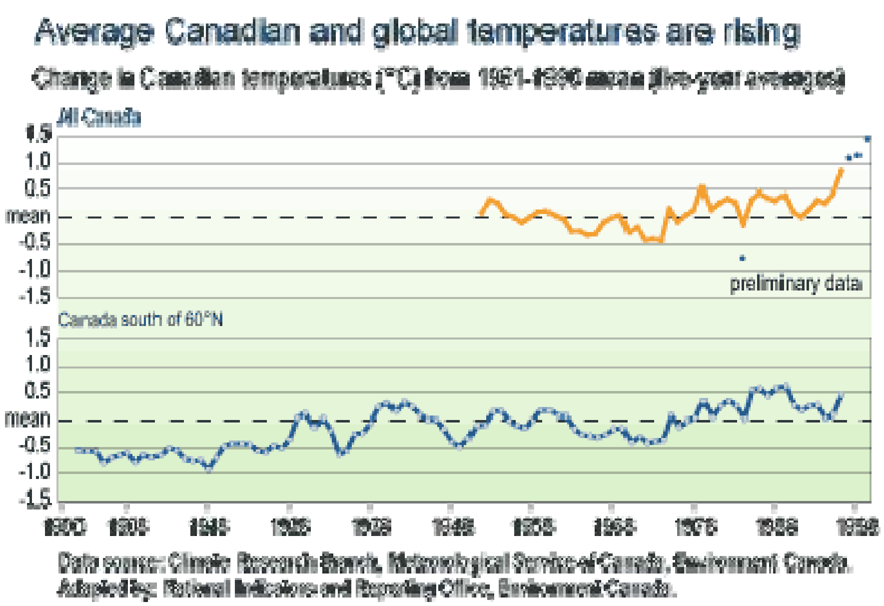
ii) What is happening?

In the past 40 years, annual temperatures in the western Arctic have climbed by 1.5°C. The average temperature in the Arctic has risen at almost twice the rate as the rest of the world in the past few decades. As the world's climate changes, temperature changes are anticipated to be greater in the North and greater in winter than in summer. According to recent climate models run by Environment Canada, annual temperature increases of greater than 5°C in the Arctic are possible by the year 2100. Figure 2.4-3 shows changes in Canadian temperatures versus the 1961-1990 climate normal period. Temperature records in the North are shorter than temperature records in the South of Canada, hence the longer trend for areas south of 60°N.

In the Mackenzie River Basin, winter precipitation has increased over much of the northern part of the basin but has decreased in the southwestern part of the basin. In contrast summer precipitation has increased in the south but has decreased somewhat in the far north. These changes, if extended over a long period of time, could have profound effects on the terrestrial and aquatic ecosystems of the basin (MRB SOAER 2003).

Additional evidence of Arctic warming comes from the widespread melting of glaciers and sea ice, and a shortening of the snow season. Increasing precipitation, shorter and warmer winters, and substantial decreases in snow cover and ice cover are among the projected changes that are very likely to persist for centuries (ACIA 2005).

FIGURE 2.4-3
ANNUAL AVERAGE CANADIAN AND GLOBAL TEMPERATURES



Source: http://www.ec.gc.ca/soer-ree/English/Indicator_series/.

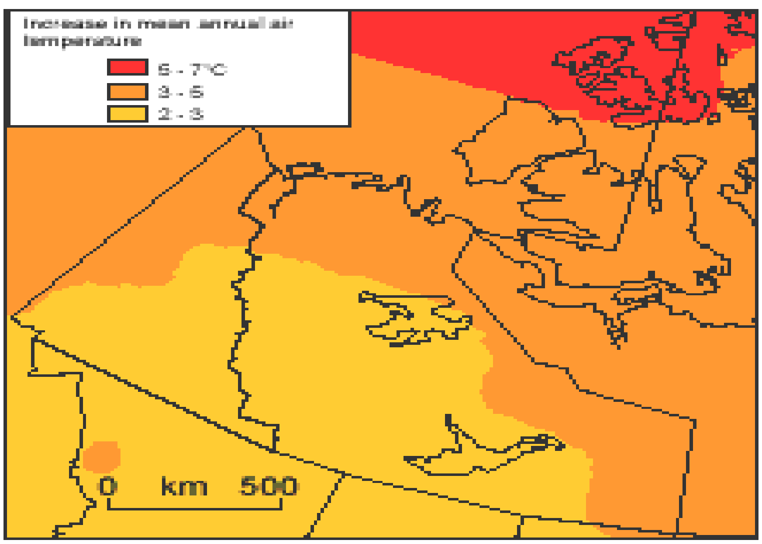
iii) Why is it happening?

Increasing global concentrations of carbon dioxide and other greenhouse gases due to human activities, primarily fossil fuel burning, are projected to contribute to additional Arctic warming of about 4-7ºC over the next 100 years (ACIA 2005).

iv) What does it mean?

Scientists use models called General Circulation Models (GCM) to predict future climate. Figure 2.4-4 shows how much warmer average annual air temperatures are expected to be in the middle of the 21st century compared to those in the last 30 years of the 20th century. The Canadian Climate Centre model predicts that average air temperatures in the western Arctic will be between 2 and 5°C higher.

FIGURE 2.4-4
PREDICTED INCREASE IN MEAN ANNUAL TEMPERATURES IN CANADIAN NORTH BY 2050



Source: Data for map from Canadian Climate Centre for Modelling and Analysis Coupled GCM. http://adaptation.nrcan.gc.ca/posters/articles/wa_02_en.asp?Region=wa&Language=en.

v) What is being done about it?

The Arctic Climate Impact Assessment (ACIA) is an international project of the Arctic Council and the International Arctic Science Committee (IASC). It is focused on the evaluation and synthesis of knowledge on climate variability, climate change and increased ultraviolet radiation and their consequences in the circumpolar Arctic. The aim is to provide useful and reliable information to governments, and to the Arctic Peoples and their organizations.

The Government of Canada created the Climate Change Action Fund (CCAF) in 1998 (http://www.ec.gc.ca/climate/CCAF-FACC/Science/fact/arctic_e.htm). The CCAF identified the Arctic climate system as a priority area of study. Several research projects were funded following a national workshop held in 1999 to identify specific Arctic climate science issues. The work supported fell into two broad areas:

- Advancing our knowledge of the climate system (ocean, atmosphere, land and cryosphere - primarily ice in all its forms, snow and permafrost) for Arctic Canada;
- Rescuing and maintaining long-term data sets of importance to determining variations in the climate of Arctic Canada.

Several studies funded by the CCAF focused on the maintenance and rescue of relevant sets of climate data. These data sets will now be available for future research studies.

- Researchers compiled an inventory of High Arctic data, including the locations of more than 600 field camps, oil industry sites, historical expeditions and automated station sites within the High Arctic islands. The data sets provide snapshots of the climate at times and places not represented by the permanent observation network.
- Several databases of importance to climate change, such as permafrost and peatlands, are now accessible through the online National Arctic Geoscience Database (NAGD), providing information on the evolution of climate systems in the Canadian Arctic over the past several thousand years.

Since the late 1980s, various researchers have been gathering climate-related data (such as tree ring information) at a network of about 70 stations across northern Quebec. This study has put in place a method to transfer raw data collected at various sites into an interactive database. Federal departments are working with Canadian universities and provincial and territorial agencies on such activities as:

- Expanding Canada's contribution to atmospheric monitoring as part of the international Global Climate Observing System Surface Network, particularly in the North;
- Deploying a series of ocean floats to measure temperature and salinity in Canadian waters, and a series of tide gauges in Canadian Arctic waters; and
- Enhancing and/or establishing Canadian monitoring systems for snow, permafrost, glaciers, and sea and freshwater ice.

The second phase of the CCAF is currently underway, and includes continued improvements to climate models, including better representation of the Arctic climate system. Projects are also being funded to address aspects of the Arctic climate system that are not well understood, including aspects relating to the Arctic sea ice and Arctic Ocean dynamics, clouds and aerosols, and snow-covered ground.

The Northern Climate Exchange (NCE) is a Yukon-based center acting as an exchange point for climate change studies in the circumpolar north. The NCE's goal is to conduct research and education on the impacts of, and adaptations to, climate change in the North; and to facilitate exchange of scientific and traditional and local knowledge, technology and expertise.

The Arctic Monitoring and Assessment Program (AMAP) was established in 1991 through the Arctic Council with responsibilities to monitor the levels of, and assess the effects of, anthropogenic pollutants in all areas of the Arctic environment, including impacts on humans. Climate change remains one of the ongoing concerns of AMAP.

Numerous programs have been initiated across Canada to study climate change and to develop plans to reduce Canadian emissions of greenhouse gases. For example, the Mackenzie River Basin Impact Study's objective was to assess the potential impact of climate change on the land, water and communities within the Mackenzie River Basin.

vi) What are the information gaps?

At the global level, climate in the Arctic is a result of the general circulation of the atmosphere and heat transfer by the oceans. It is generally agreed that fluctuations in the upper atmosphere control or influence surface conditions. The factors that influence high-latitude energy fluxes including the Arctic Oscillation (AO) are fundamental science questions that need to be addressed (http://www.ec.gc.ca/climate/CCAF-FACC/Science/reports/arctic_e.htm#16).

The magnitude, frequency, and causes of extreme events in Arctic weather, stream flow, lake and sea ice, snow cover and other climatic-related variables need careful study in order that trends in global climate change are correctly interpreted and understood. Understanding of the magnitude and speed of past and ongoing climate change in the Arctic also needs to be improved through continued monitoring and the analysis of already existing time-series data.

2.4.2.2 Atmospheric CO_2

A small group of greenhouse gases, mainly carbon dioxide, methane, nitrous oxide, and water vapour, help to regulate the Earth's climate by trapping solar energy that reradiates from the Earth's surface as heat. Emissions from human activities enhance this natural process. Since industrialization, human activities such as burning fossil fuels have increased the amount of greenhouse gases emitted into the atmosphere. It is widely believed that increased emissions have enhanced the greenhouse effect, causing the atmosphere to warm and the climate to change.

Since the industrial revolution in the late 1700s, atmospheric concentrations of carbon dioxide have increased by 31%, methane by 151% and nitrous oxide by 17%. Increases in CO_2 have been especially pronounced in the last fifty years (MRBB 2004).

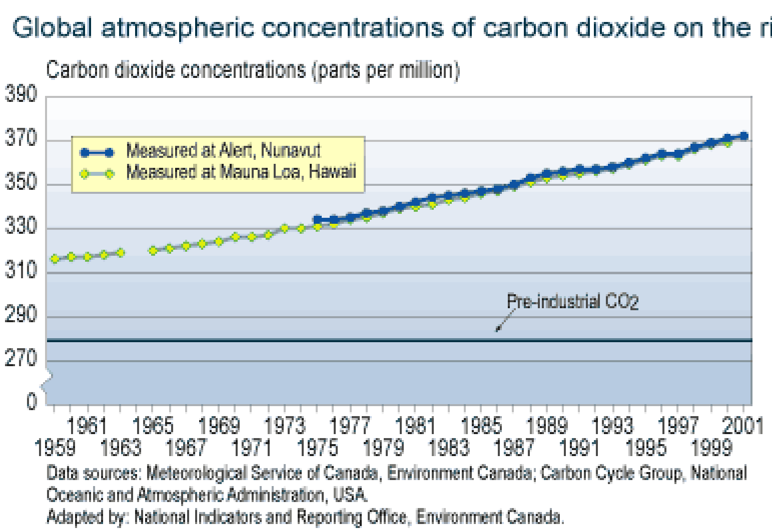
i) What is being measured?

Global concentrations of carbon dioxide have been measured since the mid-1950s. Carbon dioxide flask data has been collected on a weekly basis at 4 points in Canada (1 in the Arctic) since data collection started at Canadian stations between 1975 and 1979. The station in Alert, Nunavut, switched to more comprehensive continuous measurements in 1988. These data are comparable to that measured in Hawaii (longest running and most credible carbon dioxide measuring station in world) (McIlveen, N. and R, Desjardin 1998, Welch 2000). Historical concentrations of carbon dioxide, methane, and nitrous oxides are determined for past millennia based on study methods such as ice core analysis.

ii) What is happening?

Increased emissions of carbon dioxide are reflected in global atmospheric carbon dioxide concentrations, which have increased by 33% since the beginning of the industrial age (Figure 2.4-5). Since carbon dioxide is a well-mixed gas in the atmosphere, measurements made at any place on the globe are considered representative.

FIGURE 2.4-5
TRENDS IN ATMOSPHERIC CARBON DIOXIDE LEVELS AT MONITORING STATIONS IN HAWAII AND NUNAVUT



Source: *http://www.ec.gc.ca/soer-ree/English/Indicator_series/.*

iii) Why is it happening?

Globally, carbon dioxide emissions from energy use have quadrupled since 1950. In 1998, Canada's share of these emissions was approximately 2%. Canadian emissions of six key greenhouse gases have grown 20% since 1990.

iv) What does it mean?

While there is no conclusive scientific evidence supporting a link between weather extremes and greenhouse gas-induced climate change, there is little debate that Canadians have experienced recent changes in weather patterns and a substantial increase in the number of weather-related disasters.

v) What is being done about it?

In 1992, Canada ratified the United Nations Framework Convention on Climate Change, which set out a framework for action to limit emissions of greenhouse gases. In 2002, Canada ratified the Kyoto Protocol to the Convention, committing to reduce its greenhouse gas emissions to 6% below 1990 levels by 2008-2012.

In 2001, The NWT Greenhouse Gas Strategy was developed to identify and coordinate northern actions to begin to control greenhouse gas emissions, and to assist in developing and contributing a northern perspective as part of Canada’s national Climate Change implementation strategy. The NWT Greenhouse Gas Strategy does not specify emission reduction targets or goals. Northern CO_2 emissions are approximately 30 tonnes per person compared to the national average of 21 tonnes per person. Per capita emissions are higher in part due to larger demands for space heating and other energy consuming devices to deal with colder temperatures. The long distances between communities have also made the NWT dependent on transportation and the use of refined petroleum products. CO_2 emissions and population growth in the NWT are both increasing at higher rates than the national average. Current greenhouse gas emissions in the NWT are in the order of 1600 kilotonnes of CO_2-equivalents per annum. Compared to Canada’s total of 731,000 kilotonnes of CO_2-equivalents in 2002, the NWT contributes less than 0.5% of Canada’s total greenhouse gas emissions.

The GNWT is organizing a workshop in Spring 2005 to evaluate progress to date and identify additional measures to reduce greenhouse gas emissions (Sparling 2005).

It is important to note that reductions in emissions from fossil fuel combustion will not only reduce greenhouse gases, but will have a positive impact on local and regional air quality by directly reducing emissions of sulphur dioxide, nitrogen oxides, and volatile organic compounds and indirectly reducing levels of ground-level ozone and inhalable airborne particles formed in the atmosphere. Reductions in emissions of sulphur dioxide and nitrogen oxides can also be expected to reduce acid rain.

vi) What are the information gaps?

There is greater knowledge and confidence concerning baseline information and predicted changes to temperature than for other climate components like rain, snow and extreme events

The next stage of CCAF-Arctic should include the development of better coupled atmospheric models, the validation of such models against both paleo- and current time-series data sets, and the identification and understanding of regional variability in Arctic climate change. The latter can be approached through the continued study of sea ice, the response of northern terrestrial ecosystems, and the monitoring of critical, climate-responsive, cryospheric variables.

2.4.3 Other Climate Change Issues

2.4.3.1 Effect of Climate Variability on Contaminant Pathways

Remarkable changes occurred in the Arctic's climate during the 1990s including wind and weather patterns, ice cover, ice thickness, ice drift patterns, permafrost, hydrology, ocean-currents, precipitation and temperature patterns. These changes have significant consequences for contaminant pathways. These changes have altered the physical pathways that transport contaminants, for example diverting Russian river inflow into the Canada Basin thence to flow out through the Archipelago and altering the drift trajectories of ice within the Arctic. However, even more consequential changes are likely to occur in contaminant magnification pathways including cryoconcentration, attachment to organic-rich particles, and food-web biomagnification. Recent change in the Arctic's ice climate and ecosystem structure require a great deal of caution in interpreting contaminant trend data collected for the past couple of decades (Source: Highlights of the Canadian Arctic Contaminants Assessment Report II).

2.4.3.2 Arctic Ozone Layer

Extensive ozone losses have occurred over the Arctic in the 1990s, and there is some concern that serious depletion episodes could become even more frequent over the next 10 to 20 years. Concentrations of ozone-depleting chemicals will be at or near peak levels during that time, and changes to the Arctic stratosphere arising from global warming could create more favourable conditions for depletion processes.

Deep ozone losses over both the Arctic and Antarctic are the result of special conditions that occur over these polar regions in the winter and early spring. As winter arrives in each hemisphere, a vortex of winds develops around the pole and isolates the polar stratosphere. Without milder air flowing in from the lower latitudes and in the absence of sunlight, air within the vortex becomes very cold. At temperatures of -80°C or less, clouds made up of ice, nitric acid, and sulphuric acid begin to form in the stratosphere. These are called polar stratospheric clouds (PSCs), and they give rise to a series of chemical reactions that destroy ozone far more effectively than the reactions that take place in warmer air. The destruction of ozone begins with the return of sunlight in the spring and continues rapidly until the vortex dissipates and warmer temperatures prevent the formation of PSCs.

Arctic ozone depletion could be further enhanced over the next few decades, however, by increasing accumulations of greenhouse gases in the atmosphere. By trapping more heat near the earth's surface, these gases cause the stratosphere to become cooler. Since temperatures in the Arctic stratosphere often come within a few degrees of the threshold for PSC formation, further cooling of the stratosphere could cause PSCs to form more frequently and increase the severity of ozone losses. Preliminary studies with atmospheric models suggest that this effect could delay the recovery of the Arctic ozone layer by a decade or more.

Continued monitoring and research are essential if we are to reduce present uncertainties in our understanding of depletion processes and improve our capability to predict how the ozone layer is likely to respond to changing atmospheric conditions and stresses in the future. The future of the Arctic ozone layer will depend primarily on our success in ridding the atmosphere of ozone-depleting chemicals, but our ability to control greenhouse gases will also be important. The linkages between these issues mean that we cannot treat either of them in isolation. Instead, they indicate the importance of developing a comprehensive strategy for moderating the human impact on the atmosphere (http://www.ec.gc.ca/press/arctoz_b_e.htm).

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Arctic Monitoring and Assessment Programme
http://www.amap.no/

Environment Canada:

- http://adaptation.nrcan.gc.ca/posters/articles/wa_02_en.asp?Region=wa&Language=en
- http://www.ec.gc.ca/climate/CCAF-FACC/Science/fact/arctic_e.htm
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NCE Knowledge site http://www.yukon.taiga.net/knowledge/.

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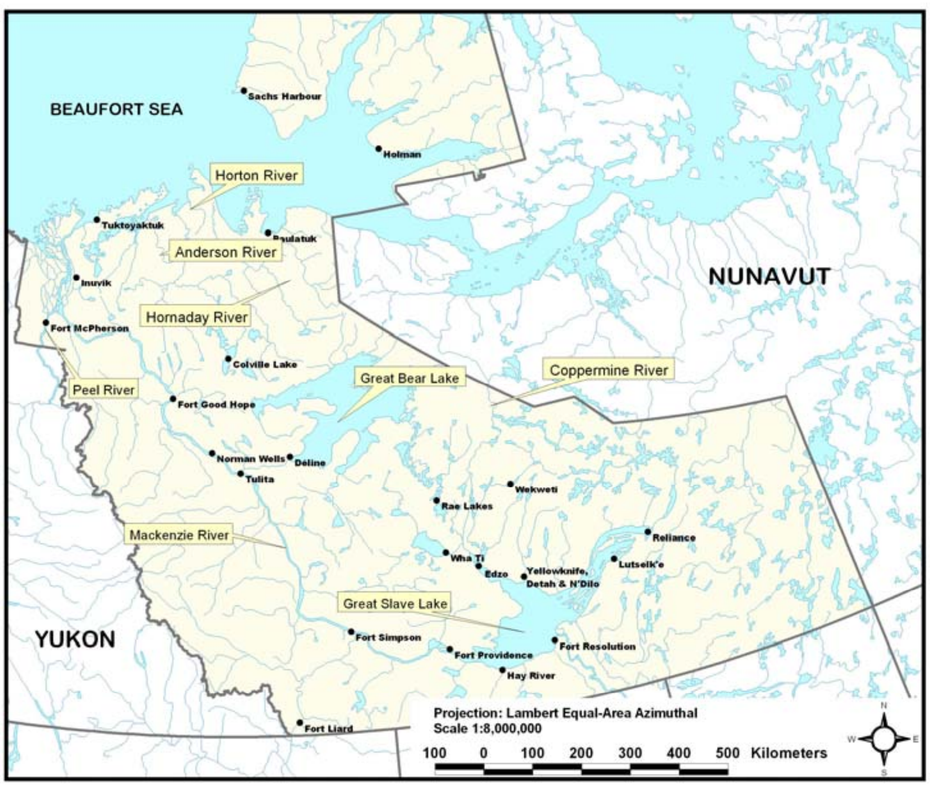
3.0 FRESHWATER AQUATIC ENVIRONMENT

3.1 FRESHWATER IN THE NORTHWEST TERRITORIES

Canada is a freshwater-rich country with Canadian rivers discharging, on an average annual basis, close to 9% of the world's renewable water supply. Water is also highly visible in Canada with no other country in the world having as much of its surface area covered by freshwater. The Northwest Territories (NWT) covers a total area of 1.34 million square kilometres, or approximately 13.5% of the total area of Canada. Of its area, about 163 thousand square kilometres of the NWT (or 13.5%) is covered by freshwater; an area equivalent to nearly 1/5th of all of Canada's surface freshwater. The two largest lakes entirely within Canada's borders are located in the NWT; they are Great Bear Lake (31,328 km^2) and Great Slave Lake (28,568 km^2). There are also several important river systems; the most notable being the Mackenzie River, the drainage basin of which accounts for about 1/5th of Canada's land mass (Mackenzie River Basin Board (MRBB), 2004). The principal lakes and rivers in the NWT are shown in Figure 3.1-1.

FIGURE 3.1-1
PRINCIPAL LAKES AND RIVERS IN THE NORTHWEST TERRITORIES



Source: Natural Resources Canada; http://www40.statcan.ca/l01/cst01/phys01.htm.

The predominant freshwater system in the NWT is the Mackenzie River Basin which covers nearly 75% of the territory and drains an area equivalent to about one-fifth of Canada's land mass. Drainage along the eastern border of the NWT is captured in the Coppermine River and Thelon River watersheds that drain into Nunavut. To the north, a portion of the runoff flows directly into the Amundsen Gulf and Beaufort Sea through the West Arctic Basin. There are eight primary watersheds either completely within the NWT or transboundary in nature. Within these watersheds are 26 secondary sub-basins. The main features of these watersheds are described below. In addition, a brief overview of monitoring and research work that has been, or is being carried out, is provided. More detailed information on the findings of monitoring activities is presented in subsequent sections.

The principal drainage basins of the NWT and their respective secondary sub-basins are shown in Figure 3.1-2.

3.1.1 Mackenzie Great Bear Sub-Basin

The Mackenzie-Great Bear sub-basin lies almost entirely in the NWT and covers 475,000 square kilometres. Its primary components are the Mackenzie River (Canada's longest river at 1,800 kilometres in length) and Great Bear Lake (the largest lake entirely within Canada at 31,328 square kilometres). The sub-basin also includes Canada's largest delta and second largest wetland, the Mackenzie Delta, covering 13,500 square kilometres. The Mackenzie River transports 60% of Canada's freshwater that drains to the north. In part because of its high water velocities, the Mackenzie River transports more sediment to the Arctic Ocean than any other circumpolar river (MRBB, 2004).

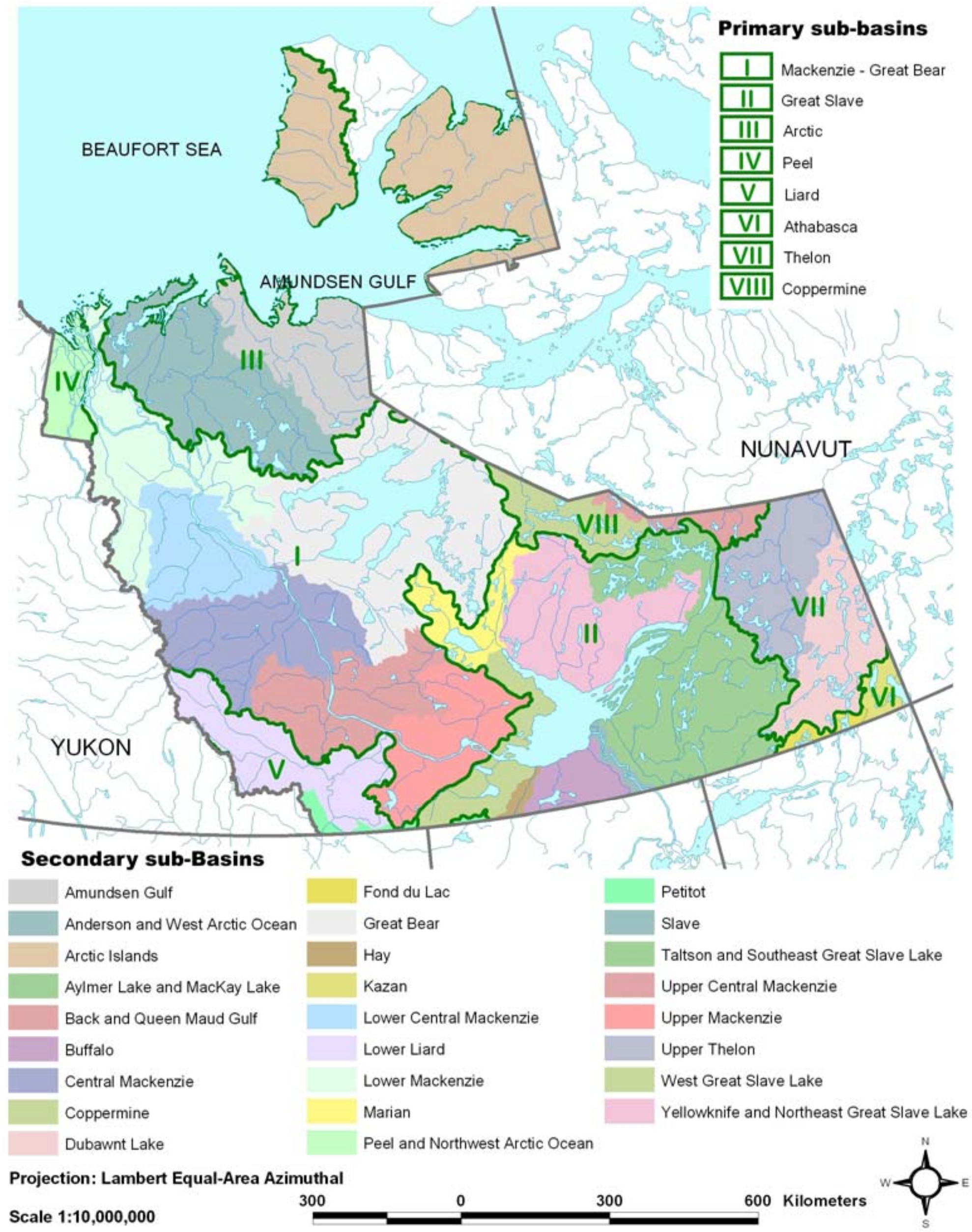
3.1.2 Great Slave Sub-Basin

The Great Slave sub-basin includes the Slave River drainage from the Peace-Athabasca Delta and all other tributary inflows into Great Slave Lake. It covers more than 379,000 square kilometres. Approximately 75% of the area is in the southeastern NWT and 20% is in northern Alberta. The remainder extends into northeastern British Columbia and northwestern Saskatchewan. Great Slave Lake is the sub-basin's largest lake and is the fifth largest lake in North America with a surface area of 28,568 square kilometres and a volume of about 2,088 cubic kilometres of water. Great Slave Lake is also the deepest in North America with an average depth of about 73 meters and a maximum depth of 614 meters.

The Great Slave sub-basin consists of fourteen major drainage systems. The largest river, the Slave, contributes about 77% of the inflow to Great Slave Lake. Other major inflows to Great Slave Lake include Taltson, Lockhart, and Hay rivers which, collectively, contribute about 11%

of the flow into Great Slave Lake. Ten other smaller drainage areas in the Great Slave sub-basin provide the remaining 12% of the inflow to Great Slave Lake.

FIGURE 3.1-2
WATERSHEDS IN THE NORTHWEST TERRITORIES



The Great Slave sub-basin straddles two distinct physiographic regions: the erosion-resistant Precambrian Shield to the east; and the Interior Plains to the west. The Shield features open, stunted taiga forest and hundreds of lakes, while the Plains are characterized by a more dense boreal forest in a landscape that was sculpted and smoothed by continental glaciers. As a result of geological and vegetative differences between these areas, annual runoff is greater in the Shield than in the Interior Plains. The presence of hundreds of small and large lakes in the Precambrian Shield produces more stable flow regimes in its rivers than in rivers of the Interior Plains (MRBB, 2004).

3.1.3 Peel Sub-Basin

The Peel River sub-basin encompasses an area of 74,000 square kilometres, from its headwaters in the Yukon to its confluence with the Mackenzie River near Fort McPherson in the NWT (see Figure 3.1-1). The Peel River has a mainstream length of approximately 350 kilometres beginning at the confluence of the Blackstone and Ogilvie rivers. Downstream of this confluence, there are several major tributaries draining the Ogilvie and Selwyn Mountains. These alpine rivers include the Hart, Wind, Bonnet Plume and Snake rivers. Further downstream, the Caribou, Trail, Road and Vittrekwa rivers drain the Peel Plateau. Mountainous terrain and permafrost, both of which cover vast areas of the sub-basin, control the flow of water in most of the rivers of the Peel sub-basin. The Peel sub-basin includes portions of the Taiga Cordillera Ecozone and the Taiga Plains Ecozone (see Chapter 5, Section 5.1.1). Wetlands such as bogs and fens are abundant in the areas of the sub-basin within the Taiga Plains Ecozone (MRBB, 2004).

3.1.4 Liard Sub-Basin

The Liard River and its tributaries drain an area of approximately 275,000 square kilometres, making it Canada's ninth largest watershed. The Liard River begins its journey in the Pelly Mountains of southeastern Yukon, flows through northeastern British Columbia and then crosses into the Northwest Territories where it drains into the Mackenzie River. At 1,115 kilometres, the Liard is Canada's eleventh longest river. With an average annual discharge of 1,970 cubic meters per second, it ranks seventh among Canadian rivers in volume of water discharged.

Much of the Liard sub-basin is covered by coniferous and mixed-wood forest. There are extensive mountainous areas, especially in the headwaters along the Yukon-Northwest Territories border and in the western portion. Some of the mountainous areas along the Yukon-Northwest Territories border are prone to massive landslides. Heavy summer precipitation, melting permafrost, deforestation and disturbances to the land caused by the petroleum industry may cause landslides. Landslides can have major effects on local water quality and quantity. (MRBB, 2004)

3.1.5 Athabasca Sub-Basin

The Athabasca River and Lake Athabasca together drain an area of about 269,000 square kilometres in Alberta, Saskatchewan and a small portion of the NWT. The Athabasca sub-basin contains several types of ecosystems from the glaciers, alpine meadows and mountain forests in the Rocky Mountains to the boreal forests and muskeg of northeastern Alberta. Forested, Precambrian Shield occurs in the extreme northeastern part of the sub-basin. The Athabasca River flows 1,375 kilometres from the Columbia Ice-field in the Rocky Mountains, across north central Alberta, and through the Peace-Athabasca Delta to Lake Athabasca (MRBB, 2004).

3.1.6 Thelon Basin

The drainage basin of the Thelon River encompasses some 142,400 square kilometres. Its source is Eyeberry Lake in the Northwest Territories, and it flows east to Baker Lake in Nunavut. The Thelon ultimately drains into Hudson Bay. From as far apart as 200 km east of Great Slave Lake and the northern Saskatchewan border, waters of the Thelon collect to flow for about 900 km to Baker Lake and Chesterfield Inlet. The Thelon watershed is the largest unaltered drainage basin emptying into Hudson Bay.

The Coppermine River is not "bounded by ... Bathurst Inlet to the east." It could perhaps be stated that to the east of the Coppermine basin is the Contwoyto Lake/Burnside River watershed. The Coppermine River does not begin in the boreal forest 850 km from the coast...

3.1.7 Coppermine Basin

The Coppermine River Basin is a coastal watershed of the Arctic Ocean Basin, a zone that is 16.7% of the land area of Canada. In total, the Coppermine River watershed is 50,800 square kilometres, and it is the 8th largest watershed in Nunavut and the NWT. Long and narrow, the southeast/northwest length of the basin is 520 km and the average width is about 100 km. The watershed lies for the most part within the Taiga Shield between Great Slave Lake to the south, Great Bear Lake to the west and the Arctic Ocean to the north and Bathurst Inlet to the east. The headwaters of the Coppermine River are in the Ursula Lake/Lac du Sauvage region.

3.2 SURFACE WATER AND SEDIMENTS

3.2.1 Monitoring and Research Activities

Several monitoring and research programs related to surface water and sediment quality and water quantity are ongoing in the NWT. Federal, territorial, and municipal agencies have ongoing mandates to conduct research and monitor freshwater issues. As identified in the recent report, *A Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program (NWT CIMP) and Audit* (INAC 2005), numerous monitoring programs are currently underway for surface water and sediment quality and surface water quantity. They are listed below. Attachment 3A provides a listing of relevant research articles and reports, as identified in the CIMP report.

3.2.1.1 Current Surface Water and Sediment Quality Monitoring

Northern Rivers Ecosystem Initiative (NREI) (Environment Canada, Government of the Northwest Territories, Government of Alberta. Other key partners are INAC, Health Canada and Alberta Health) **– 1998-2003**

The NREI (1998-2003) is a follow-up to the Northern River Basins Study (NRBS). The Ministers agreed with the direction of the NRBS recommendations and committed to focus their efforts in the areas of pollution prevention, science-based ecological management, resolving contaminant and nutrient issues, endocrine disruption, long-range transport of atmospheric pollutants and continuing environmental research in northern rivers. The NREI works with industry, Aboriginal peoples, academia, communities and others to address the recommendations from the NRBS. NREI completed information reporting on its water, sediment and biota data and that information is stored in and displayed by Eco Atlas CE IMS/GIS.

Northwest Territories Water Quality Monitoring Program (Environment Canada**) - since 1960**

Inter-Jurisdictional Rivers (IJR) Interim Aquatic Quality Monitoring Program (Environment Canada and Alberta Environment since 1988, and Government of the Northwest Territories) **– 1984-1995**

Water and sediment quality data reports are available for the Hay and Slave River sites

Nahanni National Park Reserve Aquatic Quality Follow-up Monitoring Program (Environment Canada and Parks Canada) **– since 1992**

Ongoing monitoring is taking place to fill in gaps found during intensive monitoring between 1992 and 1997, resulting in a 1998 EC-Parks report. Base flow water quality is monitored at all sites each February. Lake and pond limnology and paleolimnology on age-dated slices of sediment are analyzed for chemistry and diatom paleolimnology at several lakes and ponds.

Spatial and Temporal Trends in Loading and Historical Inputs of Mercury (and other trace metals and organics) from Age-dated Pan-northern Lake/Pond Sediment Cores (Environment Canada and Parks Canada) **– since 1998**

Transects being sampled in the Northwest Territories include Ft. Liard/Fisherman Lake area, Nahanni NPR, Tuktut Nogait NP, and Aulavik NP.

Forest Fire Effects on Water Quality and Quantity at Tibbitt Lake (INAC) **– since 1998**

Aquatic Effects Monitoring Program (BHP Diamonds Inc.) **- since 1998**

Lakes and streams near the EKATI mine are monitored to determine potential effects of the mine. A surveillance network program monitors the health of lakes and streams, providing an early warming system. Specific effects monitoring is undertaken where potential adverse effects have been identified. A sewage effects study was conducted at Kodiak Lake. Aquatic baseline and monitoring data was gathered from 1993 to 1997.

Coppermine Cumulative Effects Monitoring Program (INAC) **– since 2000**

The Coppermine River Basin is the focus of this monitoring program. An enhanced water quality sampling program is underway which includes monthly sampling at 6 to 8 sites, seasonal sampling at several other sites, and continuous monitoring at the outlet of Lac de Gras. Upcoming studies include snow surveys in a small representative basin to develop snowmelt runoff and basin rainfall-runoff ratios, and monitoring of river-ice breakup using a remote web-cam.

Slave River Environmental Quality Monitoring Program (INAC)

Water, suspended sediment and fish tissue quality are monitored on the Slave River at Fort Smith, to address transboundary issues. A five-year follow up program is currently being conducted to determine if any changes in water/sediment quality has occurred.

Liard River Environmental Quality Monitoring Program (INAC)

Water, suspended sediment, and fish tissue quality are monitored on the Liard River above the Kotanelee River, to address transboundary issues. A five-year follow up program is currently being conducted to determine if any changes in water/sediment quality has occurred.

Peel River Water & Sediment Quality Monitoring Program (INAC)

Water and suspended sediment are monitored on the Peel River above Fort McPherson, to address transboundary issues including community concerns about contaminants. Sampling was conducted in July 2002, June 2003 and August 2004.

Hay River Water & Sediment Quality Monitoring Program (INAC and Environment Canada)

Water and suspended sediment are monitored on the Hay River at the NWT/Alberta Border, to address transboundary issues. Sampling was initiated in 2004.

Ecological Monitoring and Assessment Network (EMAN) (coordinated by Environment Canada)

Water and sediment quality are monitored at selected EMAN sites in the NWT. See Attachment 3A for a complete description of EMAN.

Monitoring Related to the Proposed Mackenzie Gas Project (Environment Canada and Indian and Northern Affairs) **– 2004-2006**

In 2004, lakes near the proposed Mackenzie Gas Project (MGP) Anchor Sites in the Mackenzie Delta/Tuktoyaktuk Peninsula were sampled. Studies involve baseline water, sediment and biota characterization (zooplankton, phytoplankton, benthic invertebrates). In 2005 and 2006, stream and lake studies will be carried out along the MGP pipeline route and near MGP anchor sites. Data collected by government, NGO and industry will be stored in an Eco Atlas CE IMS/GIS, which will link/join with INAC-BGC Engineering Geotechnics IMS/GIS for the MGP development corridor.

Pre-construction Monitoring for the Yellowknife-Rae Highway (Environment Canada) **– 1999-2004**

A study was completed to characterize the pre-construction baseline conditions in waterfowl-utilized ponds and borrow pits along the Yellowknife-Rae Highway. Water, sediment, invertebrate and waterfowl data were collected.

3.2.1.2 Current Surface Water Quantity Monitoring

Northwest Territories Water Quantity Monitoring program includes 75 stations operated by the Water Survey of Canada, with funding from Environment Canada, INAC, Northwest Territories Power Corporation, and the Canadian Coast Guard. Monitoring began in 1938 but most stations were established in the 1960s and 1970s. Subsets include:

- **Northwest Territories reference hydrometric basin network** (since 1965) (water flow rates, water quantity, ice phenology)

- **Mackenzie Delta water level, flow and hydrometric data monitoring** (includes a modeling component)

- **Northwest Territories evaporation/water balance** studies were initiated in 1992 for mine site water management. Study sites are located at the Salmita/Tundra mine in the upper Lockhart River basin, the Colomac mine site in the Snare River basin, and Pocket Lake on the Giant mine site near Yellowknife (INAC).

Global Energy and Water Cycle Experiment (GEWEX) seeks to understand and model the high latitude water and energy cycles that play roles in the global climate system, and improve the ability to assess the changes to Canada's water resources that arise from climate variability and anthropogenic climate change. Canada is carrying out an investigation of the water and energy cycles of the Mackenzie River, under a program called the Mackenzie GEWEX Study (MAGS). A series of large-scale hydrological and related land-atmosphere studies are being conducted in the Mackenzie Basin to help understand the role of high latitude hydrological and meteorological processes in the global climate system. MAGS is one of 7 regional experiments in different regions of the world. For further details see http://www.msc-smc.ec.gc.ca/GEWEX.

Water Balance Studies at Lower Carp Lake and in the Snare River Basin as part of the Mackenzie GEWEX study were established in 1997. Additional GEWEX studies have been initiated for hydrological research in the Baker Creek watershed (Yellowknife area) (Environment Canada), and for ice jam studies at Hay River (Indian Affairs and Northern Development, University of Alberta). MAGS researchers studied lake evaporation from Great Slave Lake from 1997 – 2003 and from 2000 – 2003 on smaller lakes in the Yellowknife area. Investigations studying evaporation from Great Bear Lake began in 2004.

The Coppermine Cumulative Effects Monitoring Program is an enhanced program of water quality and water quantity monitoring. Hydrological studies include a snowmelt-runoff study started in 2001 at Daring Lake (INAC) and a small basin hydrologic study that began in 1999 (Wilfrid Laurier University).

Dendrochronological Sampling and Analysis Project was initiated in 1999. This project correlates standardized tree ring widths with stream flow and precipitation records. Hydrological records have been extended to the late 1600s with these proxy data methods. Sampling has been done in several locations, including the Yellowknife area, along the Mackenzie Highway, in the South Nahanni Watershed, the East Arm (Great Slave Lake) watershed, the Mackenzie River Delta and the Great Bear Lake watershed (INAC, Environment Canada, and University of Regina).

3.2.2 Focus of the Assessment

With the predominant freshwater system in the NWT being the Mackenzie River Basin and its component primary and secondary sub-basins (see Figure 3.1-2), the emphasis of the surface water and sediment quality and surface water quantity assessment in this report is on that basin. The Mackenzie River Basin covers about 75% of the NWT and contains within its area communities that are home to 90% of the resident population. Furthermore, as discussed in Section 3.3.3, the landscape within the Mackenzie River Basin also experiences most of the NWT's industrial development.

This assessment was conducted by reviewing the scientific literature, reports, and scientific and government on-line resources. The objective of the review of background material was to develop a consensus from several perspectives of the status of the indicators.

The valued components and indicators investigated in this assessment are listed in Table 3.2-1 together with the rationale for their selection.

TABLE 3.2-1
WATER QUALITY AND QUANTITY VALUED COMPONENTS AND INDICATORS

Valued Component	Indicators	Rationale
Surface Water and Sediment Quality	• Contaminants of primary concern (COPC): turbidity, aluminium, iron, copper, zinc, and mercury	• Water quality in the Mackenzie River and several of its tributaries is affected by a high natural sediment load. • Water quality studies such as the 2003 Mackenzie River Basin State of the Aquatic Ecosystem Report have shown that there are only a limited number of COPCs that frequently exceed water quality guidelines at routinely monitored stations. • Besides the noted COPCs, arsenic is also a concern in the area around Yellowknife due to historic releases from the Giant Mine and Con Mine. • There is only limited data on bacteriological parameters and organic compounds to use in analysis of trends. • There is only limited sediment quality data and mostly what is available is of short duration.
Surface Water Quantity	• Discharge rates • Ice phenology • Lake levels	• The Mackenzie River Basin, as Canada's largest watershed, has a discharge rate of over 9,900 m^3/s. • Flow monitoring on tributary rivers like the Liard River have shown a decreasing trend in the mean annual discharge rate. • Flow in the Mackenzie River has not shown the same trend to date, presumably due to the influence of Great Slave Lake in particular but also Great Bear Lake in moderating the river flow. • Monitoring data on the time of ice over and ice out at river crossings in the southern part of the NWT have shown variability. • Monitoring data on Great Slave Lake suggest a possible lowering of the average lake level although the trend is not conclusive given the large size of the lake.

3.2.3 Stressors on Aquatic Systems

Lacustrine and riverine ecosystems in the NWT are vulnerable to a wide range of anthropogenic and natural stressors, each with the potential to affect their ecology in different ways. Chief among these stressors, but listed in no particular order, are:

- climate change;
- contaminants; and,
- industrial development.

3.2.3.1 Climate Change

Several comprehensive assessments have been written on the present and future effects of a warming climate on northern regions. Groups such as the Intergovernmental Panel on Climate Change (IPCC)[1] and the Arctic Climate Impact Assessment (ACIA 2004) of the Arctic Monitoring and Assessment Program (AMAP)[2] have considered the evidence of climate change on a global scale and explicitly consider the effects to the northern landscape. International teams of scientists made up of several disciplines, including meteorologists, geologists and biologists, conducted these assessments. The teams used data collected over the last several decades to document ongoing changes and used computer models to predict the extent of changes over the next few decades. Summaries of the assessments are available at their websites. Recent research on the potential impacts of climate change in Canada has revealed that a warming climate could have wide-ranging effects on Canada's environment and the human community. Numerous impact scenarios are presented in the digital atlas of Canada on the website of Natural Resources Canada[3].

The greatest effects of a changing climate are expected in the higher latitudes, where melting ice and large tracts of drying tundra cause significant changes to the natural hydrologic cycle and carbon exchange. Overall, it has been estimated that the air temperature over the arctic landmass has increased at a rate of 0.40°C per decade since the 1960s. ACIA reports that average winter temperatures in the western Canadian Arctic have increased by 3 to 4°C in the last 50 years, and that precipitation appears to have increased by 8% across the Arctic (ACIA 2004). ACIA predicts that total annual precipitation will increase by 20% in the Arctic by the end of the century. These prolonged changes to the climate are expected to have major effects on northern aquatic regimes. Figure 3.2-1 shows a sensitivity projection for NWT's river regions in response to climate warming. Climate warming has the potential to cause substantial changes to flow in rivers and degradation of permafrost (Ashmore and Church 2000).

The most direct effects of projected climate change on the hydrologic cycle are likely to be an increase in floods and river erosion. In the Northern Shield area, permafrost is at risk of being reduced. The IPCC (IPCC 2001a) concludes that significant erosion of permafrost has already occurred in some areas of the north. This erosion of permafrost will lead to changes in surface water drainage and an increase in the active growth layer (i.e., the layer between permafrost and ground surface). This will likely alter the seasonality of runoff and affect soil instability, which will have implications for the landscape, ecosystems and infrastructure. The direct impact of climate change on permafrost is currently still under study.

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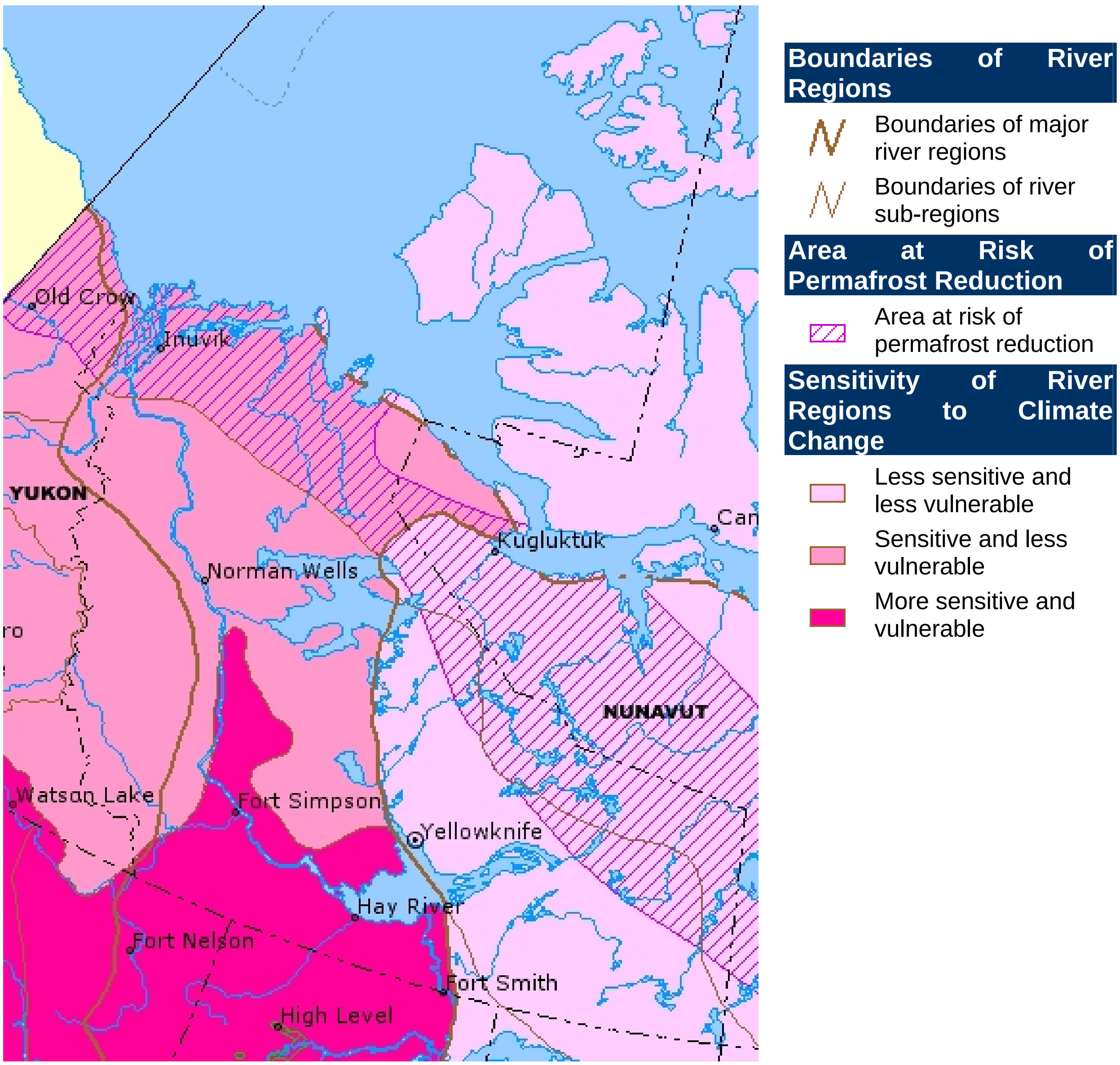
[1] http://www.ipcc.ch/
[2] http://www.amap.no/acia/index.html
[3] http://atlas.gc.ca/site/english/index.html

A warming climate would also result in erosion of soils and thermokarst, and the possibility that wetlands and lake levels will be reduced IPCC 2001a. Increases in the melting of snow and ice could cause the ponding of surface waters in some areas, but drying out of wetlands in other areas because of increased evaporation and transpiration. IPCC (2001b) cite studies in which the area of tundra cover is predicted to decrease by as much as 66% of its present size.

FIGURE 3.2-1
SENSITIVITY PROJECTION FOR NWT'S RIVER REGIONS IN RESPONSE TO CLIMATE WARMING

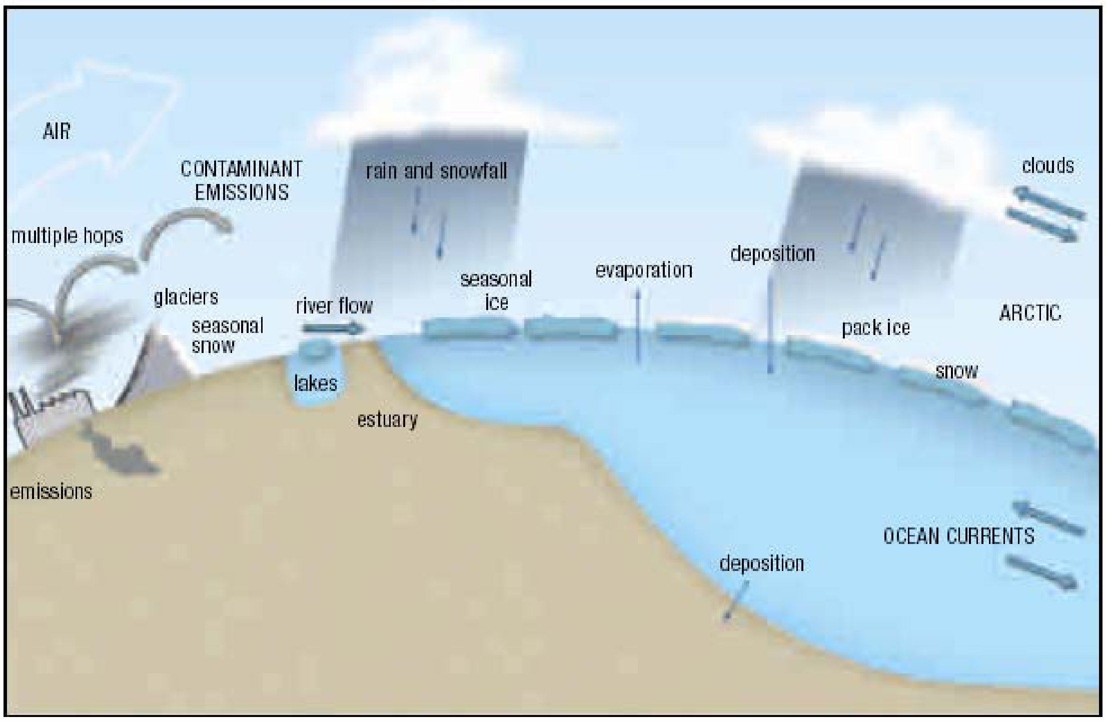


Source: Digital Atlas of Canada, Natural Resources Canada - http://atlas.gc.ca/site/english/maps/climatechange/potentialimpacts/sensitivityriverregions.

3.2.3.2 Contaminants

The presence of contaminants in aquatic systems in the NWT can be the result of both natural and anthropogenic activities, and either local or long-range sources. In northern Canada, human activities are responsible for most of the contaminants present in the environment, and most of these chemicals are deposited by long-range atmospheric transport processes; coming from industrialised regions outside of the Canadian North (INAC 2003). Figure 3.2-2 illustrates the various pathways for contaminants in the northern physical environment.

FIGURE 3.2-2
PATHWAYS FOR CONTAMINANTS IN THE NORTHERN PHYSICAL ENVIRONMENT



Source: Canadian Arctic Contaminants Assessment Report II (INAC 2003).

The predominant research conducted on contaminants in the Arctic has been through the Northern Contaminants Program (NCP). NCP was established in 1992 in response to studies that showed the presence of contaminants in the Arctic ecosystem. Many of these contaminants have no Arctic sources and yet some are found at high levels in animals at the top of the Arctic food chain and in humans. The three main contaminant groups of concern are persistent organic pollutants (POPs), heavy metals and radionuclides[4]. Examples of contaminants studied in the NCP are summarized on Table 3.2-2.

[4] http://www.ainc-inac.gc.ca/NCP/abt/des_e.html

TABLE 3.2-2
EXAMPLES OF CONTAMINANTS STUDIED IN THE NORTHERN CONTAMINANTS PROGRAM

Contaminant	Why Does it Exist? What is it Used for>	Where Does it Come From?
Persistent Organic Pollutants (POPs)		
• polychlorinated biphenyls (PCBs)	• used widely as coolants and lubricants in transformers, capacitors, and other electrical equipment; • found in old electrical transformers.	• mostly locally contaminated soils/plants, landfill sites, and also can be created when burning.
• dichlorodiphenyltrichloroethane (DDT) • toxaphene • endosulfan • chlordane • hexachlorocyclohexanes (HCHs) including lindane	• pesticides used mainly in agriculture to kill pests (e.g., unwanted animals such as insects) or to prevent human diseases.	• northern hemisphere, particularly mid-latitudes, including North America, Asia, Europe.
• chlorinated paraffins (PCAs)	• used in making plastics and in materials to reduce the risk of fire.	• mostly industrial sources in the northern hemisphere.
• polychlorinated naphthalenes {PCNs)	• used in electrical insulation fluids and as wood preservatives; • also come from burning metal waste and garbage.	• mostly industrial sources in the northern hemisphere.
• polycyclic aromatic hydrocarbons (PAHs)	• produced whenever something is burned, from meat to vehicle exhaust to industrial sources.	• mostly industrial sources in the northern hemisphere.
• brominated fire retardants (e.g., polybrominated diphenyl ethers PBDEs)	• used in materials to reduce the risk of fire.	• mostly industrial sources in the northern hemisphere.
• butyltins	• used in e.g., special paint to prevent unwanted growth of plants or animals on ship hulls.	• from passing ships.
Heavy Metals		
• mercury and methylmercury	• are all naturally occurring elements in rocks and soils. • mercury can also be released from flooded lands when reservoirs are created.	• mostly Europe, Asia and North America.
• cadmium	• released to the environment from mining and smelting (processing) metals	
• lead	• lead is released from coal-burning power stations, incinerators and from burning leaded gasoline	
Radionuclides		
• cesium	• except for cesium, are naturally occurring radioactive elements in rocks and soils.	• mostly natural sources in the Canadian North
• polonium		• some very limited transport from northern Europe and Russia.
• uranium	• can be released to the environment from atmospheric testing of nuclear weapons, dumping of nuclear waste, and nuclear accidents.	

Source: Indian and Northern Affairs 2003. Canadian Arctic Contaminants Assessment Report II. Northern Contaminants Program.

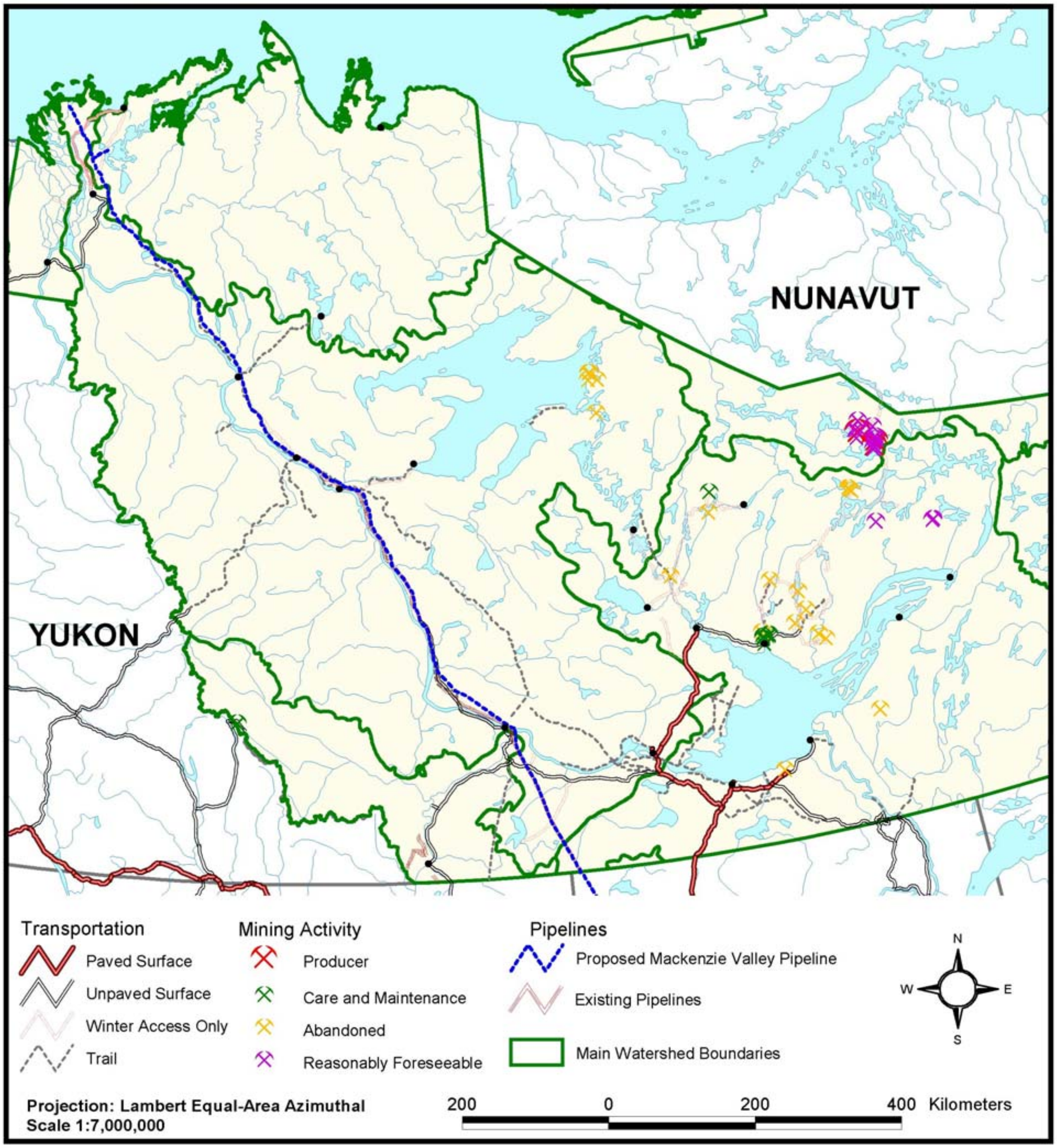
3.2.3.3 Industrial Development

Another significant threat to the freshwater lacustrine and riverine systems in the NWT is the cumulative impact of large-scale development projects that make changes in watersheds. These changes combine to produce stress within the catchment, downstream regions, and can affect aquatic and terrestrial organisms. Past, current, and reasonably foreseeable industrial development in the NWT includes base metal, diamond, gold and uranium mining; oil and gas exploration and production, and hydroelectric generating stations. Development has been an integral part of the northern environment for several decades; however, individual projects have been relatively small and widely dispersed. Historically, mines have affected local environments by building roads and other infrastructure and releasing contaminants to air, soil and water but the physical footprints of the mines were relatively small in nature compared to currently proposed projects. Proposals for extensive oil and gas development, pipelines, permanent roads, hydroelectric projects and several mines within the same watershed will likely make considerable changes to the landscape. A summary of some of these activities in the NWT is presented in Figure 3.2-3.

i) Hydroelectric Development

Hydroelectric development has occurred on the Snare, Taltson, and Yellowknife River systems. Potential for additional development has been identified on other rivers, including the Great Bear, Mackenzie, and Lockhart Rivers, as well as expansion of existing hydroelectric development on the Talston River. Hydro development may involve regulation of flow, changes in water level (including flooding), diversion, and construction of barriers. It may also cause changes in the natural regime (e. g., a shift or spread of peak discharge events). Transmission corridors that carry power from generation sites to user sites also create many of the same environmental stresses that are associated with road transportation. Many changes create stress on both terrestrial and aquatic habitats and their effects are long term, and some are more or less permanent. (WKSS 2001)

FIGURE 3.2-3
INDUSTRIAL ACTIVITY IN THE NORTHWEST TERRITORIES



ii) Diamond Mining

All producing mines currently in the NWT are diamond mines. Two are currently in full production (BHP Ekati and Diavik), a third is under construction (De Beers Snap Lake), and a fourth is being prepared for an environmental assessment process (De Beers Gachue Kue). Diamond mining in the NWT has significant direct, local impacts on aquatic systems. Lakes are completely or partially drained to allow for open pit access to the kimberlite pipes, water diversion systems are required, and large volumes of waste rock are deposited on the surface. Examples of these components of diamond mining in the NWT are shown in Figure 3.2-4.

FIGURE 3.2-4
EXAMPLES OF COMPONENTS OF DIAMOND MINING IN THE NWT BHP EKATI MINE

Panda Pit Panda Diversion Channel Waste rock piles

Source: Independent Environmental Monitoring Agency (http://www.monitoringagency.net/)

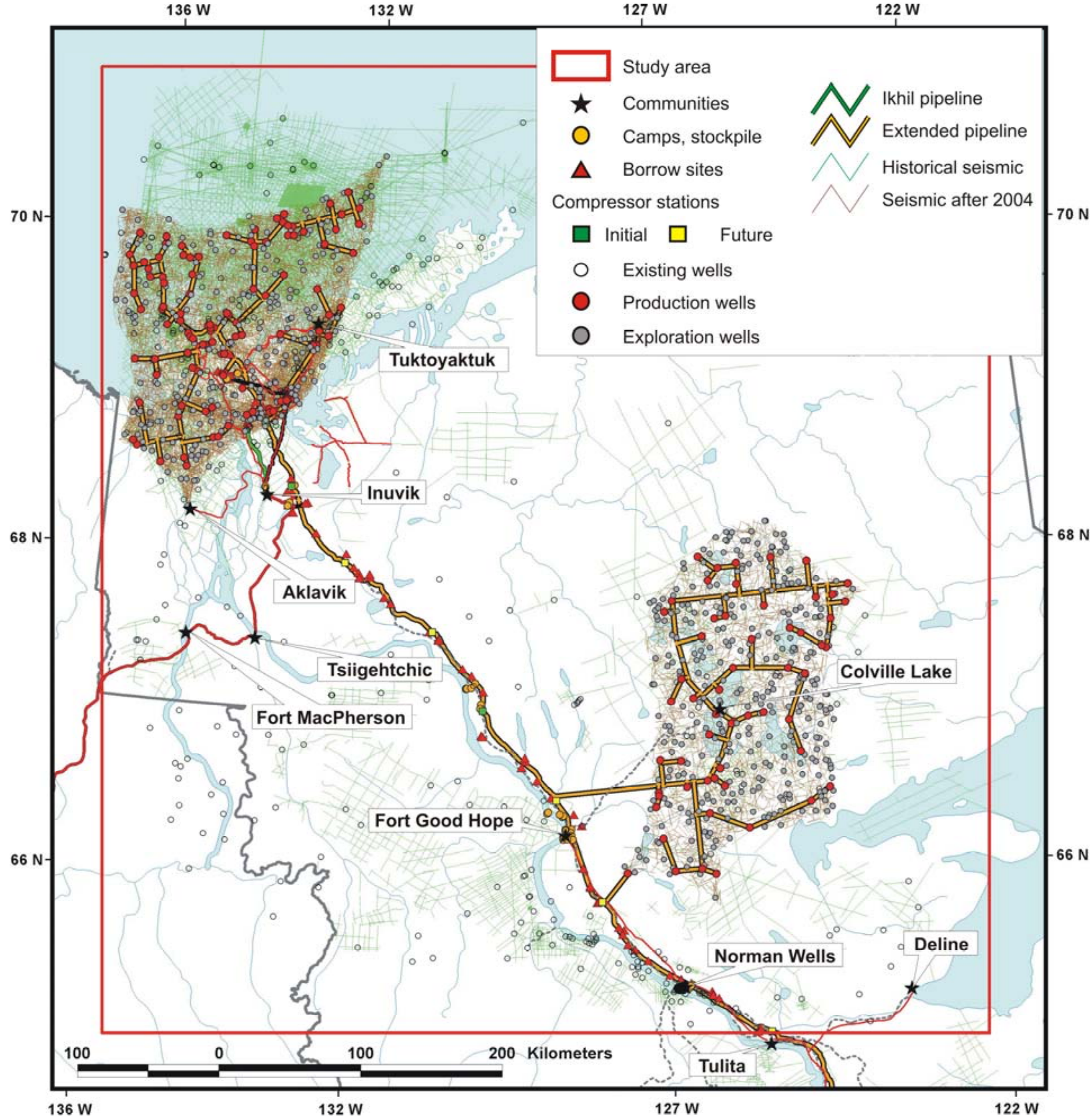
iii) Oil and Gas Exploration and Production

Oil and gas exploration and production activities can have impacts on ecosystems that far exceed the physical footprints of the development. Exploratory drilling for oil or gas deposits has the potential to impact the environment through product or waste spills, road construction, wastewater discharges, and waste disposal. Development of a production field requires access to, or construction of, infrastructure that includes roads, pipelines, power lines, temporary housing, and drilling facilities. Access roads required by oil and gas development can affect the local landscape by modifying permafrost, the drainage of surface water and by the transport of dust (Walker Everett 1987, Walker *et al*. 1987). Increased infrastructure can lead to increased sedimentation in surface waters from erosion. Spills and contaminated water discharged from drilling operations can cause significant impacts on human health and the environment.

The cumulative impacts of oil and gas development were thoroughly reviewed in the U.S. National Academies National Research Council report, *Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope* (Committee on Cumulative Environmental Effects of Oil and Gas Activities on Alaska’s North Slope (CCEEOG) 2003). The report identifies accumulated environmental, social and economic effects of oil and gas leasing, exploration, and production on Alaska's North Slope. In the NWT, the proposed Mackenzie Gas Project (MGP) is currently undergoing an environmental review. If approved, the development will involve the construction of a 1,200 kilometre pipeline to deliver natural gas from three anchor fields in the Mackenzie Delta to northern Alberta. The proposed MGP would also stimulate further natural gas exploration and production in the region. A recent study used industry reports and existing estimates of natural gas reserves in the Mackenzie Valley to derive future development scenarios that could arise as a result of construction of a Mackenzie Valley pipeline (CARC 2005). Figure 3.2-5 is taken from that report and presents a scenario for 2027.

The development of oil reserves in Alaska provides a very good comparison to the type of development that is beginning to occur in the NWT. Walker and Walker (1991) suggest that although the local impacts from the oil industry are small in scale (less than 1 m^2 to 1 km^2), the cumulative impact from all the development affects the region on a larger scale of 1 km^2 to 10,000 km^2. Based on the Alaskan experience, it is not unreasonable to expect that a similar level of development in the NWT will result in significant changes to the terrestrial environment.

FIGURE 3.2-5
ESTIMATED CUMULATIVE EXPLORATION AND PRODUCTION RELATED TO THE PROPOSED MACKENZIE GAS PROJECT – 2027 SCENARIO



Source: Canadian Arctic Resources Committee 2005. Cumulative Effects Modelling of the Mackenzie Gas Project – Scoping and Development. www.carc.org

iv) Export of Bulk Water

Another possible future stress that could be placed on watersheds in the NWT is the exportation of bulk water. The serious problem of water scarcity and poor water quality in many parts of North America could put pressure on Canada's water resources. There is a perception that Canada has plentiful water resources; however, much of the water is tied up in ice and deep lake storage, and is not available through annual river flow (INAC 2003). Removing water in bulk from a drainage basin can have negative impacts within the donor basin. It can compromise existing and future in-stream water uses, alter the ecology of water habitats, and threaten cultural values and cultural activities of residents of the basin.

For the present, the need to protect, conserve and properly use Canadian water resources is recognised by all levels of government. To this end, in December 2003, a federal policy was released that prohibits bulk water removal from major river basins in the Northwest Territories[5]. However, there may be mounting political pressure in the future to ship bulk water south, therefore it will be important to be aware of this eventuality.

3.2.4 Surface Water and Sediment Quality

Good water and sediment quality are important to the health of both the natural and cultural environments. The Canadian Council of Ministers of the Environment (CCME) has established Environmental Quality Guidelines (EQG) for protection of aquatic life in water and sediment and for a number of water uses. These guidelines are threshold concentrations of chemical, physical and microbiological substances that are deemed to be safe for most forms of freshwater aquatic life or for various types of uses (e.g., livestock watering, irrigation, recreation and aesthetics, community water supply).

Water and sediments are inextricably linked as a result of biogeochemical processes taking place at the sediment-water interface of lacustrine and riverine environments. Within the NWT the important relationship between water and sediment is of particular note in the Mackenzie River which has the largest sediment load of any river in the Arctic circumpolar world. Its sediments contain very large amounts of non water-soluble organics and metals (up to 20 times greater than larger northern rivers). Many of these contaminants (e.g., POPs and radionuclides) are typically found at very, very low concentrations in surface waters. Hence, only those contaminants which have been found to exceed Environmental Quality Guidelines on a frequent basis are discussed below.

[5] *A Policy Respecting the Prohibition of Bulk Water Removal from Major River Basins in the Northwest Territories* (http://www.ainc-inac.gc.ca/ps/nap/wat/pdf/polprohnwt_e.pdf)

3.2.4.1 Surface Water Quality

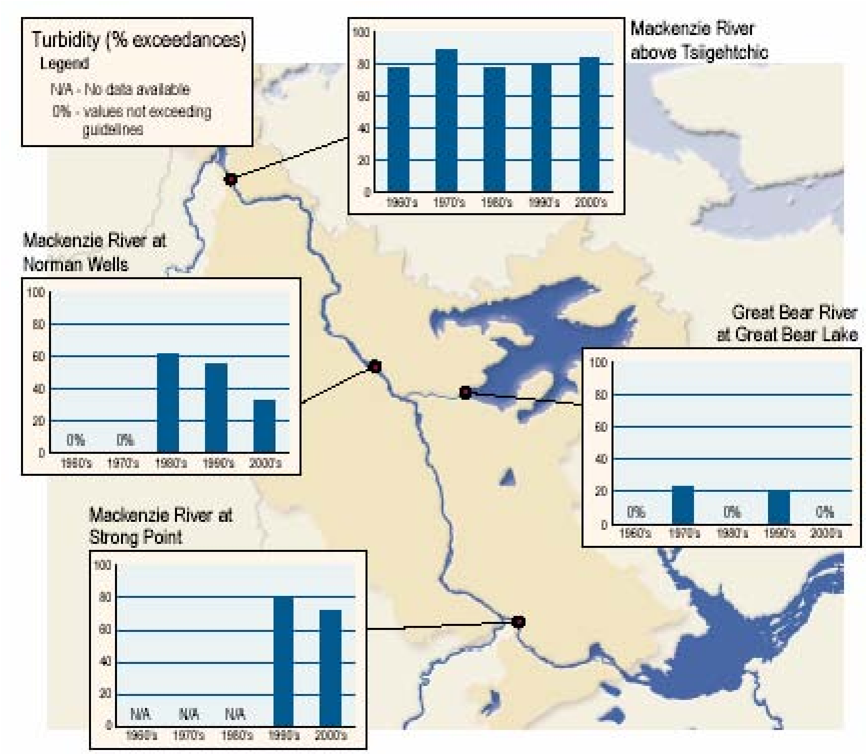
i) What is being measured?

Regional surface water quality monitoring is carried out routinely at a number of locations in the Mackenzie River basin, primarily by Environment Canada and INAC. Project specific water quality monitoring is carried out by proponents of mining operations or oil and gas developments and by INAC at several abandoned mine sites and former military sites. Limnological research has been carried out recently on lakes of the Mackenzie Delta/Tuktoyaktuk Peninsula, Mackenzie Valley, Great Bear Lake Area, Fort Simpson-Trout Lake Area, Nahanni NPR, Tuktut Nogait NP and Aulavik NP. A summary of monitoring activities in the NWT is provided in Section 3.2.1.

ii) What is happening?

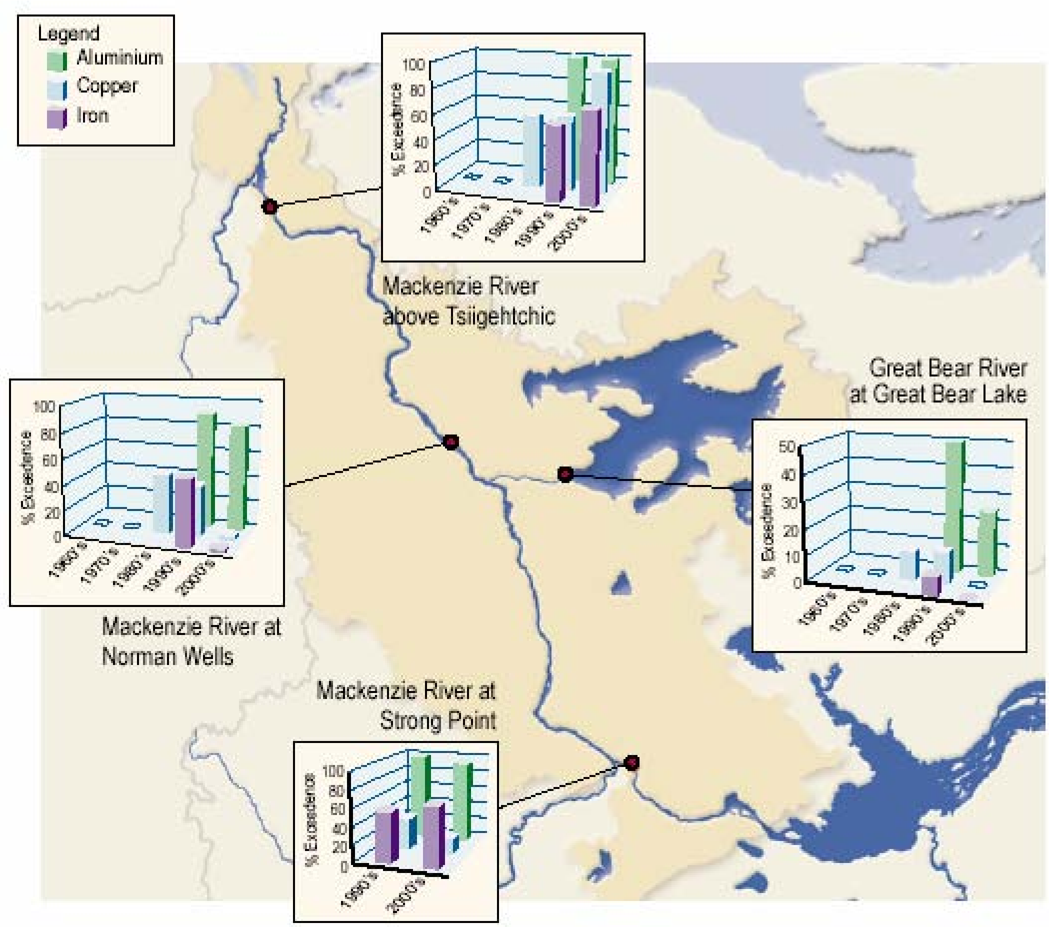
Mackenzie Great Bear Sub-basin: Not surprisingly, turbidity levels measured at three locations on the Mackenzie River have fairly consistently exceeded the guideline level for protection of recreation/aesthetics as demonstrated on Figure 3.2-6. Turbidity, a measure of the "cloudiness" of water, is dependent on the suspended sediment and dissolved solids content of water. At the downstream location above Tsiigehtchic, it is seen that the turbidity level has consistently exceeded the guideline on approximately 80% of the samples collected since the 1960s. A consequence of the elevated suspended sediment levels in the Mackenzie River is elevated levels of certain metals (aluminium, copper and iron) as demonstrated on Figure 3.2-7. By contrast, on Great Bear River near the outlet of Great Bear Lake the turbidity level was mostly below the guideline (i.e., there were few exceedances of the guideline) and the frequency of exceedance of the respective guideline values for the metals was lower with the exception of aluminium in the 1990s.

FIGURE 3.2-6
TEMPORAL TURBIDITY MONITORING AND EXCEEDENCES FROM VARIOUS LOCATIONS ALONG THE MACKENZIE RIVER



Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.

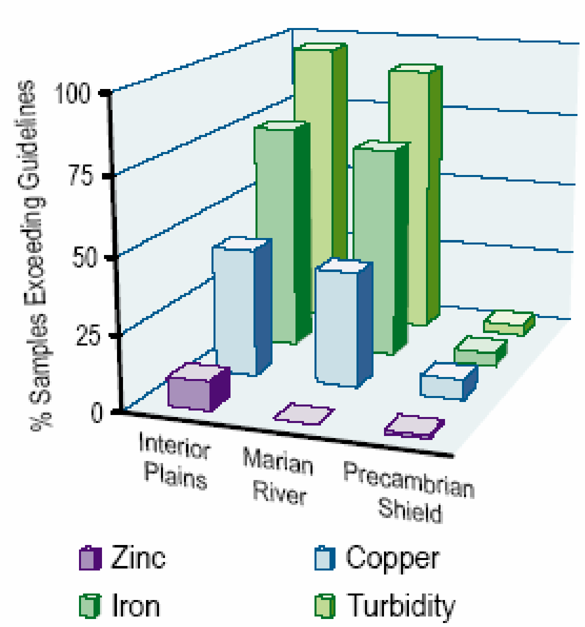
FIGURE 3.2-7
TEMPORAL METAL (ALUMINIUM, IRON, COPPER) MONITORING AND EXCEEDENCES FROM VARIOUS LOCATIONS ALONG THE MACKENZIE RIVER



Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.

Great Slave Sub-basin: The MRBB (MRBB 2004) in its analysis of water quality data on rivers in the Great Slave Sub-basin, separated the rivers according to whether they originated in the Interior Plains, Precambrian Shield or the Marian River watershed. Again the data were evaluated to determine the frequency of exceedance of CEQG. Figure 3.2-8 presents a summary of the analysis of turbidity, copper, iron and zinc data. On the Interior Plains and Marian River, turbidity and iron exceeded the guidelines most of the time and copper was above the guideline on over 25% of the samples. In contrast, turbidity and metals seldom were above the guideline values in rivers on the Precambrian Shield.

FIGURE 3.2-8
ANALYSIS OF TURBIDITY, COPPER, IRON AND ZINC DATA



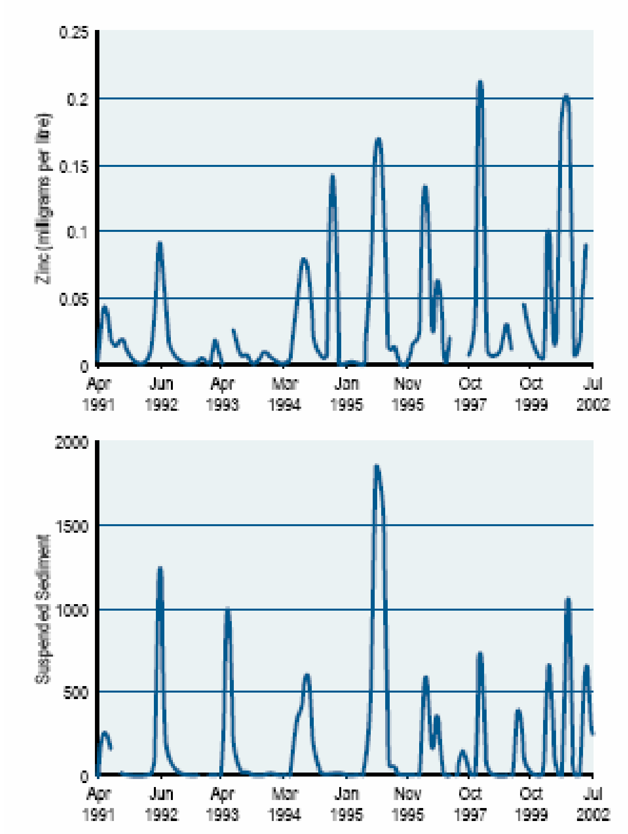
Source: Mackenzie River Basin Board 2003.

Besides the metals noted above, arsenic is also elevated in local watersheds draining the Giant Mine and Con Mine sites near the City of Yellowknife. For example, on Baker Creek, which flows through the Giant Mine site, the arsenic concentration upstream of the mine averages approximately 70 µg/L (Steffen Robertson and Kirsten 2002). By comparison, the arsenic concentration in the Yellowknife River, which is the city water supply, averages less than 0.3 µg/L.

Peel Sub-basin: Water quality monitoring in the Peel River near Fort McPherson has shown dramatic differences between winter and summer. Figure 3.2-9 prepared by the MRBB (2004) demonstrates the temporal variation in suspended and zinc concentrations in the Peel River between 1991 and 2002. The low levels of suspended solids and zinc observed in the winter contrast sharply with the high levels measured in the summer. Elevated concentrations of suspended solids, zinc (and other metals) in the Peel River are attributable to natural erosion processes occurring in the watershed.

Liard Sub-basin: As in the other watersheds, elevated concentrations of suspended solids and metals (notably copper and zinc) have been observed on several occasions at monitoring stations in the Liard River. The overall frequency of exceedance of CCME guidelines is reported to range from 0% to 34%.

FIGURE 3.2-9
TEMPORAL VARIATION IN SUSPENDED AND ZINC CONCENTRATIONS IN THE PEEL RIVER BETWEEN 1991 AND 2002



Source: Mackenzie River Basin Board 2003.

iii) Why is it happening?

High levels of several metals have been observed to occur mostly in the spring and summer when river flows and turbidity levels are highest. The main factor contributing to elevated turbidity, suspended solids and metal concentrations in the rivers in the Mackenzie River Basin is erosion of soils. River sediment loads are affected by the landscape and underlying geology of a region. For example, the sedimentary rocks and glacial tills of the Interior Plains are more easily eroded than the crystalline bedrock that characterizes the Precambrain Shield.

At the local level, elevated metal concentrations around many of the abandoned mine sites in the NWT are attributable to historic releases and in most cases ongoing discharges of either treated or untreated waters. These waters originate from tailings basins, waste rock piles, mine site contaminated areas, open pits and/or underground mine workings.

iv) What does it mean?

The CCME Environmental Quality Guidelines were developed as national reference guidelines. When using the guidelines, the natural environmental conditions and unique aspects of specific water bodies or watersheds must be considered. Therefore, the fact that several exceedances of the guidelines have been observed in the Mackenzie River Basin waters in the NWT does not necessarily mean that plants and animals that are native to these waters are at risk.

Metals, including aluminium, copper, iron and zinc, exist in various chemical forms in water, depending on numerous characteristics of the water. Depending on the metal form, it may or may not be toxic to aquatic life. Because some metals have likely been present at elevated concentrations for thousands of years in rivers on the Interior Plains, it is likely that the plants and animals present in these waters have adapted to these conditions or that the metal of concern is not bioavailable to the organism (MRBB 2004).

v) What is being done about it?

Water quality monitoring continues be carried out by federal, territorial and municipal governments at long-term sites and by industrial proponents at new developments. Federal, territorial and regional legislation is in place to regulate the discharge of wastewaters to the natural water bodies in the NWT. Also, water licences are required by communities and industries for the use of water and discharge of wastewater. The licences set limits on the amount of water that can be used and on the quality and quantity of wastewater that can be discharged. When developments are proposed, environmental and health impact assessments must be carried out and submitted to the appropriate authorities for review.

Under the federal contaminated sites action plan (FCSAP) being administered by INAC, corrective action is being taken at a number of priority sites to remediate existing conditions and minimize the future release of untreated mine waters. As part of the process, detailed environmental risk and impact assessments are required to ensure that adequate protection of the environment is incorporated into the remediation design.

vi) What are the information gaps?

While turbidity and levels of some metals exceed CCME environmental quality guidelines in all sub-basins, the causes are largely natural in origin. Future monitoring will be useful in determining changes in water quality as they relate to climate change effects. The number of long-term monitoring station is limited however, in comparison to the geographic size of the NWT. Logistical and cost considerations have limited the number of stations and frequency of sampling that has been undertaken in the past. Means of expanding the current regional surface water quality monitoring to include key locations in unmonitored watersheds would be beneficial. Integration of more intensive local research into the long-term monitoring network database would be another means of expanding the water quality database. .

With respect to arsenic in the environment surrounding Yellowknife, both the Giant and Con mines have ceased operations but treatment of contaminated site waters continues. Remediation plans are being developed for both sites which will result in contaminated materials being removed from the surface and disposed in a secure manner and thus eventually eliminate the need for treatment of contaminated mine waters in the long term. Continued monitoring at these sites will be required though to demonstrate the effectiveness of the remediation measures.

Studies on levels of contaminants in lake water and sediments should continue as these are very sensitive to changes in inputs from the atmosphere, runoff and rivers.

Although snow is known to be important for bringing contaminants to the surface (e.g., mercury), more needs to be understood about how this happens, and what happens to the contaminants once they reach the surface

3.2.4.2 Sediment Quality

i) What is being measured?

Measurement of contaminant levels in sediments is important for several reasons. First, even trace levels of contaminants in surface water can be removed and accumulate in river or lake sediments. Second, contaminated sediments have been demonstrated to be toxic to sediment-dwelling organisms and fish. Third, sediment core samples can provide insight to trends in environmental contaminant inventories in the environment. For example, many contaminants make their way in the north via atmospheric dispersion processes. Steps taken to reduce or eliminate the usage of certain contaminants are reflected in the levels measured in sediments. In this regard, a number of sediment core investigations have been undertaken in the NWT.

ii) What is happening?

Various types of POPs have been found in sediments in Great Slave Lake and some high Arctic lakes. In Great Slave Lake, POPs are usually found at higher levels in the sediments at the mouth of the Slave River in the West Basin than elsewhere in the lake (INAC 2003). Sediment cores taken close to the mouth of Slave River showed increased trends in PCB concentrations with time and a similar trend in PAHs with most of the increase associated with lightweight

PAHs of probable petrogenic origin. Concentrations of PCDDs were highest in the 1950s and decreased thereafter. No trend was evident for PCDFs, which occurred in substantially lower concentrations than PCFFs (INAC 2003).

Investigations into the fate of POPs and mercury in Amituk Lake on Cornwallis Island have shown that a majority (greater than 95%) of the POPs are not removed to lake sediments but rather either remain in the water column or disappear over time (INAC 2003). For example, half of the HCHs and over 90% of the endosulfan were observed to disappear within a year. For these contaminants, microbial degradation has been identified as an important reason why some POPs have disappeared. In contrast, it was found that approximately 25% of the mercury entering Amituk Lake was removed to the lake sediment. A large portion (approximately 70%) of the mercury input to the lake was attributed to atmospheric deposition on the watershed.

A number of studies of mercury in sediments have been undertaken in the NWT and are summarized in NCP Phase I and II reports. In general mercury levels in sediments were below the CCME Interim Sediment Quality Guideline of 170 nanograms per kilogram. Mercury levels measured on a series of sediment cores taken from the Mackenzie Delta showed no enrichment of mercury in the upper layers suggesting no increase in inputs of mercury from any sources. A notable exception to the above observation is seen in Giauque Lake, which was impacted historically by the operation of a gold mine that used mercury in the gold recovery process. Core samples taken from Giauque Lake were found to provide accurate accounts of the history of the mine operation. Elevated mercury levels have also been recorded on sediment samples collected from the east end of Great Bear Lake near former silver mine operations.

In Yellowknife Bay on the North Arm of Great Slave Lake, elevated arsenic levels have been measured throughout the bay (SRK 2002). The accumulation of arsenic in the lake sediments has been attributed to uncontrolled releases to the atmospheric and aquatic environments from the Giant Mine and Con Mine during the early years of their operation. While the Giant Mine and the Con Mine, also located near the City of Yellowknife, continue to release treated effluents to Yellowknife Bay, arsenic levels in the lake sediments originated primarily from historic operations.

iii) Why is it happening?

The decline observed in most POPs in lake sediments is related to declines in atmospheric concentrations over northern Canada. Decreases in the HCH pesticides are due to restricted usage of chemicals and to microbial degradation of residual levels found in the environment. The main exceptions are the insecticides dieldrin and endosulfan, which are still being used in some parts of the world (INAC 2003). There is no clear indication whether mercury levels in the atmosphere, which is the main source of mercury input to the aquatic environment, are increasing or decreasing over northern Canada.

iv) What does it mean?

The concentrations of POPs in lake sediments in the NWT are generally not considered to pose a risk to sediment-dwelling organisms or to fish. As a consequence of restrictions on the use of several toxic insecticides and pesticides, the concentrations in lake sediments are decreasing. While some POPs are amenable to biodegradation, most are only slowly degradable in the environment. The cold conditions prevalent most of the year in the NWT also does not favour biodegradation of POPs.

Of the metals, mercury is of the greatest concern due to the fact that it biomagnifies in the food chain. Elevated mercury levels in some fish species in some parts of the NWT has caused consumption advisories to be issued. Monitoring data on mercury levels in lake sediments do not indicate an increasing trend which suggests that there has not been an increase in mercury input sources in the NWT. Atmospheric levels of mercury, which is the principal source of mercury input to the aquatic environment, similarly do not show an increasing or decreasing trend.

v) What is being done about it?

Actions to reduce or eliminate sources of POPs and mercury have been initiated by several countries including Canada. Continued initiatives through the United Nations and other international bodies are being pursued to research the toxicity and global transport of contaminants in the Arctic circumpolar regions.

vi) What are the information gaps?

Information on PCBs, pesticides, polycyclic aromatic hydrocarbons (PAHs), dioxins and furans and heavy metals in sediments is very limited with exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

3.2.5 Surface Water Quantity

i) What is being measured?

Stream flows have been measured at a number of locations in the Mackenzie River Basin since the early 1960s. Some stations have been monitored continuously since that time while others are monitored only during the ice free period. For the most part, flow monitoring is carried out by the Water Survey of Canada and by INAC.
Records of water usage are maintained by the GNWT and INAC.

ii) What is happening?

Mackenzie Great Bear Sub-basin: Flow at the mouth of the Mackenzie River averages approximately 9,000 cubic meters per second of which 60% originates from Great Slave Lake and 20% is provided by the Liard River. Great Bear Lake provides about 4% of the flow in the summer and 12% in the winter when flow in other tributaries is reduced. The historic record of flows in the Mackenzie River (see Figure 3.2-10), is seen to vary substantially from year to year over the forty period of record. Analysis of the flow record by the MRBB (2004) and others has indicated no significant trend in mean annual flows in the Mackenzie River.

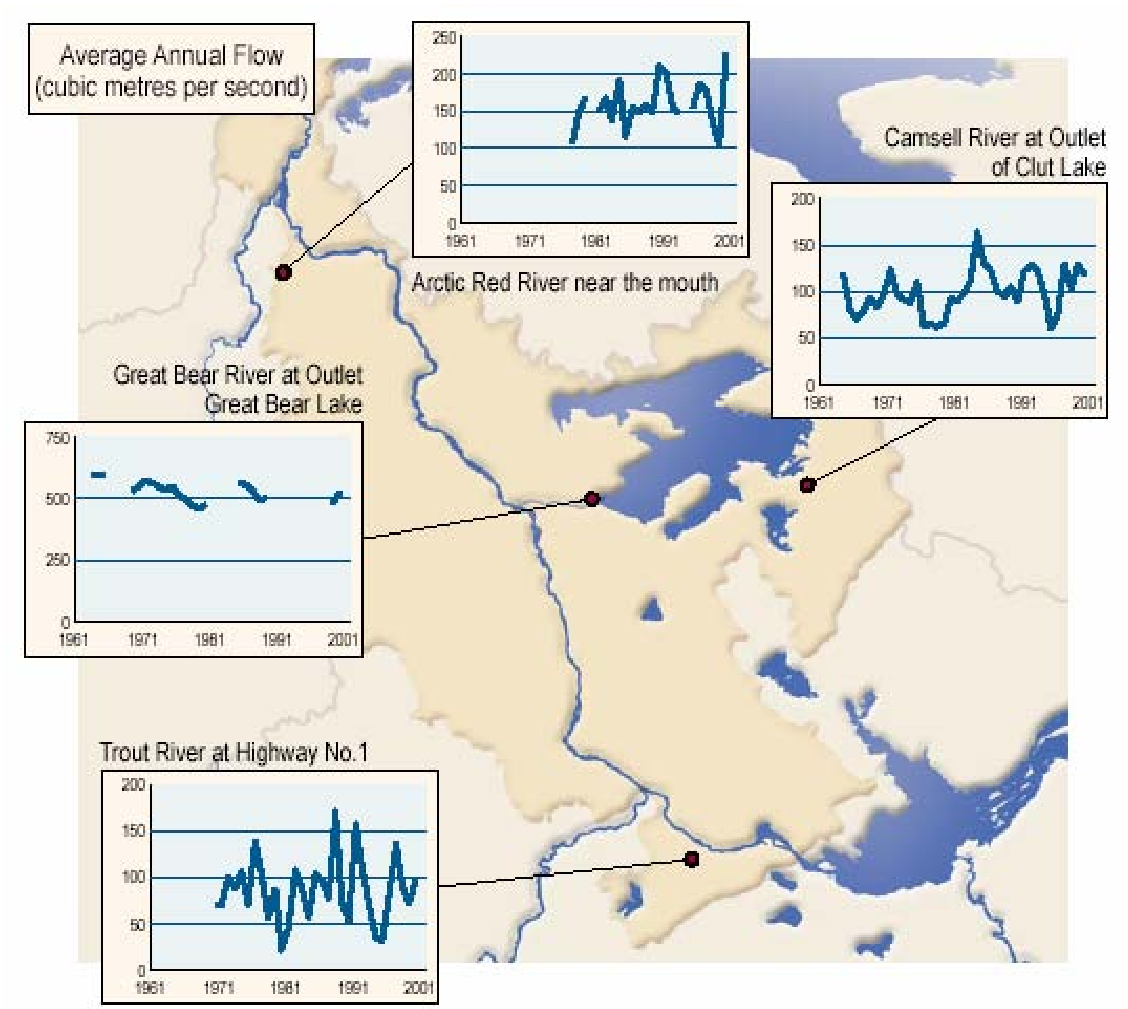
The annual hydrograph of Great Bear River presented on Figure 3.2-11 illustrates the effect of water storage in Great Bear Lake in attenuating variations in the outlet flow. The mean daily discharge rate only varies by about 100 cubic meters per second over the course of a year (MacDoanld *et al*. 2004). Excess water that flows into the basin during snow melt and rainfall events is stored in the lake. Figure 3.2-12 summarizes the long-term record of annual surface water levels measured on Great Bear Lake. The lowest levels were recorded in the 1940s and the highest during the mid 1950s. The data suggest a slight downward trend since the 1960s; however, this may simply reflect a natural cycle.

Water use by ten licenced communities and one licenced industry in the sub-basin in the year 2000 is shown on Figure 3.2-13. The total volume of water withdrawn in 2000 by the communities equalled 874,425 cubic meters and by the lone industry was 2.8 million cubic meters. The combined flow of all water users equalled an extremely small fraction of the flow in the Mackenzie River.

Great Slave Sub-basin: Flow in the Slave River has been found to be affected by the operation of the Bennett Dam some 1,500 kilometres upstream of Great Slave Lake (MRBB 2004). Average flows from May to October have been reduced by 20% while the average minimum winter flow has doubled. These effects are demonstrated on Figure 3.2-14.

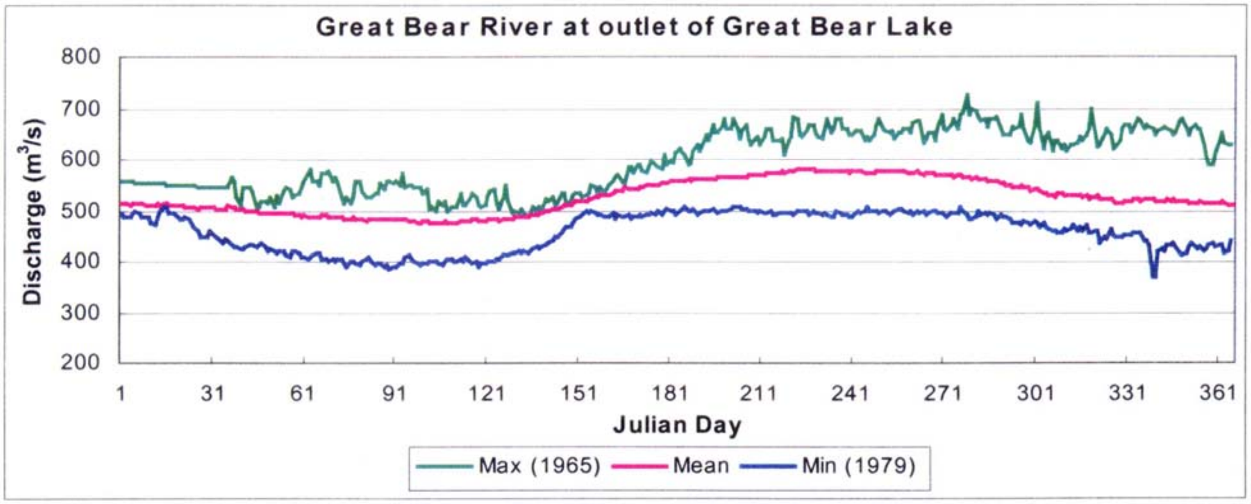
Peel Sub-basin: Flow in the Peel River is affected by snowmelt in the May or June period, particularly in the small headwater streams that originate on the Peel Plateau. Rainstorms can also result in dramatic increases in steam flow in the Peel River and its tributaries. Figure 3.2-15 presents the maximum flow record over the 1960 to 2000 period at the Canyon Creek station. The figure indicates that the high flows recorded between the mid 1960s and early 1980s have not been matched in recent years.

FIGURE 3.2-10
AVERAGE ANNUAL FLOW IN FOUR TRIBUTARIES OF THE MACKENZIE GREAT BEAR BASIN



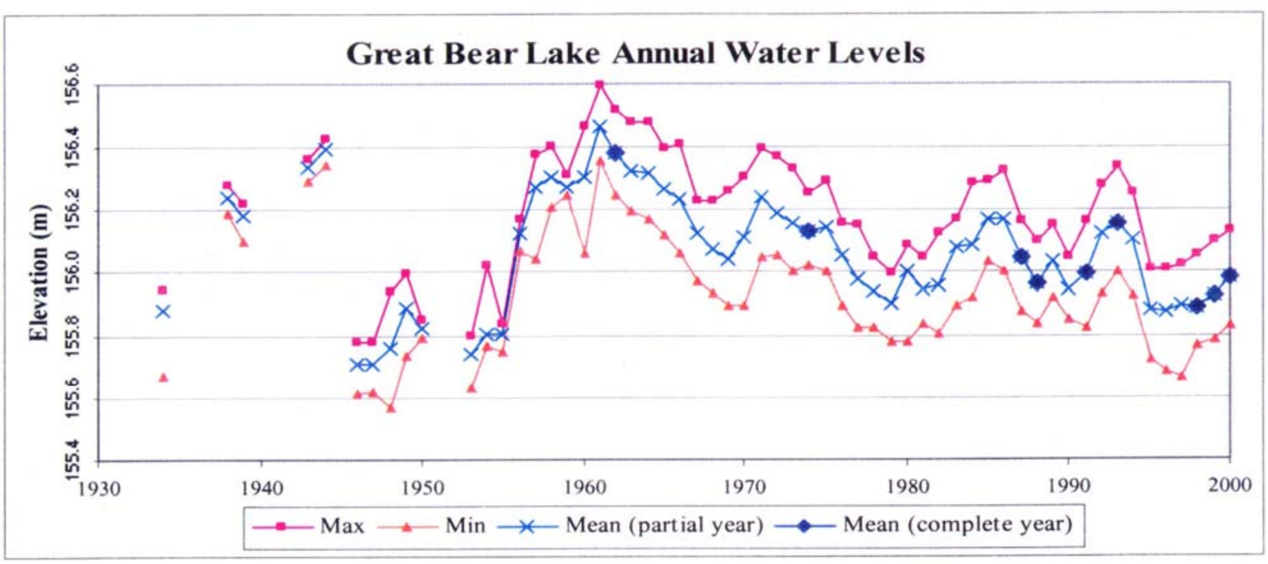
Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.

FIGURE 3.2-11
ANNUAL HYDROGRAPH OF THE GREAT BEAR RIVER, 1961-1999 (KOKELJ 2001)



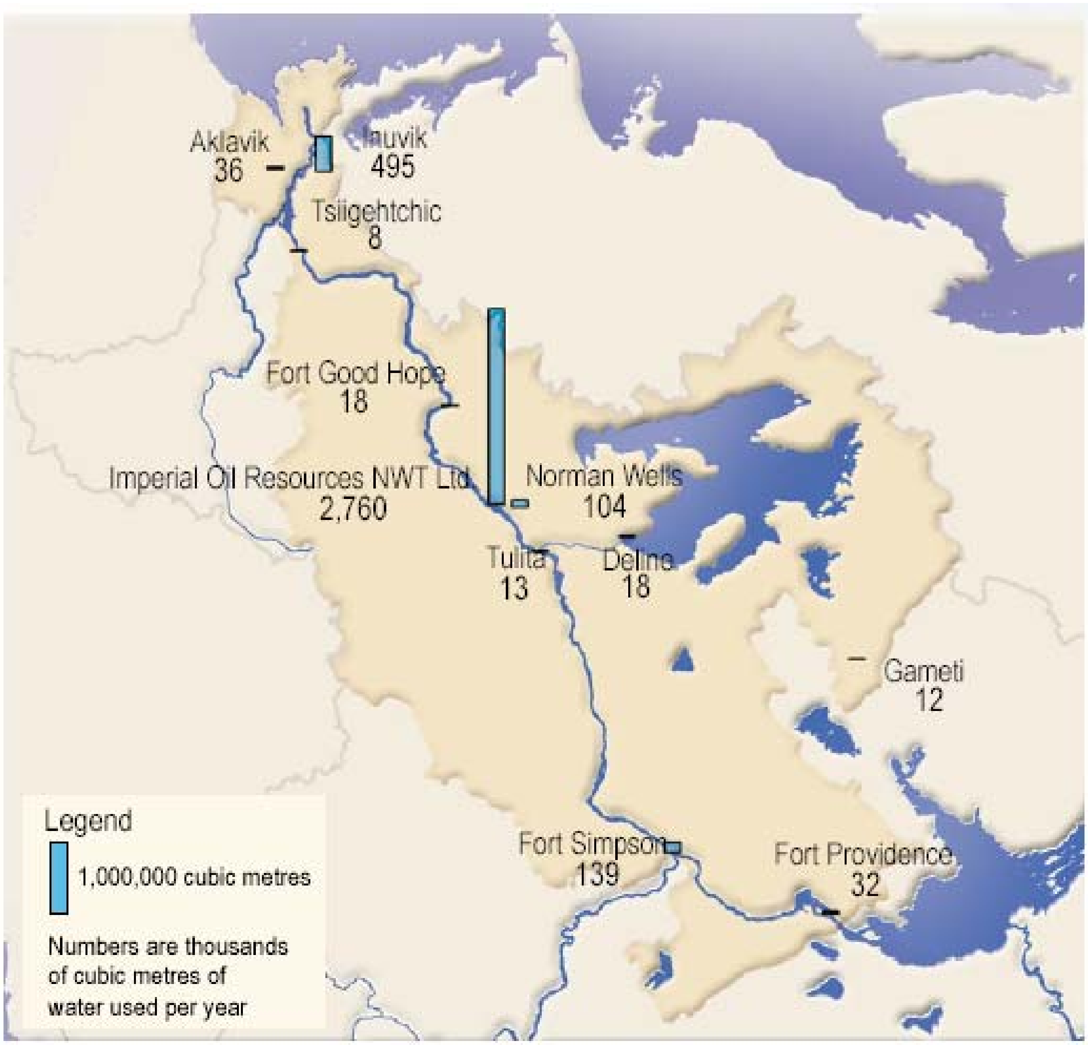
Source: MacDonald et al. (2004).

FIGURE 3.2-12
ANNUAL SURFACE WATER LEVELS FOR GREAT BEAR LAKE, 1934-2000



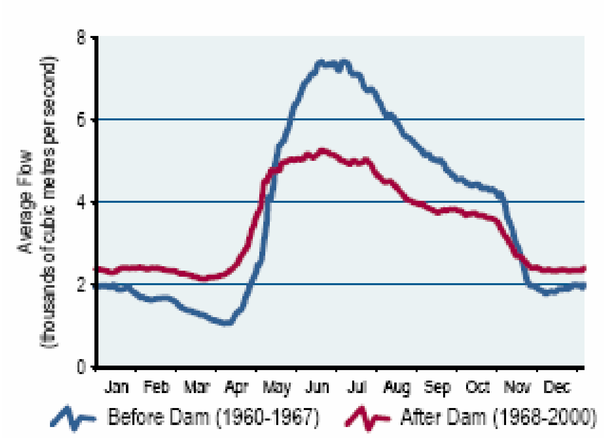
Source: MacDonald et al. (2004).

FIGURE 3.2-13
INDUSTRIAL AND DOMESTIC WATER USE ALONG THE MACKENZIE RIVER SYSTEM



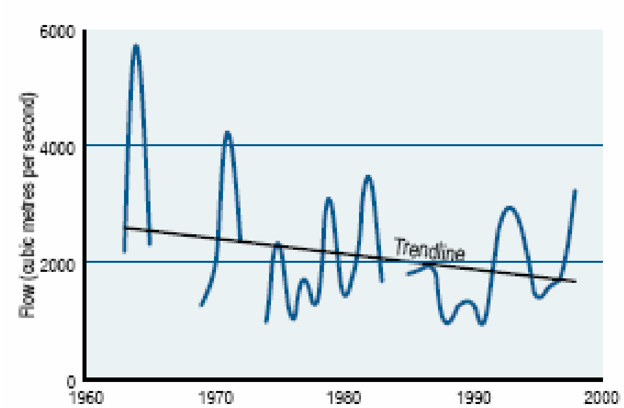
Source: Mackenzie River Basin State of the Aquatic Ecosystem Report 2003. Mackenzie River Basin Board 2004.

FIGURE 3.2-14
AVERAGE FLOW IN SLAVE RIVER



Source: Mackenzie River Basin Board 2003.

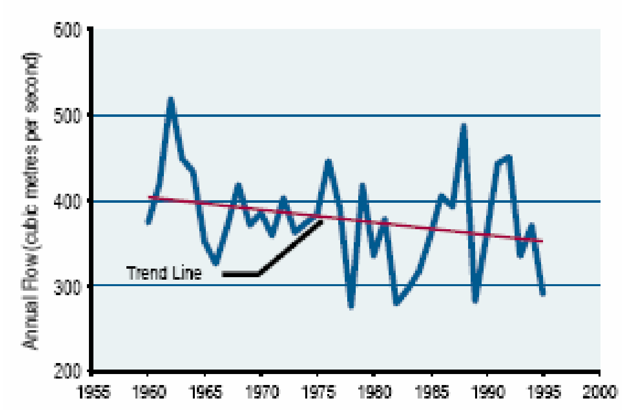
FIGURE 3.4-15
HIGH FLOWS AT CANON CREEK STATION IN PEEL SUB-BASIN



Source: Mackenzie River Basin Board 2003.

Liard Sub-basin: Flow is recorded on the Liard River at five-stream flow stations. Average annual flows measured at Upper Crossing (see Figure 3.2-16) were found to decline by 12.5% between 1960 and 1995 (MRBB 2004). Similar trends were reported at two other downstream flow monitoring stations.

FIGURE 3.2-16
AVERAGE ANNUAL FLOWS ON LIARD RIVER AT UPPER CROSSING



Source: MacDonald Environmental Services Ltd. (2004).

iii) Why is it happening?

River flow is influenced by several factors including landscape features and climate change effects. The MRBB (2004) in its report suggests that the decline in flow in the Liard River may be related to a decrease in precipitation reported at monitoring stations in the study area. On the Peel sub-basin, it was speculated that warmer temperatures may have contributed to more frequent snow melts and thus a reduction in peak flows. On the Slave River, operation of the Bennett Dam has had a marked effect in reducing peak summer flows and augmenting winter time minimum flows. In contrast, a significant change in flow in the Mackenzie River has not been observed.

iv) What does it mean?

Changes in river flow rates may affect habitat and populations of fish and other aquatic species. Reduced river flows may also affect shoreline erosion, channel scouring, and sediment deposition. These factors could have a significant effect on the formation of the Slave River Delta. It is not clear whether there would be any measurable impact on the Mackenzie River Delta. In all cases, the potential effects of climate change will require several years of additional monitoring to discern the extent of potential effects.

v) What is being done about it?

Environment Canada and INAC continue to monitor climate and river flows throughout the region. Research is also continuing, examples being the Mackenzie GEWEX Study and the Canadian Climate Impacts and Scenarios project.

vi) What are the information gaps?

River flow monitoring data suggest that there may be a change in the average flow peak flows in some sub-basins however; there are no clearly defined trends. Continued flow monitoring together with monitoring of climate data will be required to better understand the effects of climate change on river flows in the NWT.

3.2.6 Ferry and Ice Bridge Seasons

Transportation routes in the NWT are dependent on ferry and ice bridge crossings on the Mackenzie River at five locations; Yellowknife Highway at Fort Providence, Mackenzie Highway at N'Dulee and Liard River, Dempster Highway at Tsiighetchic and Peel River.

i) What is measured?

The number of days each year that the crossings are open for ferry service and for winter road use are recorded.

ii) What is happening?

The number of days each year that ferries operated and the winter bridge crossing was open between 1990 and 2002 is shown on Figure 3.2-17. At the two southern crossings the number of days of ferry service increased and the ice bridge was at Fort Providence was open for fewer days. A similar consistent trend was not observed at the northern most crossing.

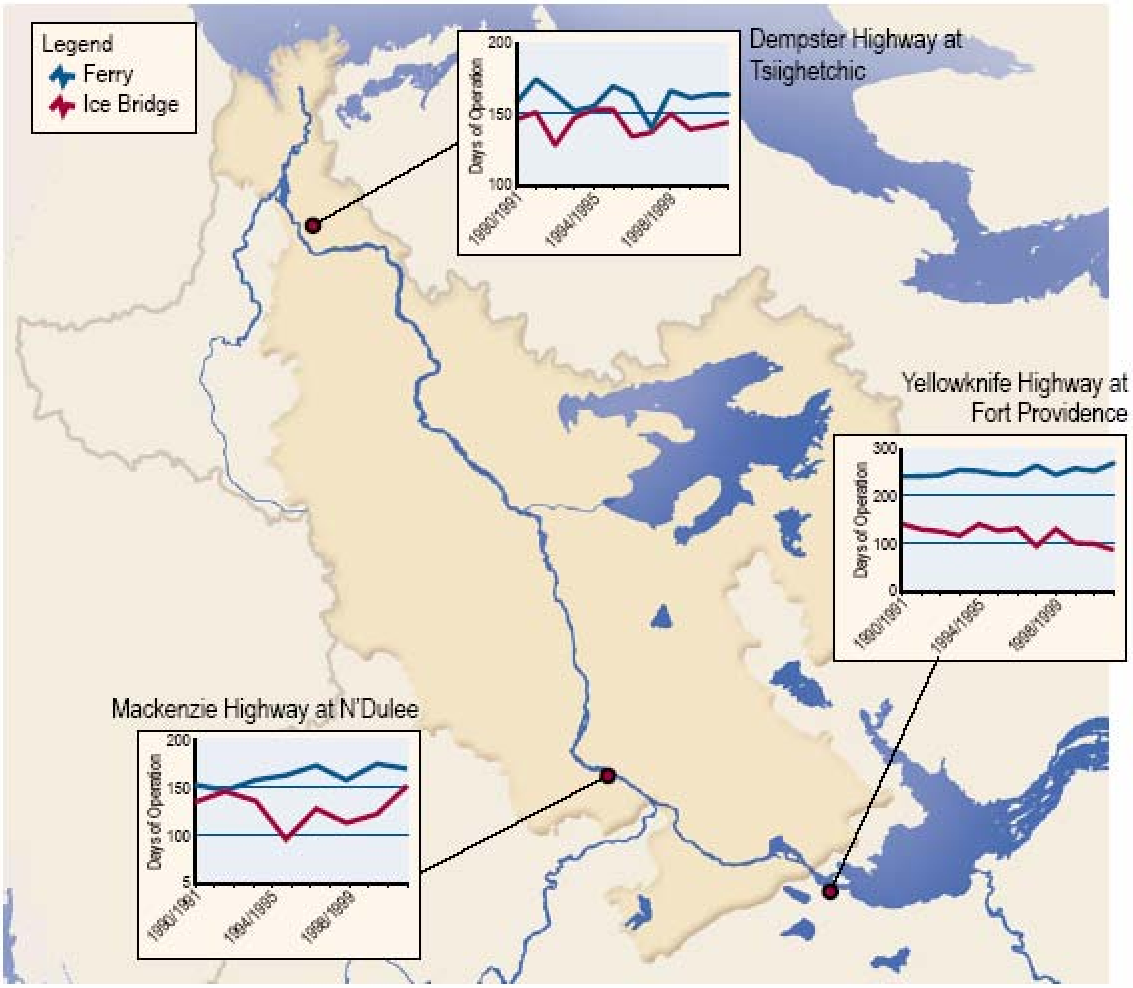
iii) Why is it happening?

Warmer temperatures in the southern part of the NWT is believed to be a factor contributing to the longer ferry operating season at Fort Providence. It is reported (MRBB 2004) that changes in technology and improvements in operating methods have enabled longer ferry and ice road operating seasons which may have offset some of the effects of climate change.

iv) What does it mean?

The transportation system at the Mackenzie River crossings has continued to operate efficiently with few interruptions despite the rise in air temperature that has been observed. Should temperatures continue to rise as many expect, than it is possible that ferry seasons will become longer. It is also anticipated that the frequency of interruptions in ferry service may increase due to more frequent ice jams and reductions in water flow.

FIGURE 3.2-17
NUMBER OF DAYS EACH YEAR THAT FERRIES OPERATED AND THE WINTER BRIDGE CROSSING WAS OPEN BETWEEN 1990 AND 2002



Source: Mackenzie River Basin Board 2003.

v) What is being done about it?

The MRBB (2004) notes that the NWT Transportation Department is committed to ensuring that the three major river crossings remain open for as much of the year as possible. With the increased activity in the NWT, it is possible that a bridge may be built across the Mackenzie at Fort Providence.

vi) What are the information gaps?

Ferry and ice bridge services are important components of the transportation network in the NWT. Continued monitoring of climate change, river flows, frequency and timing of ice jams and days of operation of the ferry and ice bridge operations will be important in determining effects of changing conditions on the viability of these services.

3.2.7 Overall Assessment

In 2000, the National Round Table on the Environment and the Economy, launched the Environment and Sustainable Development Indicator initiative to identify the assets necessary to sustain a dynamic economy and a healthy society and environment for Canadians. Fresh Water Quality is one of the six national-level environmental indicators that are to be used for reporting on an annual basis. This initiative gave rise to the development of a standardized Water Quality Index (WQI) protocol by the Canadian Council of the Ministers of the Environment (CCME) in 2001. The index compares measured water quality to CCME Canadian Environmental Quality Guidelines (CEQGs) and site-specific water quality objectives where appropriate. The WQI values range from 0 for poor water quality to 100 for excellent water quality. The water quality categories include Excellent, Good, Fair, Marginal and Poor.

The MRBB's State of the Aquatic Ecosystem Report (2004) compared water quality measurements from the Liard, Peel, Great Slave and Mackenzie-Great Bear sub-basins to CCME CWQGs. Guideline values were found to be frequently exceeded for water quality variables such as turbidity, total aluminium, copper, iron and zinc. It was noted that CCME guidelines for these contaminants were exceeded most often during high river flow conditions. As metals and other substances are usually bound to suspended solids (particles) during periods of high flow, they have a much reduced effect on aquatic plants and animals. It was concluded therefore that surface water quality in the Mackenzie River Basin was capable of supporting all the basin's native aquatic plants and animals (MRBB 2004). Also, they are effectively removed by sedimentation and filtration in drinking water supply treatment plants.

In addition to the above work, water quality data for several sites in the Mackenzie-Great Bear Sub-basin were evaluated against site-specific water quality objectives using several different protocols as recommended by the CCME Water Quality Index technical sub-committee (Sharma 2002, Halliwell 2004). Based on the results of the assessment using the background concentration technique, water quality in the basin was characterized as 'excellent' to 'fair' (Halliwell 2004). Water quality at all sites in terms of major ions (chloride, sulphate, fluoride, calcium and sodium) was categorized as excellent with no obvious increasing or decreasing trends. Due to the high suspended solids load carried in the Mackenzie River and its tributaries, trace metal concentrations frequently exceed guideline values for protection of aquatic life and the waters were categorized as marginal to poor.

In summary, water quality in the Mackenzie River and its tributaries largely reflects natural conditions. There are localized areas with elevated metals or nutrients attributable to wastewater discharges or industrial effluents but the effects are not obvious at the regional level due to the large flow carried by the Mackenzie River and its major tributaries. Stricter regulations and technological improvements have resulted in reductions in contaminant loads entering the environment and in improvements in receiving water quality (MRBB 2004). Current initiatives to remediate abandoned mine sites and former military sites in the NWT will also contribute to improvements in environmental quality near these sites. Similarly, the creation of monitoring oversight committees on new developments which involve Aboriginal people will help ensure that future impacts are minimized.

Continued water quantity and quality monitoring is required to measure the effects of climate change in the North. While flows in some tributaries have remained fairly constant, flows in other tributaries (e.g., the Liard River) have been seen to show a decreasing trend consistent with climate change model predictions. Other predicted changes include the timing of ice formation and break-up, loss of permafrost conditions in areas with discontinuous permafrost, frequency and intensity of peak precipitation events. All of these factors may affect not only water quantity but also water quality. In addition, water resource development projects, such as the W.A.C. Bennett hydroelectric dam on the Peace River, can have a significant effect on both flow and sediment loads. It is important therefore, that comprehensive flow and quality monitoring be carried out so that adaptive water management strategies can be formulated to take into account the potential effects on water resources in the NWT of all of these factors.

With the exception of some instances of elevated metals at a local scale (e.g., arsenic in Yellowknife Bay), the overerall condition and anticipated trends for sediment quality were found to be favourable based upon the information available. However, it was found that information on PCBs, pesticides, polycyclic aromatic hydrocarbons, dioxins and furans, and heavy metals in sediments is very limited with the exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

3.3 ARCTIC FRESHWATER ECOLOGY

3.3.1 Monitoring and Research Activities

Freshwater research in Arctic Canada and much of what is known about freshwater ecology has been discovered from three programs (Welch 1996):

- The first was the Char Lake Program (1969-1973) at Resolute. Researchers described lake energy flows and trophic dynamics. Char Lake was representative of lakes with sedimentary rocks of the high Arctic Archipelago.
- The second was the Saquaqjuave (Saq) Program (1977-1983) on the northwest coast of Hudson Bay, near the hamlet of Chesterfield Inlet. The program focussed on whole-lake fertilization experiment (phosphorus and nitrogen). Saq lakes were representative of small lakes in the central barrens. P&N, Jade and Far lakes were exposure lakes, and Spring Lake was a reference lake.
- The third was the Lionel Johnson's Char and Lake Trout Program at Nauyak Lake, Kent Peninsula, and his work elsewhere in the arctic, which produced much of the information on arctic fish populations (Johnson 1980 and references within).

Smaller scale research work occurred at Keyhole Lake on Victoria Island, Lake Hazen and many others on Ellesmere Island, Sophia and Amituk lakes on Cornwallis Island, and Netiling and Ogac lakes on South Baffin. It is of note that comprehensive research on large to very large arctic lakes in Arctic Canada are missing. Lakes over 1,000 km^2 lying in the Northwest Territories (NWT) include Great Bear Lake (31,328 km^2), Great Slave Lake (28,568 km^2), Lac la Marte (1,776 km^2), and MacKay Lake (1,061 km^2).

NWT freshwater ecosystems provide a resource base for many people, including food and recreation for those who live both within and adjacent to the region (Gitay *et al.* 2001). These ecosystems are characterized by low water temperature and, in some cases remain frozen in summer (Anisimov and Fitzharris 2001). Polar freshwater systems are distinguished from temperate and tropical systems by the seasonal variation in incoming solar radiation with 24-hour sun in the summer to near complete darkness in the winter (Anisimov and Fitzharris 2001). This fluctuation results in large annual changes in biota and, in fact, the maximum daily radiation received in mid-summer by arctic lakes is greater than tropical lakes (Horne and Goldman 1994).

The Mackenzie Delta is the largest Delta in Canada and the second largest northern delta in the world (Marsh 1998). The Mackenzie Delta alone has 25,000 lakes. This bounty of lakes differs from temperate and tropical areas where deltas have marshes and swamps. Likewise, NWT lakes do not show the same organic material infilling that is characteristic of temperate and tropical lakes. Infilling changes result from the deposition of sediment in the lakes, the draining of lakes as the main river channels cut into the banks, the formation of deltas that divide larger lakes into smaller water bodies, the melting of permafrost immediately surrounding the lakes which results in enlargement of the lake and the creation of new lakes as channels are abandoned (Marsh 1998).

NWT channels and rivers also show constant water level change throughout the year due to freezing and thawing, not only because of changes in volume but also because ice slows water movement (Marsh 1998). Although ice jams can occur at both freeze-up and break-up and both times can result in partial blockage leading to very high water levels in the upstream areas, the break-up jams are typically the largest and therefore most important (Marsh 1998). Ice thickness is controlled by both air temperature (colder temperature means thicker ice) and snow cover (less snow depth means thicker ice). Lake ice in the NWT usually reaches 0.6-1.5 m thick and small shallow lakes may only reach depths of 1-2 m. Therefore, even small changes to depth may result in freezing of the entire water body (Marsh 1998).

Lakes actually receive very little snowmelt from the surrounding areas because most of the water is absorbed by the soil only to subsequently evaporate or transpire. Except under channels and lakes, much of the Mackenzie Delta, and the rest of the NWT, is underlain by permafrost. Loss of surface water to groundwater is usually very small because the lakes tend to be underlain with silts and clays that have low permeability (Marsh 1998).

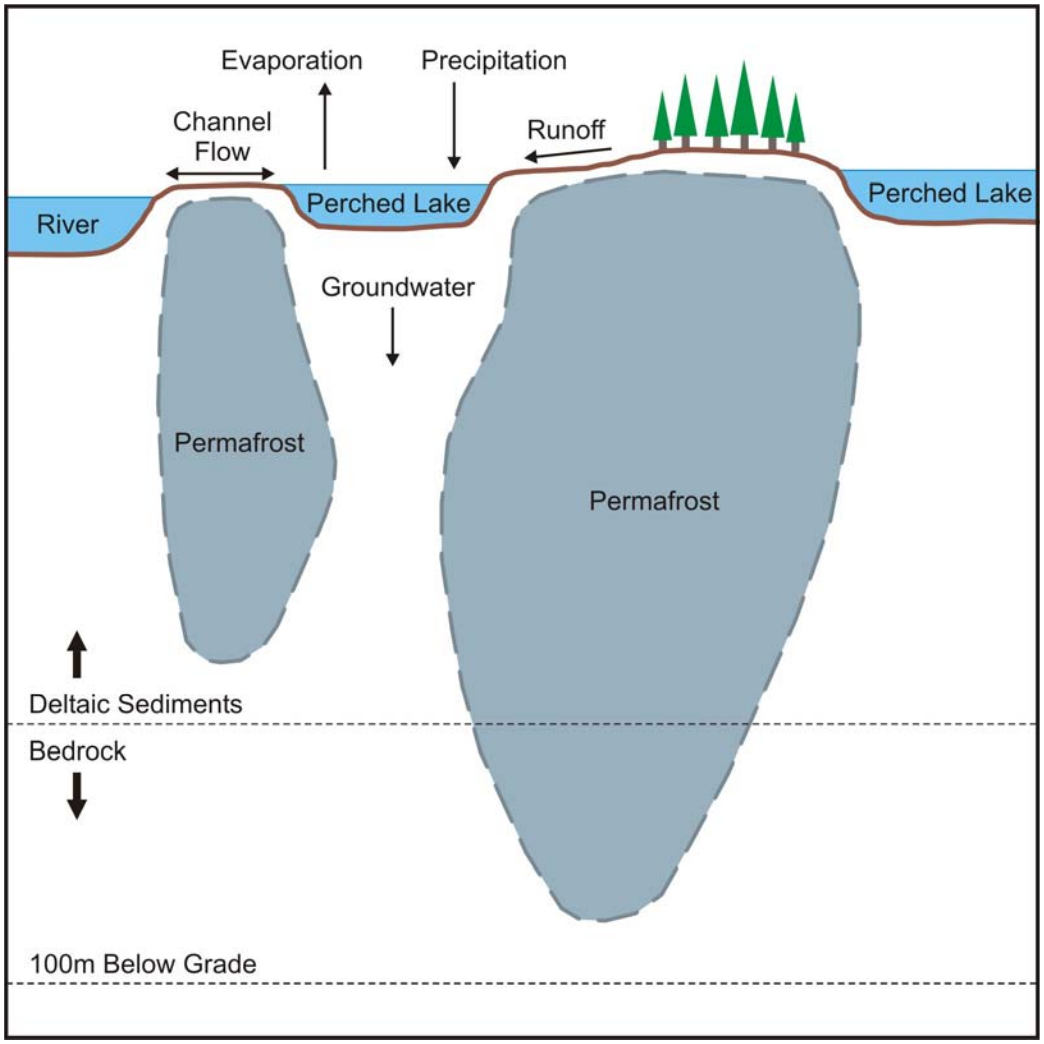
Typical of the Mackenzie Delta, perched lakes sit at elevations above river channels. Figure 3.3-1 is a diagram of the water cycle for perched lakes. The large grey areas represent the permafrost layer. These perched lakes require periodic flooding; typically from ice jamming. Usually this flooding occurs annually or at least every 2 to 5 years but on the highest lakes, it may only occur every 10 years (Marsh 1998).

Despite the permafrost and the long ice periods and snow cover, the Mackenzie Delta area is very productive biologically (Marsh 1998). NWT, and the Arctic/sub-Arctic in general, are home to a variety of highly distinct biomes, including many migratory species (Anisimov and Fitzharris 2001).

Summer primary production may actually be inhibited because of high levels of incoming solar radiation, which inhibits photosynthesis. This inhibition may not be compensated in some of the more shallow lakes. However, this loss of production may be compensated by benthic algal or moss growth (Hornes and Goldman 1994).

On-going threats to the northern environment include the extraction of oil and mineral resources, especially because of the associated disturbances caused by construction of roads and pipeline corridors. Changes in land use can lead to soil erosion, which threatens the availability of clean water (Macdonald *et al*. 2003). The entire NWT is being and has the potential to be further impacted by climate change, hydroelectric development, mining development and contamination at abandoned mine and former military sites (Marsh 1998).

FIGURE 3.3-1
SIMPLE WATER CYCLE OF PERCHED LAKES



Source: Marsh 1998.

3.3.2 Freshwater Stressors

Freshwater ecosystems in the NWT are sensitive to a wide range of anthropogenic and natural stressors. These stressors include:

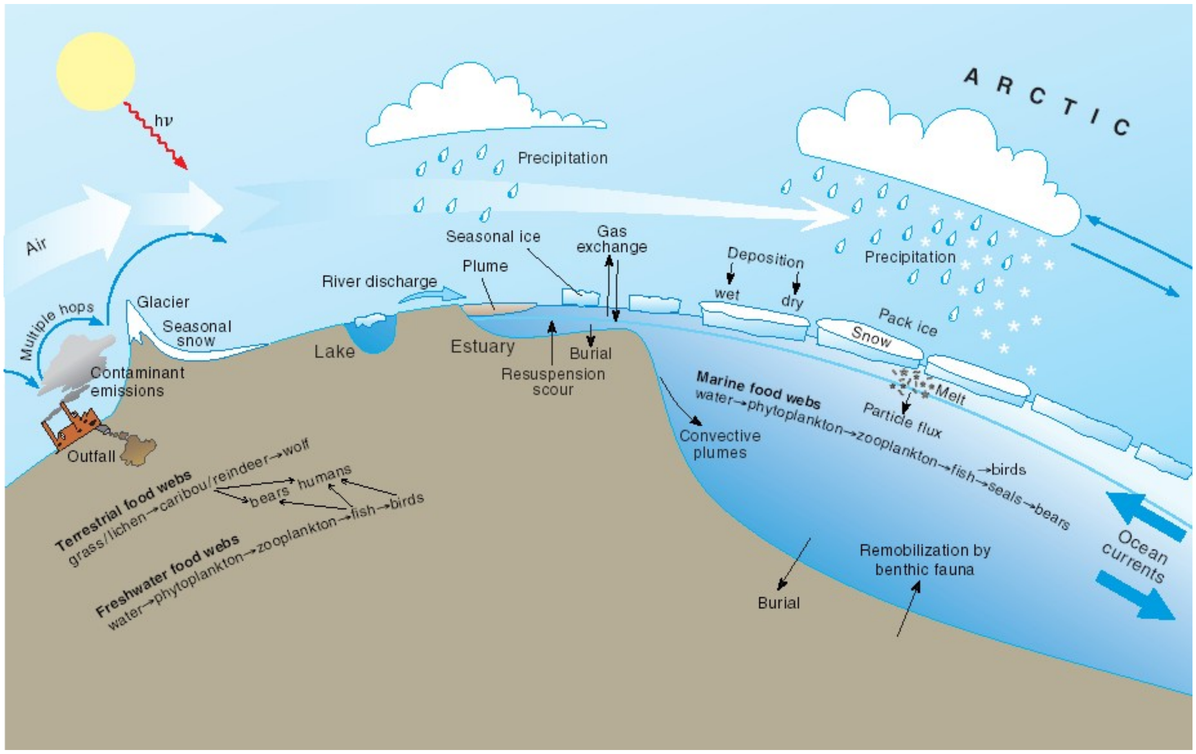
- Organic and Inorganic Contaminants;
- Harvesting;
- Habitat Disruption and Disturbance;
- Species Introduction;
- Climate Change.

3.3.2.1 Contaminants

The term contaminant as used herein encompasses a host of organic and inorganic constituents, some of which occur naturally and others that are the product of human activity. These contaminants may be derived from local sources or originate in far away places. Local sources of contaminants include mine water discharges, sewage treatment plant effluents, forestry industry runoff, petroleum industry releases, surface and subsurface drainage from contaminated sites and other facilities as well as natural sources such as erosion of soils, weathering of exposed mineral veins and releases from forest fires. Many chemicals are also transported globally through atmospheric processes and subsequent deposition (MRBB 2004). The major sources of atmospheric contaminants to the NWT are countries other than Canada (INAC 2003). A simplified schematic of atmospheric transport and deposition processes and pathways of contaminant movement through the Arctic environment is presented on Figure 3.3-2.

Of most concern in recent times has been the effect of climate change on contaminants. The difficulty in understanding change results from the inability to detect trends because data collection is neither long nor comprehensive. Additionally, there is a lack of understanding of the linkages between easily understood changes like ice cover and those of greater complexity like ecological structure and function and the hydrological cycle (Macdonald *et al.* 2003). It is agreed that there will be surprises and that some of the most significant changes are likely to be lurking in the subtle and non-intuitive linkages that exist between global and regional pathways; particularly for contaminants. In this regard, the potential exists for surprising changes to occur in the complex processes of bioaccumulation and biomagnification (Macdonald *et al.* 2003).

FIGURE 3.3-2
SIMPLIFIED PATHWAY OF CONTAMINANT TRANSPORT
IN THE ARCTIC ENVIRONMENT



Source: AMAP 2002.

3.3.2.2 Harvesting

Fishing, whether for commercial, sport or subsistence (traditional) purposes, is an important source of household food and income for residents of the NWT (NWT Biodiversity Team 2004). Fishing is also an activity with important cultural and social connections to the land, particularly for the aboriginal inhabitants of the NWT (NWT RWED 2000). In the past, much of the catch was used as food for dog teams (NWT RWED 2000, MRBB 2004). In general, population numbers, trends and catch rates have only been sporadically investigated for both commercial and sport fisheries (MRBB 2004), except on Great Slave and Great Bear lakes.

While most fish populations and stocks remain healthy because of the low human population density over the landscape, local overexploitation has occurred in some areas. This has resulted in community based management plans that use both traditional and scientific knowledge so that harvesting can be balanced with community needs (NWT RWED 2000). Management plans also aim to sustain stocks so that they can balance competing harvest from subsistence, sport and commercial fishing. However, at least on Great Slave Lake, while the sport fishing pressure has increased, commercial fishing is actually declining (MRBB 2004). Within the NWT, user groups and management boards have been established to make recommendations regarding the harvest of fish species in particular areas. For example, the Great Bear Lake Watershed Working Group and the Great Slave Lake Advisory Committee work to assess fishery activities on the respective lakes and make recommendations to the federal Department of Fisheries and Oceans (DFO) regarding user allocations and allowable catch levels. DFO also develops management plans for some stocks (NWT Biodiversity Team 2004).

The only large-scale commercial fishery in the NWT is the year-round fishery on Great Slave Lake that has been active since the 1940s. This fishery provides primarily whitefish, lake trout (*Salvelinus namaycush)* and northern pike (*Esox lucius)* to the local and U.S. markets at levels that are below the total allowable catch for the lake. Other commercial fishing operations occur in Kakisa Lake and the Mackenzie Delta (NWT Biodiversity Team 2004). Sport fishing lodges and outfitters are located throughout the NWT to service the demand, including that from other parts of Canada and elsewhere.

3.3.2.3 Habitat Disruption and Disturbance

In more southern environments, habitat change and exotic species introductions have caused the most damage to wild native species with subsequent impact on the economy (NWT Biodiversity Team 2004, MRBB 2004). Fish species that already have limited habitat will always be most susceptible to habitat changes (NWT Biodiversity Team 2004).

The Great Bear Lake Watershed Working Group, composed of representatives from the local community and aboriginal groups, a non-government organization and the federal and terrestrial governments, is working with the goal that "Great Bear Lake must be kept clean and bountiful for all time." To this end, the group has developed a management framework and is working on management plans for the lake. On a regional scale, environmental agreements are signed between governments and proponents to set out specific environmental protection responsibilities for specific projects such as that for the diamond industry (NWT Biodiversity Team 2004).

Factors that contribute to habitat disruption and disturbance include natural and semi-natural events. Natural events may include increased wave action on lakes, which would increase the potential for significant shoreline erosion and sediment release into the water column. Semi-natural events include factors such as climate change, which is likely to result in changes in ice thickness, snowfall cover depth, permafrost conditions and river and lake water levels. In addition, anthropogenic factors that contribute to land use changes include mining and hydroelectric developments, land clearing and so on. In mining where earth works are built in water bodies to contain tailings (i.e., the gangue material left after removal of valued minerals) or other mining activities alter water bodies, fish compensation plans are implemented with the objective of achieving no-net loss of fish habitat.

3.3.2.4 Species Introduction

Species introduction may prove to be one of the most damaging stressors to native species and communities. The scientific communities' ability to estimate the risk that exotic species pose to freshwater systems is hampered by the lack of knowledge of the damage that they may have on the northern ecosystem (NWT Biodiversity Team 2004). As such, governments and stakeholders must work together closely in order to assess the risks versus the benefits of such actions.

Current Canadian legislation provides a list of species that must be prevented from entering Canada. However, this style of reactive legislation requires prior knowledge of the species entry as well as potential for damage to the receiving ecosystem. The *NWT Wildlife Act* provides some measure of protection against species introduction by requiring that the importation of wildlife first be permitted. With respect to the NWT freshwater systems, legal introduction of fish has included rainbow trout (*Oncorhynchus mykiss)* and brook trout (*Salvelinus fontinalis)*. However, this type of introduction is no longer permitted (NWT Biodiversity Team 2004).

While new vertebrate populations are often detected soon after introduction, detection of alien invertebrates or smaller life forms is difficult. Lack of information in the NWT on freshwater systems is an issue (NWT Biodiversity Team 2004).

Pathways of introduction include the pet industry, road and ship travel, road maintenance, land clearing, land restoration, farming and importation. However, the NWT does not have an international shipping port, and this eliminates a major means of introducing foreign species. Other tools that can be used to block the importation of foreign species include education, inter-jurisdictional cooperation, monitoring for species and preventative policies and legislation (NWT Biodiversity Team 2004).

3.3.2.5 Climate Change

The NWT hydrological system is particularly sensitive to climate change because of the dominance of frozen water, ice, snow, glaciers and permafrost, in controlling and influencing the water cycle. Changes in temperature and precipitation will ultimately combine to change the hydrological cycle of the NWT (Anisimov and Fitzharris 2001).

Physical changes will occur as a result of climate change, which will affect the warming or cooling across the freezing threshold (Anisimov and Fitzharris 2001). However, physical changes due to warming are still somewhat speculative and effects may offset each other.

An earlier transition from winter to spring and more water storage capacity as permafrost is lost is expected and this is anticipated to result in a more drawn out melt with less intense runoff resulting in less seasonal fluctuation in flow (Anisimov and Fitzharris 2001). It is expected that with warming, more precipitation will be delivered as rain resulting in flattening of the seasonal flow cycle and an increase in winter flow under ice (Anisimov and Fitzharris 2001). A decrease in ice jams may cause problems in perched lakes that rely on seasonal high floods to receive water (Anisimov and Fitzharris 2001). However, warming may also result in a shortened snowmelt that results in flooding followed by drought in the later growing season and this will be reinforced by land use changes including forest harvesting (Gitay *et al.* 2001) and, rivers may also become more prone to ice jams potentially resulting in larger flood peaks (Anisimov and Fitzharris 2001). Finally, it is also expected that evaporation and transpiration will increase and thus likely result in a reduction in the ponded water and runoff (Anisimov and Fitzharris 2001).

Loss of permafrost will allow for water exchange between surface water and groundwater that was once blocked by the permafrost layer and this new exchange could lead to drainage of smaller ponds. This same loss of permafrost may also lead to the formation of new wetlands or ponds, even drainage systems through thermokarst development (Anisimov and Fitzharris 2001). Thermokarst results from the melting of permafrost that subsequently collapses forming mounds, pits, troughs and depressions that may fill with water (Gitay *et al*. 2001).

Warming is generally expected to result in shifts in geographic distribution of freshwater biota and the potential to affect the freshwater food chain (Macdonald *et al*. 2003). Climatic warming of 4-10ºC, as predicted by the end of the century, is likely to lead to increases in decomposition, nutrient release and primary production (Gitay *et al*. 2001). Although microbial decomposition will be enhanced with increases in water temperature, species such as Arctic grayling (*Thymallus arcticus)* and trout will not benefit. Similarly, changes in water level will affect any fish that depend on small refugia in the winter or freshwater coastal corridors (Macdonald *et al*. 2003).

Changes in snow and ice cover will result in changes to the light and nutrient availability of freshwater systems (Macdonald *et al.* 2003). Total productivity should increase with an increase in the ice-free season, thinner ice cover and warmer overall water temperatures (Anisimov and Fitzharris 2001). The shortened ice season may result in thinner ice cover allowing for more under-ice productivity from increased solar radiation penetration and less ice jamming (Anisimov and Fitzharris 2001). This may be further enhanced by increases in available organic matter and nutrients that will drain from the more biologically productive terrestrial system and the thawed permafrost layer (Anisimov and Fitzharris 2001, Macdonald *et al*. 2003) and because less ice cover will allow for greater mixing of relatively nutrient rich runoff during freshet (Macdonald *et al*. 2003).

An increase in under-ice productivity due to the decrease in ice thickness will result in an increase in oxygen production and decrease in the potential for winter fish kills. However, the depth of mixing and lower oxygen concentrations that will result from the longer ice-free season may stress coldwater organisms (Anisimov and Fitzharris 2001).

From the human perspective, it will not be the overall change in temperature that will cause the greatest impacts but the change in seasonal timing. The greatest warming has occurred in January and July. Between 1846 and 1995 there was a mean delay of 5.8 days and 6.5 days per century respectively for freeze-up and break-up of ice, implying a 1.2ºC temperature increase per century (Macdonald *et al*. 2003).

In the NWT, longer ice-free seasons are likely to result in increases to shipping, tourism, oil and gas exploration and other industrial activities that bring the potential for associated contamination and the introduction of exotic and pest species and diseases. It is also possible that warmer temperatures will result in increased agriculture, which will bring associated issues such as potential soil erosion, increased water use and pesticide, herbicide and fertilizer use. It is also possible that warmer temperatures will result in demographic shifts such that the population increases resulting in increased demand on the local environment and associated local contaminant release from power use, fuel consumption, and sewage production (Macdonald *et al*. 2003).

3.3.3 Freshwater Environmental (FE) Indicators

Freshwater fishes total 48 species in the NWT, and a good number of them offer a potential for monitoring trends and cumulative impacts on the freshwater environment. Some fish species such as non-anadromous Arctic char, Dolly Varden (*Salvelinus malma),* inconnu (*Stenodus leucichthys),* or the strictly freshwater Arctic grayling, bull trout (*Salvelinus confluentus),* burbot, lake trout, northern pike, walleye and whitefish can be monitored for a variety of stressors. It can be argued that such freshwater "resident" fishes are more appropriate species for monitoring changes in the environment than the "migrating" or anadromous fishes such as the sea-run Arctic char, Dolly Varden or inconnu, which have a more complex life-history period in the sea and therefore incorporate a "marine environment" component into their physiology and growth patterns.

Freshwater "resident" fishes positioned high in the food web are particularly sensitive to environmental changes, accumulation of contaminants, and overexploitation due to localized fishing pressure. The large, exclusively freshwater fishes are an important source of fish food to humans year round and are prized sport fish.

The report prepared for the NWT CIMP and Audit Working Group by INAC (2004) entitled "*A Preliminary State of Knowledge of Valued Components*" identified Fish Habitat, Fish Population, Fish Harvest, and Fish Quality as Valued Components (VCs). The report also identified several potential indicators that could be utilized to measure changes and trends over time due to environmental stresses. Table 3.3-1 lists those indicators that are believed to be potentially most useful and the rationale for their selection.

Table 3.3-2 provides a qualitative overview of the availability of data to define baseline conditions. To date, the data collected is limited to fish habitat, harvest, and management issues (including contaminant levels in fish) that are of importance to humans. Such information is available for Great Slave Lake and Great Bear Lake, and some inland lakes in the upper Mackenzie River system and northern Mackenzie River. However, as such data are not available on a representative number of waterbodies, from small creeks to large lakes, and on several sub-watersheds throughout the NWT, it is not feasible to establish baseline conditions, evaluate the status of the fish Valued Components (VCs), assess cumulative impacts other than in general terms, or analyze data for trends, except on harvest tonnages on a local and regional basis.

TABLE 3.3-1
POTENTIAL FRESHWATER ENVIRONMENTAL QUALITY INDICATORS AND RATIONALE FOR SELECTION

VC	Indicators	Rationale
Fish Habitat, Population and Harvest		
Fish Habitat	• Aquatic habitat structure and quality • Spawning, rearing and over-wintering locations	• Key determinant of Arctic freshwater processes at all ecosystem levels • Sensitive to climate change, incl. wetlands and lakes drained, increased erosion/siltation and increased landslides frequency associated with melting permafrost; measurable over NWT by satellite • Duration of waters and extent of ice cover; measurable over NWT by satellite • Important determinant of harvesting, transportation, and development activities
Fish Population	• Distribution and abundance	• Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by birds and mammals • Widely distributed over the landscape • Vulnerable to environmental changes and fish species invasions

TABLE 3.3-1 (Cont'd)
POTENTIAL FRESHWATER ENVIRONMENTAL QUALITY INDICATORS AND RATIONALE FOR SELECTION

VC	Indicators	Rationale
Fish Habitat, Population and Harvest		
Fish Harvest	• Population size and age/size distribution of fish stocks • Fish condition (including maturity and fecundity)	• Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by humans • Widely distributed over the landscape • Important traditional food source for residents and supports economically important commercial and sport fisheries • Vulnerable to over-exploitation • Population dynamics and fish condition monitored • Vulnerable to environmental changes and fish species invasions
Fish Quality		
Fish Quality	• Contaminant levels • Diseases and parasites	• Low to mid-level consumer, eats invertebrates and smaller fish and is eaten by birds, mammals, and humans • Widely distributed over the landscape • Important traditional food source for residents and supports economically important commercial and sport fisheries • Contaminant levels, and diseases and parasites monitored

TABLE 3.3-2
QUALITATIVE ASSESSMENT OF THE AVAILABILITY OF DATA TO DEFINE BASELINE CONDITIONS IN THE NWT

Valued Component		Data Available			
		Poor	Moderate	Fair	Excellent
Fish Presence:	Habitat	√			
	Population	√			
	Harvest		√	√	√
Fish Quality:	Contaminant levels			√	
	Diseases & Parasites	√			

Note: For Great Slave and Great Bear lakes, data available are from fair to excellent.

3.3.3.1 FE Indicator – Fish Habitat

The NWT offers a diversity of aquatic habitats that support a variety of aquatic flora and fauna. The habitats include headwater streams originating high in the mountains on the western flank, numerous small and large rivers (including the Mackenzie River), numerous small lakes, two very large water bodies (Great Bear and Great Slave lakes), extensive wetlands and deltas (including the Mackenzie Delta) and finally the Beaufort Sea. Each of these habitats supports many species that rely on the aquatic environment. The status of these ecosystems and habitats may be affected by a range of factors including changes in land use, industrial developments, construction of pipeline and transportation corridors, long-range transport of contaminants and climate change.

i) What is being measured?

Habitat investigations in the NWT have generally been restricted to project or site specific endeavours including:

- Habitats assessments completed when housing, residential/commercial, transportation, mining, gas pipeline or industrial developments are being proposed.
- Habitat data compiled along with fish stock and harvest evaluations for Great Slave and Great Bear lakes and their tributaries.

Detailed descriptions on aspects relating to fish spawning, rearing, and overwintering areas are not generally available, unless there is a good reason to obtain it. Such information often relies first on local knowledge, then is substantiated with radio-telemetry data of adults, trap netting, examination and release of adults, and the collection of eggs and the capture of fish larvae and/or young-of-the-year on spawning and nursery areas. A second approach adopted by governments has been to define local potential spawning areas of fishes, along with some data indicating the relevance of these areas for fishes. Investigational work is needed to compile and review this material.

Climate change studies such as the Mackenzie GEWEX Study (MAGS 2005) relate to fish habitat by monitoring and developing an understanding of how climate variability and change affect the atmosphere and hydrological system of the Mackenzie River Basin.

In the Liard River system, a downward trend in annual stream flow has been observed from 1960 to 1995. The Liard mountain areas are prone to landslides due to heavy summer precipitation, melting permafrost, and deforestation (MRBB 2004). Changes in stream flow and landslides can have major effects on fish and fish habitat. In the Peel River, annual maximum stream flow measured at Canyon Creek has decreased, and much of the watershed has been warmer than usual in recent years (MRBB 2004). As a result, changes in river channels and plant succession would ultimately affect invertebrates and fish. In the Great Slave basin from 1964, peak spring freshet flows have occurred two days earlier per decade on the Hay River. In addition since 1953, the annual Slave River peak flow has occurred on average six days earlier per decade (MRBB 2004). Fish migration, spawning and other key activities, often timed around peak discharge rates, may be initiated earlier, with consequences that are unknown at this time. In the Mackenzie-Great Bear basin, flow has varied greatly from year-to-year and thus no consistent trends have been observed.

ii) What is happening?

Climate change is expected to directly and indirectly affect fish habitat and its biodiversity. These effects will be gradually induced as a result of physical and chemical changes. Increasing water temperature and precipitation, thawing of permafrost, reductions in durations and thickness of lake and river ice, increases in water infiltration in soils, changes in the timing and intensity of runoff, and increases in the amounts of contaminants, nutrients, and sediments are all predicted to occur (ACIA 2004).

iii) Why is it happening?

Changes in hydrological conditions due to climate warming are expected to affect freshwater habitats. Consequences of climate warming induced changes to aquatic ecosystems are being observed and documented by the Mackenzie GEWEX Study (MAGS 2005). These changes have yet to be correlated with changes in life-histories and population dynamics in fishes.

iv) What does it mean?

Increases in water temperature, thawing permafrost, ice cover changes on rivers and lakes, and increasing levels of contaminants, are some examples of changes that will affect fish habitat. Less than optimum thermal conditions may significantly reduce the ranges of some arctic freshwater fishes, including broad whitefish (*Coregonus nasus),* Arctic char, and Arctic cisco.

With rising temperature and permafrost thawing, drainage from lakes and rivers into groundwater is expected to occur with the consequence that fish habitat may be eliminated in some areas. On the other hand, collapsing of the earth surface will create depressions where new wetlands and water bodies may develop and add new fish habitat to other areas. Major shifts in the landscape may occur along with fish habitat and fish species.

Changes in the timing of ice break-up will affect water temperatures, dissolved oxygen levels, nutrient supplies, sediment loads, and water levels. A change in any of these physical and chemical attributes has the potential to alter the freshwater species composition. A longer ice-free period may also increase evaporation, and lower water levels, however, this effect may be countered by in increase precipitation. Low flows and flood patterns will modify the sediment loads carried by streams and rivers. All of these environmental changes will be reflected by changes in the species composition of freshwater ecosystems (ACIA 2004).

Climate warming is anticipated to increase the rate of contaminant transfer to the Arctic. An increase in atmospheric moisture and precipitation will increase the levels of mercury and persistent organic pollutants (POPs) that are deposited in NWT. With rising temperature, ice and permafrost will melt, mobilizing contaminants. An increase in contaminant levels in arctic lakes can be expected to translate into higher levels in fish, and episodes of high levels of contaminants in watercourses may have lethal effects on aquatic life (ACIA 2004).

v) What is being done about it?

Fish habitats have been and will continue to be assessed on a need / regular basis at new and proposed project sites. To monitor flow and climate, Environment Canada will continue the Mackenzie GEWEX Study (MAGS 2005), and important supporting data will be generated through this program to understand fish habitat changes.

vi) What are the information gaps?

Aside from fish habitat assessments near residential, transportation, and industrial sites, fish habitat information is not commonly collected in the NWT. Within government agencies with objectives to protect and enhance aquatic ecosystems, there has been no consolidation of programs or data, which would allow for an assessment of parameters as indicators of well-functioning aquatic ecosystems over time. As a result, it is not possible to assess changes in fish habitat status. Information on fish habitats and indicators for Great Slave and Great Bear lakes may require some attention to become readily available, and may need to be augmented. Such information for the whole of NWT would be prohibitive and is not considered a gap in the baseline data.

<u>Fish habitat data (spawning, rearing, and overwintering):</u> Effort should be made to compile this data on various fish habitats for the Great Slave and Great Bear lakes, as it relates to the fish harvest data. This data should reach a level of detail that would be useful for future comparisons.

<u>Monitoring of physical changes to habitat, which might result from natural occurrence as bank slumping or from industrial activity:</u> Archiving of high-resolution satellite images of NWT would allow future comparison of changes in the physical environment that could potentially

affect freshwater habitat. This would be of particular importance in the future if habitat changes due to bank slumping over (major) fish spawning areas are found to occur and affect fish population parameters, such as year-class strength and harvest. Targeted areas for investigations should include Great Slave and Great Bear lakes, and possibly areas such as in the upper Mackenzie River system and the northern Mackenzie River regions.

3.3.3.2 FE Indicator – Fish Population

Within the NWT, 48 fish species, primarily freshwater, inhabit the Mackenzie River system and countless lakes. In general, there is "little" information on these species and their populations or stocks (RWED 2000, CIMP 2005). In particular, fish species other than commercially harvested species have not received much attention, and these account for approximately 36 species of the total of 48 species. For the harvested fish species, data are available on stock status in Great Slave and Great Bear lakes and the upper Mackenzie and northern Mackenzie regions (DFO Science Stock Status Reports), as discussed in a subsequent section.

Fish distribution data along with habitat preferences, physiology and ecology are most useful to study effects from changes in environmental factors and climate on fishes. Such data are generally not reported in the NWT. As well, information on their basic life history patterns is also missing (RWED 2000).

i) What is being measured?

Studies available on the biology of various fish species, populations and stocks include:

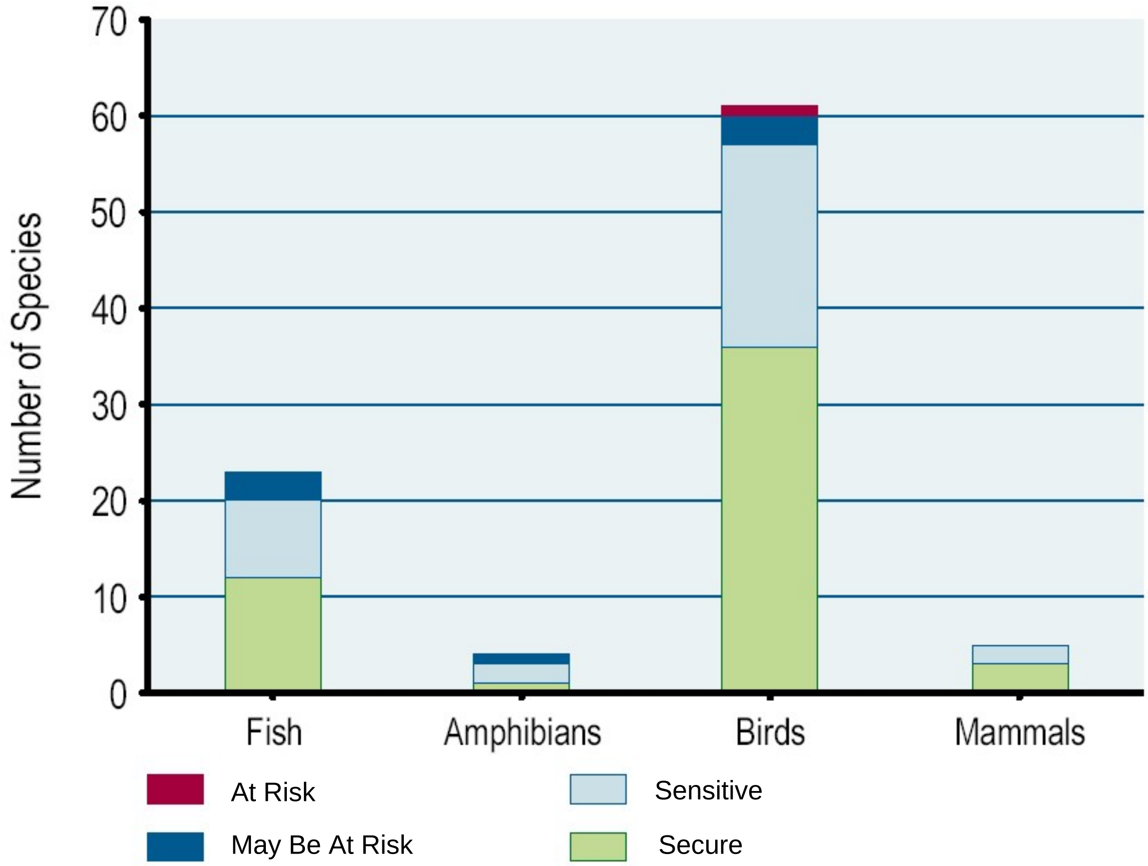
- Some 1970's fish surveys from the Mackenzie Valley Impact Study Reports (DFO 1970-79), which data need to be up-dated;
- The range extension of bull trout in Liard and Mackenzie River basins, with notes on identification and distribution of Dolly Varden in the western Canadian Arctic (Reist et al. 2002);
- The General Status Ranks of Wild Species, which have been assigned to a number of freshwater fish species (RWED 2000). One of four ranks was provided: "at risk", "may be at risk", "sensitive" or "secure". In some fishes, the problem with current status was related to lack of information;
- The stock status in Great Slave and Great Bear lakes on some fish species, and;
- The DFO Science Stock Status Reports on some fish species and stocks, including Mackenzie River Inconnu (DFO 1998), Hornaday River Arctic Char (DFO 1999), Rat River Dolly Varden (DFO 2001), Firth River Dolly Varden (DFO 2002), and Big Fish River Dolly Varden (DFO 2002).

ii) What is happening?

The Department of Fisheries and Oceans fish survey of the 1970s for the Mackenzie Valley Impact Study needs to be up-dated. Little data is available for the non-commercial species. Some information exists on commercial fish populations and their distribution in the NWT, but it needs to be compiled appropriately and augmented. Research on fish taxonomy, communities and assemblages, life history types, population structures, and biogeography of Arctic fishes, including landlocked and anadromous fishes are being lead by Dr. Jim Reist of DFO. This research program is much needed. Fish distribution (and of communities/assemblages) is not documented and is expected to change with climate warming.

Within the NWT, three fish species are listed as “may be at risk”, eight species are considered as “sensitive”, and 12 are assigned the “secure” status (Figure 3.3-3) according to the list of species at risk assessment provided by the NWT Department of Resource Wildlife and Economic Development (RWD 2000) for the Mackenzie River Basin. The short jaw cisco (*Coregonus zenithicus)*, the bull trout and the inconnu of the Upper Mackenzie River and Great Slave Lake are listed as “may be at risk” species due to excessive harvesting.

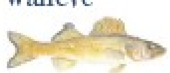
FIGURE 3.3-3
NUMBER OF AQUATIC AND RIPARIAN-DEPENDENT WILDLIFE SPECIES AT RISK IN THE MACKENZIE RIVER BASIN WITHIN NWT



Source: Mackenzie River Basin Board 2004.

The population status of some fish species in Great Slave Lake is summarized in Table 3.3-3. In the 1960s and 1970s, changes occurred in the fish populations and assemblages caused by commercial gillnetting, certainly with some decline in the populations of some species. Lake trout declined dramatically, while inconnu and walleye populations were reduced locally. In recent years, fish stocks in Great Slave Lake are reported as stable (MRBB 2004).

TABLE 3.3-3
STATUS OF MAJOR FISH SPECIES IN GREAT SLAVE LAKE

Species	Population Status
Lake Whitefish 	The lake whitefish population appears to be stable in the western basin of Great Slave Lake, where this species is commercially fished. Fishing at or below the current quota appears to be sustainable.
Lake Trout 	Lake trout accounted for 64% of the catch in 1945, when commercial fishing began, but accounted for only 4% of the catch in the western basin in 1985. Although populations in the west basin have declined dramatically, populations in the East Arm are doing well. However, increasing pressures from recreational fishing in the East Arm may be of concern.
Northern Pike 	Stocks appear to be stable in all areas of the lake, although this assessment is based on inadequate information.
Walleye 	Information about walleye populations is inadequate. While there is concern for Hay River and Little Buffalo River populations harvested for subsistence and sport, no current problems with fish stocks have been reported. The Mosquito Creek population was overexploited from 1973 to 1988, but closing that sport fishery has resulted in a stable population.
Inconnu 	Spawning stocks on the Taltson, Little Buffalo and Hay rivers were extirpated by the 1960's. The Buffalo River stocks were overfished in the late 1970s and early 1980s. Protection has helped but inconnu still needs protection and updated assessment. Stocks on the Slave River and in Great Slave Lake appear to be stable.
Burbot 	There are currently no concerns regarding the burbot stocks.
Sucker 	There are currently no concerns regarding the sucker stocks.

Source: Mackenzie River Basin Board 2004.

In the Mackenzie Great Bear basin, an assessment of stocks for the inconnu in the Mackenzie River, as well as for twelve lakes in each of the Deh Cho and Sahtu areas have recently been completed. This type of assessment, however, is not usually performed on a regular basis.

iii) Why is it happening?

On Great Slave Lake, exploitation has affected fish populations and stocks. Commercial fishing for instance decimated the lake trout stocks in the West Basin of the lake, as the species is unable to withstand intense commercial gillnetting. In contrast, whitefish is more resilient and commercial fishing has not affected their populations to the same degree (MRBB 2004).

iv) What does it mean?

Overall, the NWT ecozones are largely untouched by human activities, and as a result, relatively few species are at risk compared with areas in Canada's south. Great Slave Lake fish are exploited by several types of fisheries activities, which can affect and deplete populations and stocks. It is therefore imperative to manage the fisheries with proper planning and regulations, record and monitor harvests, and assess the stocks (MRBB 2004).

On Great Bear Lake, a quota was placed on the trophy lake trout stock in 1987. Although there have not been any lake trout population studies on Great Bear Lake since 1984, it is believed that the lake trout population is not at risk as annual harvest have been well below the quota (MRBB 2004).

v) What is being done about it?

Overall, DFO performs management and research activities on fish populations and stocks in co-operation with stakeholders. Research by Dr. Jim Reist and colleagues are examples.

The NWT Department of Resources, Wildlife, and Economic Development (RWED) compiles data on the status of fishes, populations and stocks, and uses this information to set conservation objectives. A committee to assess the status of species at risk in NWT is in the planning stage under proposed legislation. New legislation is to be introduced to protect species at risk in NWT.

With respect to Great Slave Lake, the East Arm is managed for a trophy lake trout fishery and some inshore areas are for subsistence fishery. The incomplete fishery information has lead DFO to take a conservative approach in protecting fish stocks. On Great Bear Lake, fish management is carried out through a cooperative arrangement between the various local, regional, territorial and federal parties. A five-year study is underway to assess the lake trout population in Keith Arm (MRBB 2004).

vi) What are the information gaps?

Information on distribution and abundance of fish species (commercial and non-commercial): Fish distribution, communities and assemblages, life history types, population structures for Arctic freshwaters are relatively unknown. This type of data is most important for the study of cumulative impacts and climate warming. Major changes in fish distribution (communities/assemblages) are expected. It has been postulated that some fish species that are currently present in the southern regions of the NWT will disappear and be replaced by other fish species found further to the south that have adapted to warmer water conditions. In this regard, the distribution of commercial and non-commercial fish species should be monitored on the most important water bodies in the NWT.

Data from the fish harvest could be useful to derive population and stocks parameters: These data can be used to derive population parameters relating to: (1) Energy Use; growth and reproductive investment, (2) Survival; age structure and length frequency analysis, and (3) Energy Storage; condition. Fish abundance is measured from fishing effort indices. Sufficient information appears available to derive new data, even assess trends at some local and regional levels within the NWT.

Freshwater fishes that "may be at risk": Freshwater fish species that are listed as "may be at risk" is an example of an area where there is a lack of information that should be resolved. Fish species monitoring is important for a continued awareness of changes to the ecosystem.

Freshwater fish populations and stocks: Population and stock status of most species is relatively unknown and more work is needed on that subject. For instance, on Great Slave Lake, fish stock assessment studies are needed to determine the current status of lake trout as well as other important fish species throughout the lake. In the Mackenzie-Great Bear Sub-basin, broad whitefish and lake whitefish remain the most sought after species for food. However, status on these species, populations and stocks are unknown.

3.3.3.3 FE Indicator – Fish Harvest

Throughout the NWT, fishing is a most important activity whether it is for subsistence, sport or commercial purposes. These different aspects of fishing bring competing demands on the natural aquatic resource and pose a challenge to fisheries managers. Overall, information on subsistence, sport and commercial harvests is diverse making interpretations difficult to apply over the NWT (MRBB 2004).

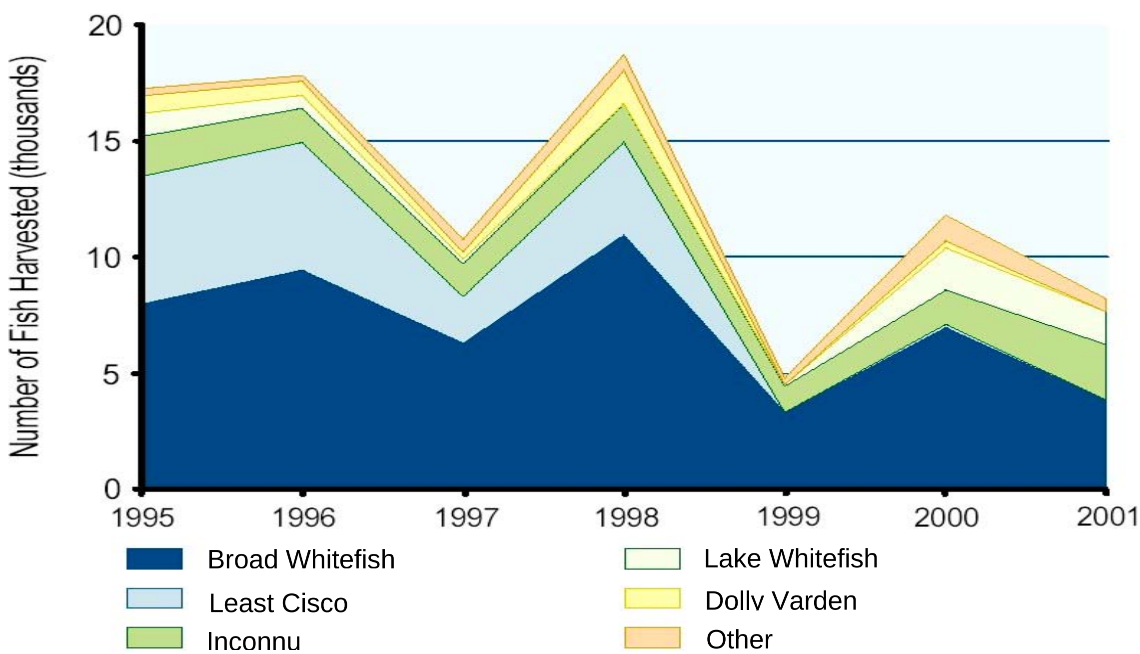
Commercial fisheries harvest whitefish (broad whitefish and lake whitefish, inconnu (coney), lake trout, northern pike, burbot or loche (*Lota lota)*, and walleye (*Stizostedion vitreum)*. While most of the fish populations and stocks remain healthy over the landscape, few populations or stocks have been as overexploited in the past by the localized fishing than Arctic char (*Salvelinus alpinus)*. Today, Arctic char is the subject of community-based management plans designed at sustaining harvest over time in those areas once overexploited (RWED 2000).

i) What is being measured?

From the several harvest studies available, information can be sorted for the Peel Sub-basin, the Great Slave Sub-basin, which includes Great Slave Lake, and the Mackenzie-Great Bear Sub-basin, which includes Great Bear Lake.

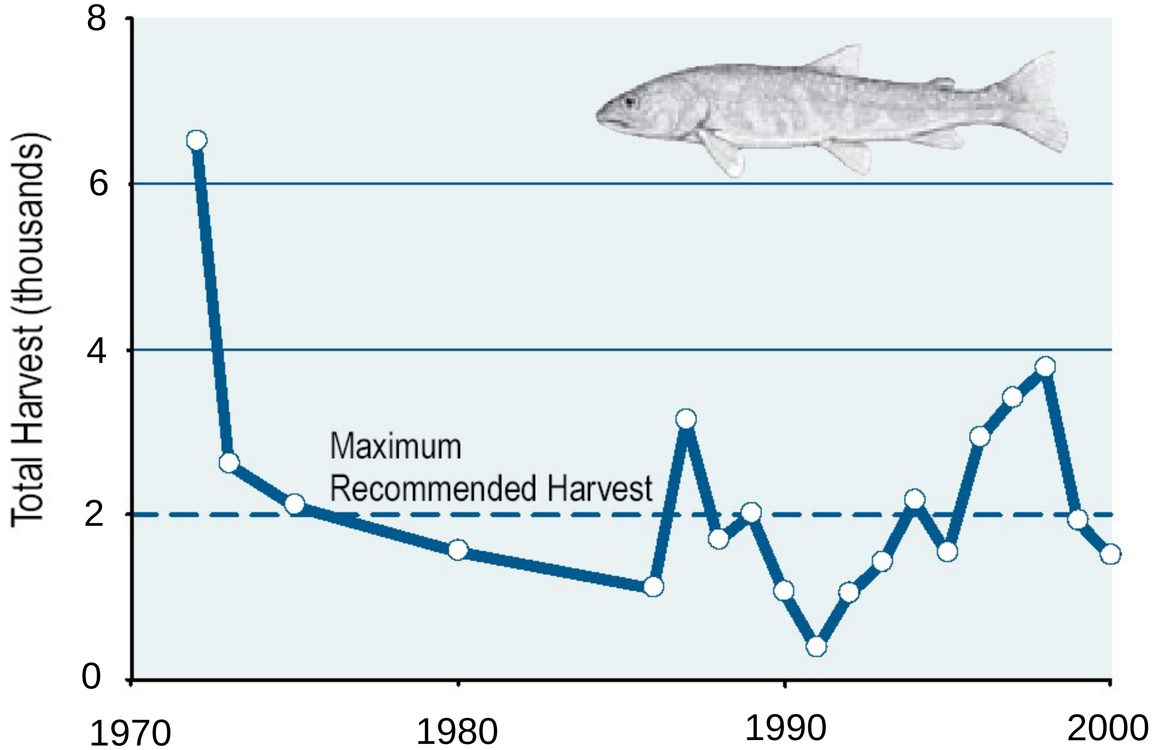
In the Peels Sub-basin at Fort McPherson, the subsistence fishery has been recorded for the Tetlit Gwich'in First Nation (Figure 3.3-4). Several fish species are part of the catch but the most important one was the broad whitefish. The maximum recorded harvest was 18,000 fish in 1998. Furthermore, for the Gwich'in of Aklavik and Fort McPherson, the Rat River (Char) Dolly Varden stock thought of as being over-harvested became a concern and a monitoring program was initiated in 1995. The Dolly Varden stock was estimated in the range of 10,000 to 15,000 fish. At an annual sustainable harvest of 10 to 15%, the recommended DFO maximum harvest was calculated at 2,000 fish annually (Figure3.3-5).

FIGURE 3.3-4
CATCH RECORD AT FORT MCPHERSON, PEEL RIVER BASIN



Source: Mackenzie River Basin Board 2004.

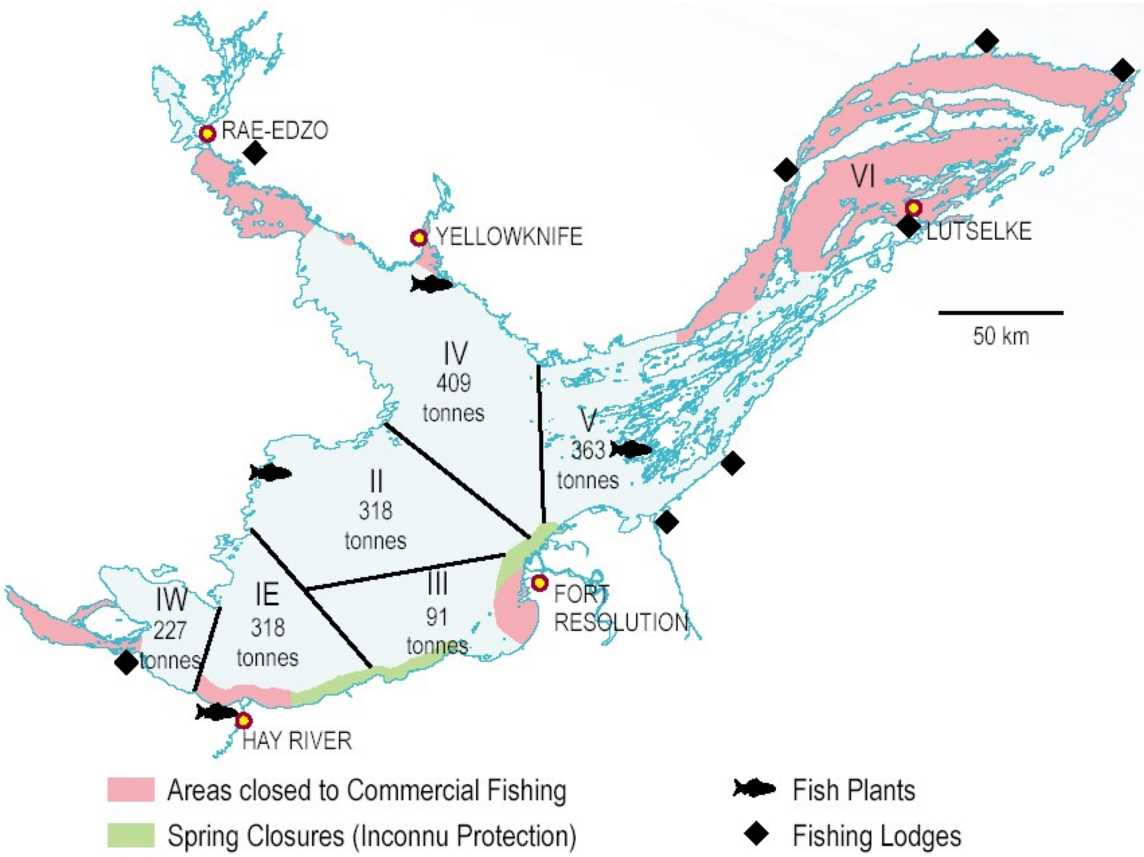
FIGURE 3.3-5
DOLLY VARDEN HARVEST IN THE RAT RIVER



Source: Mackenzie River Basin Board 2004.

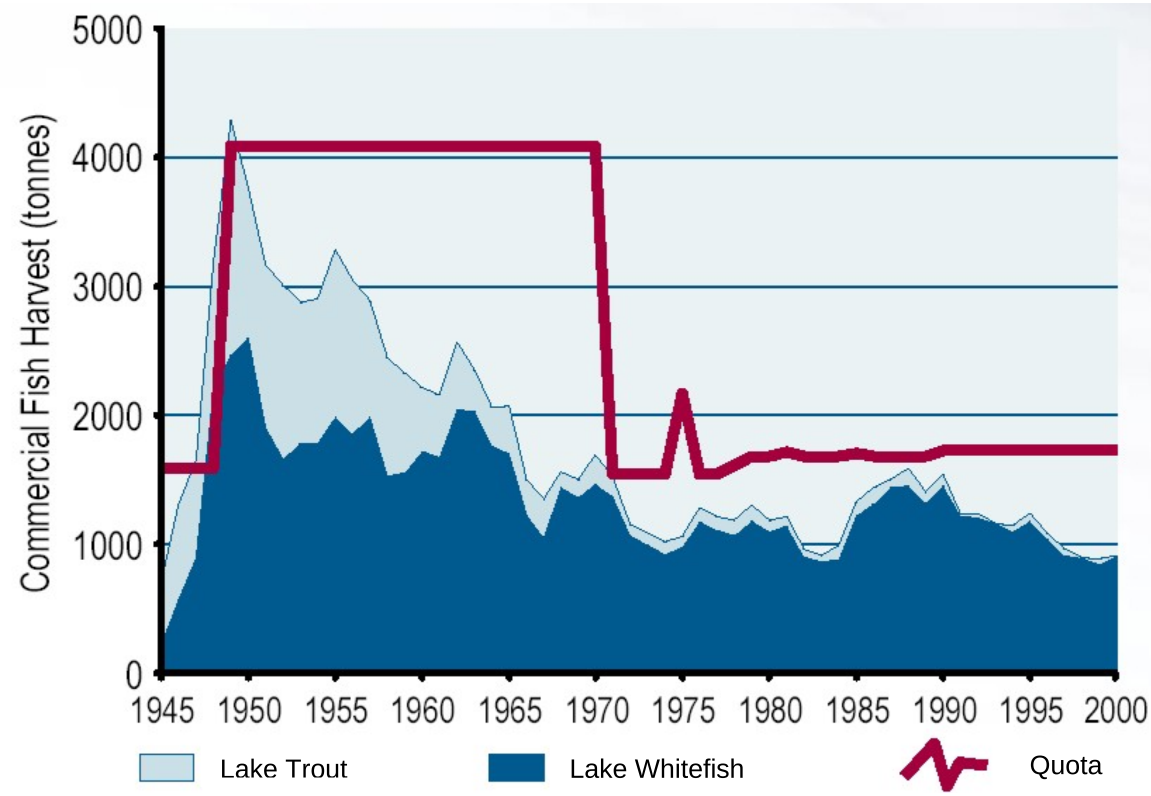
On Great Slave Lake, fisheries management is a matter of achieving a balance between subsistence, sport and commercial fishing versus the sustainability of all fish species and stocks. Great Slave is divided into six management areas (Figure 3.3-6), each with its own fisheries plan. Commercial fishing occurs in the western and central areas, while the East Arm area is managed as a trophy lake trout fishery and some other areas are managed for subsistence fishing. In the western area, the commercial fishery has been primarily targeted at lake whitefish since the collapse of the lake trout stocks in the mid 1960s. Trends over time of the commercial harvests show declines in harvest of both lake trout and lake whitefish (Figure 3.3-7). Lake whitefish represents 68% of the commercial catch in recent years. The trophy lake trout sport fishery has increased in the East Arm. Available surveys from 1986 to 1994 indicate that the sport fishery has nearly doubled during that period.

FIGURE 3.3-6
MAP OF ADMINISTRATIVE FISHING AREAS IN GREAT SLAVE LAKE



Source: Mackenzie River Basin Board 2004.

FIGURE 3.3-7
COMMERCIAL FISHING HARVEST AND QUOTA FROM GREAT SLAVE LAKE, 1945 TO 2000



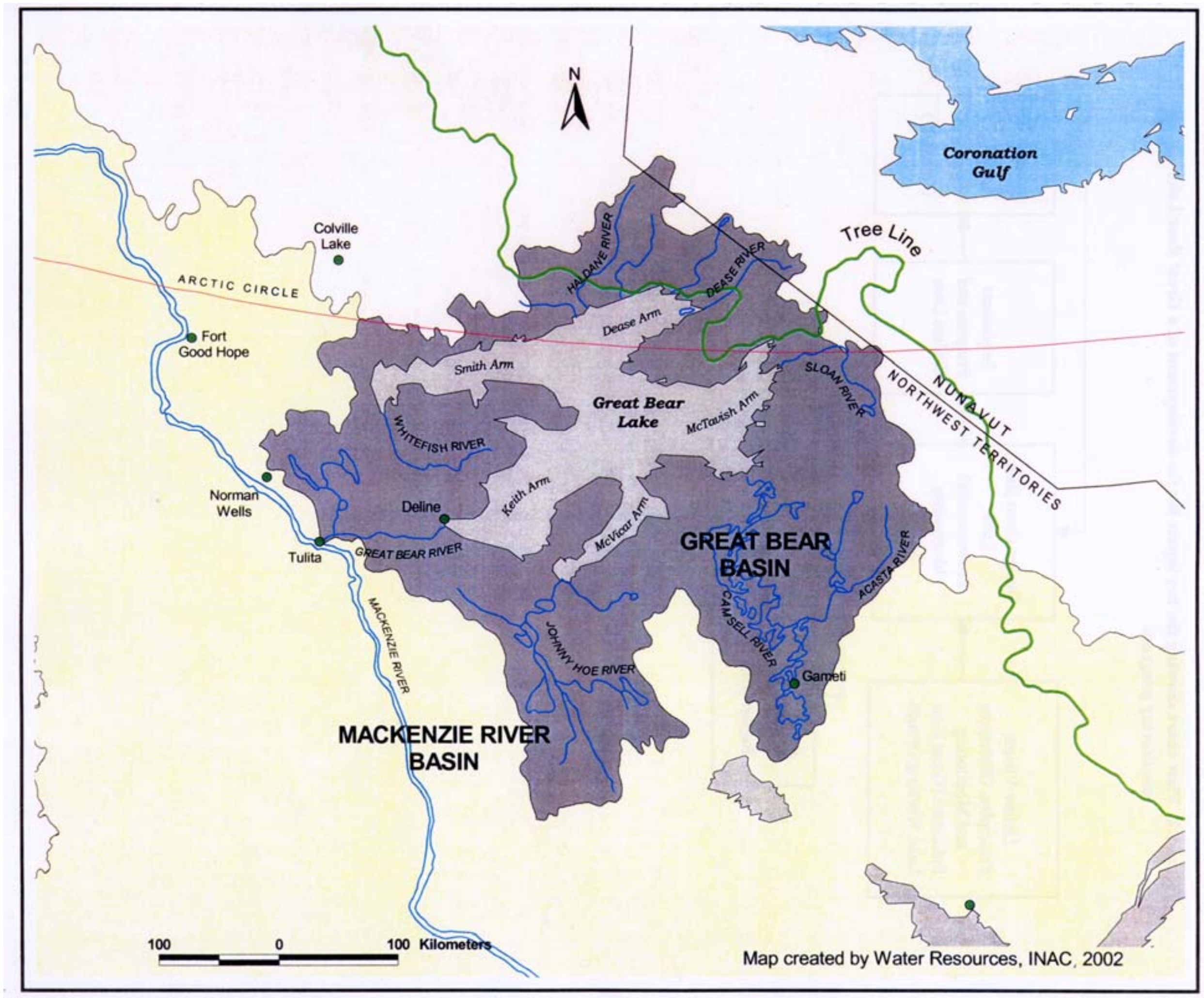
Source: Mackenzie River Basin Board 2004.

In the Mackenzie-Great Bear Sub-basin, subsistence harvests have been monitored since the early 1990s in the Inuvialuit, Sahtu, Gwich'in and Deh Cho areas. First Nations have traditionally harvested inconnu in the Mackenzie River and Delta, and at present levels of harvest, populations are in an excellent state under current habitat protection of the Delta. Recent harvests of broad whitefish in the Delta are also only 5 to 10% of the estimated harvest numbers of the 1950s. Subsistence fisheries occur in the Inuvialuit, Gwich'in, Sahtu and Deh Cho areas. Beginning from the early 1990s, several years of monitoring indicate that broad whitefish and lake whitefish are the two most important species harvested. Inconnu and lake cisco are also important in other communities.

The trophy lake trout fishery on Great Bear Lake is shared between the subsistence and sport fisheries, as well as one commercial fishery. The lake is divided into five lake trout management areas, with one area (Keith Arm) still without a fishery plan. Figure 3.3-8 shows the boundaries of the Great Bear Lake watershed and the five arms comprising the lake. The lake trout harvest from

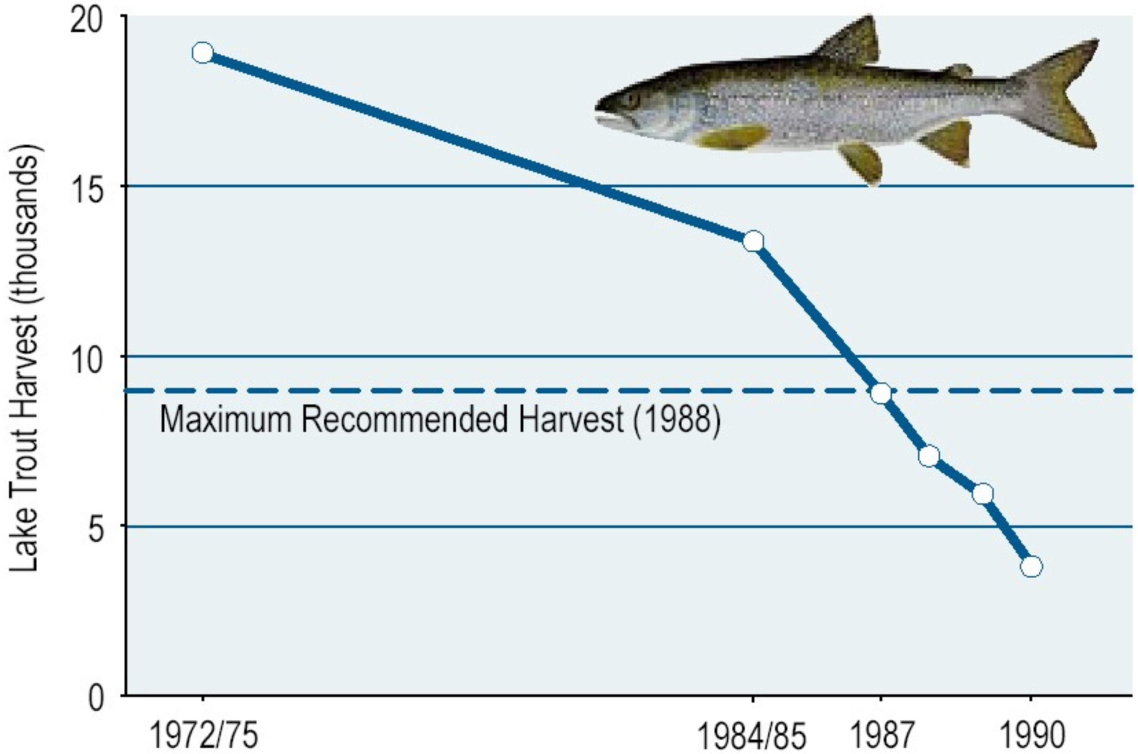
Great Bear Lake declined steadily from the early 1970s to 1990 (Figure 3.3-9) and is believed to be in good shape.

FIGURE 3.3-8
BOUNDARIES OF THE GREAT BEAR LAKE WATERSHED AND THE FIVE ARMS COMPRISING THE LAKE



Source: MacDonald et al. (2004).

FIGURE 3.3-9
LAKE TROUT HARVEST IN GREAT BEAR LAKE, 1972 TO 1990



Source: Mackenzie River Basin Board 2004.

i) What is happening?

In the Peel Sub-basin at Fort McPherson, it is expected that the fish harvest will continue to be recorded due to the importance of the subsistence fishery to the Tetlit Gwich'in First Nation (MRBB 2004). However, for the Gwich'in of Aklavik and Fort McPherson, the Rat River (Char) Dolly Varden stock has not been monitored since 2001.

The largest commercial fishery in the NWT is in the western and central areas of Great Slave Lake. Commercial fishing is not allowed in certain areas important to subsistence fishing, or the East Arm, which is managed for trophy lake trout sport fishery.

Great Bear Lake fishing also includes subsistence, sport and commercial, but the latter is only present in some local areas of the lake. The management goal of Great Bear is to conserve a world-class trophy lake trout fishery. The lake trout stock declined until 1984, when studies demonstrated that conservation measures were warranted and quotas were put in place. The current harvest is considered below the maximum sustainable yield.

ii) Why is it happening?

In the Peel Sub-basin at Fort McPherson, the Tetlit Gwich'in First Nation has traditionally relied on the subsistence fishery. In particular, the Dolly Varden is one of the highly desired species but few populations are found in the region. As a result, over-harvest has occurred in recent years, leading to the 1997 Charr Fishing Plan, where fishers voluntarily reduced their catch by 30% since 1998.

In the Great Slave Sub-basin on Great Slave Lake, the commercial harvest has declined since 1990. This is due to a reduction in fishing effort and number of commercial boats on the lake. As for the sport fishery, it has increased due to a considerable growth in the Yellowknife population, improvements in highways and increased tourism.

The Mackenzie Delta, with Inuvik as the largest community in the Mackenzie-Great Bear Sub-basin, has the most important subsistence and sport fisheries. Subsistence fishing has declined in recent years due to a decrease in the number of dog teams, which were fed fish. The decline in the number of trout harvested from Great Bear Lake is due to a more conservation-oriented sport fishery, including a catch and release policy.

iii) Why is it happening?

The reduced take of commercial, subsistence and sport fish is due in large part to the adoption of fisheries management plans and harvest quotas aimed at preserving the long-term viability of fish stocks in key fishing areas.

iv) What does it mean?

In the Peel Sub-basin at Fort McPherson, fish harvest studies are important in determining the subsistence use of fisheries resources for the Tetlit Gwich'in First Nation. From these studies, sustainability of harvesting fish and potential effects on the aquatic ecosystem can be evaluated. In addition, for the Gwich'in of Aklavik and Fort McPherson, following a voluntary reduction in the catch of the Rat River Dolly Varden stock, it is predicted that it will sustain itself if the harvest is maintained at the 1999-2000 levels.

In the Great Slave Sub-basin on Great Slave Lake, the use of the fisheries resources has the potential to seriously affect populations and stocks of fishes. Therefore, it is important that the fisheries be managed, regulated, recorded and monitored over time, along with fish stocks evaluation when applicable (See Section 3.3.3.2; FE Indicator – Fish Population).

In the Mackenzie-Great Bear Sub-basin, subsistence, sport and commercial fishing are most important, although there has been a decline in subsistence fishing (fish food to dog teams). Broad whitefish and lake whitefish remains the most sought after species for food. However, harvest status on these species, as well as the status on populations and stocks is unknown. In Great Bear Lake, earlier studies showed that the lake trout population had declined until 1984. To maintain a trophy fishery, quotas were assigned for each management area of the lake in 1987, for a grand total of 9,000 fish. Since then, and currently, the lake trout harvest has been much lower than the maximum sustainable yield.

v) What is being done about it?

In the Peel Sub-basin at Fort McPherson, the Gwich'in Renewable Resources Board continues its fish harvest studies. For the Gwich'in of Aklavik and Fort McPherson, the Rat River Dolly Varden stock is managed through co-operative arrangements between Renewable Resources Boards, Renewable Resource Committees in each of the communities, and DFO. Allowable harvests, licensing of sport and commercial fishing as well as fish stocks studies are decided by these agencies.

In the Great Slave Sub-basin on Great Slave Lake, DFO is responsible for the fisheries management as well as the fish stocks assessment. However, the Great Slave Lake Advisory Committee makes recommendations to DFO on matters of fisheries management. DFO restricts the commercial fishery with quotas, minimum gillnets mesh sizes and limiting number of commercial operators. Regarding lake trout sport fishing, DFO is conservative in its approach with daily catch and possession limits lowered to one and two fish respectively, and mandatory use of barbless hooks since 2004, along with live release practices.

In the Lower Mackenzie River and Delta, a fishery plan has been completed for inconnu. For that same area, a stock status report and management plan for lake whitefish and broad whitefish has been completed as well. In the Mackenzie-Great Bear Sub-basin, management of the fisheries is based on cooperative programs between Renewable Resources Boards, Renewable Resources Committees, and NWT Department of Resources, Wildlife and Economic Development, which make recommendations to DFO. For Great Bear Lake, a lake trout study is underway in Keith Arm and a fishery plan is under development.

vi) What are the information gaps?

Subsistence, sport and commercial fisheries:

- In the Liard Sub-basin of the NWT, the First Nation's subsistence fishery is not monitored (MRBB 2004).
- On Great Slave and Great Bear lakes fishing pressures have the potential to affect, even disrupt fish populations. It is imperative that the fisheries are looked at closely and managed to ensure sustainability of stocks overtime. Detailed information is required about fish populations and stocks in order to achieve a corresponding good level of fisheries management. On Great Slave Lake, additional information is needed on the subsistence and sport fisheries to complete the understanding of the fisheries resources. Current harvest data for subsistence fisheries are available for Fort Resolution and Fort Smith only.
- In the Mackenzie-Great Bear Sub-basin, subsistence, sport and commercial fishing are most important. Broad whitefish and lake whitefish remains the most important catch. Harvest status on these species is unknown and needed.

3.3.3.4 FE Indicator - Fish Quality

Fish such as lake trout, northern pike, walleye, burbot, whitefish and inconnu are increasingly subject to degradation in quality because of contaminants, as well as diseases and parasites. Numerous contaminants have been studied, and since fish play an important part in traditional diets for NWT inhabitants, contaminant levels occurring in fish flesh have been of particular concern. There are three basic classes of contaminants that are generally considered to be of concern; heavy metals, POPs and radionuclides.

Heavy metals that have been found at elevated levels in fish include mercury, cadmium, lead, arsenic, copper, selenium and zinc. POPs that have been found in fish include polycyclic aromatic hydrocarbons (PAHs), chlorinated phenolics, hexachloro-benzene (HCB), hexachloro-cyclohexane (HCH), dichloro-diphenyl-trichloroethane (DDT), polychloro-biphenyls (PCBs), chlordane, toxaphene (chloro-bornanes), dioxins and furans and dieldrin. Of the three classes, radionuclides have received the least attention.

The presence or absence of diseases and parasites is a more visual clue for fish quality. Diseases and parasites are often identifiable at a glance either externally or internally upon cleaning. However, easy identification does not necessarily translate into recognition of changes in fish quality either spatially or temporally.

i) What is being measured?

Availability of baseline fish quality data varies by watershed, lake or river and fish species. Although fair amounts of sporadic information exist on specific fish species in certain water bodies, there is a general lack of long-term, comprehensive monitoring (CIMP 2005).

Longer-term monitoring of contaminants in freshwater fish has been conducted at Fort Good Hope, Great Slave Lake and Slave River. Current data collection includes:

- Burbot for heavy metal and POPs contaminants at Fort Good Hope by DFO since 1999.
- Burbot, and late trout for heavy metal and POPs contaminants as well as early warning for new contaminants from Great Slave Lake (West Basin and East Arm) by Environment Canada, and DFO since 1999. Some similar information has been collected since the 1970s.
- Burbot for heavy metal and POP contaminants from Slave River by Environment Canada and DFO since 1999. Similar information was also collected from 1993 to 1995.
- Lake trout for metals and POPs in Great Bear Lake by DFO.
- Lake trout or whitefish in 10 other lakes every five years.

Heavy Metal:. *Levels of mercury have been measured since the early 1970s. However, these samples have been limited to commercially important species as well as a range of sizes. More recently, the focus has been on capturing a broader range of sizes from fewer locations. However, the overall data is still largely from fish that are of commercial or traditional interest (INAC 2003). Current data collection includes*:

- Mercury, selenium and arsenic in western NWT by DFO and Environment Canada since 1996.

- Mercury information was collected from the Sahtu and Deh Cho regions from 1996 to 2000.

- Mercury in predatory fish in lakes of the Fort Simpson area by Environment Canada and DFO since 1998. Previous research for some lakes (Cli Lake, Little Doctor Lake, Willow Lake, Sibbeston Lake and Tsetso Lake) is available.

- Metals in whitefish, northern pike, walleye and lake trout from Lac Ste. Therese by DFO.

Persistent Organic Pollutants: *Aside from previously mentioned studies, no other studies that focus on POPs in the NWT were identified.*
Radionuclides: *Studies specifically designed to measure radionuclides in the NWT were not identified.*

Observation of diseases and parasites in fish are not regularly monitored in the NWT. Information that has been collected is by traditional knowledge and not using any particular methodology (CIMP 2005). A community-based monitoring survey conducted by the Arctic Borderlands Ecological Knowledge Co-op in the communities of the lower Mackenzie River basin is active. Annual surveys are conducted to record resource users including fish for quantity and quality by species and location.

ii) What is happening?

The fish contaminant, disease and parasite information that has been collected thus far in the NWT has provided a base of information on which to build. However, the Mackenzie basin has undergone exceptional warming since the 1960's. Although this has not been clearly characterized in the complex hydrology of the Mackenzie River, any change related to atmospheric contaminant pathways due to global warming is likely from the North Pacific (influences alternate between Pacific and Eurasian air masses; AMAP 2002).

Although a comprehensive study has not been completed, there exists large spatial variation in contaminant concentrations in predatory fish within the NWT (INAC 2003). A five-year study on the Slave River (1990-1995) showed low levels of liver enzyme inductions indicating that the environment was relatively pristine (Sanderson et al. 1998). It is of note that fish have a limited ability to degrade contaminants like POPs, as they are excreted very slowly.

Heavy Metals: *Most data produced with respect to heavy metal contamination in fish is on mercury because of human consumption concerns. However, studies have looked at arsenic, cadmium, lead and selenium although levels for these parameters are rarely of concern (INAC 2003).*

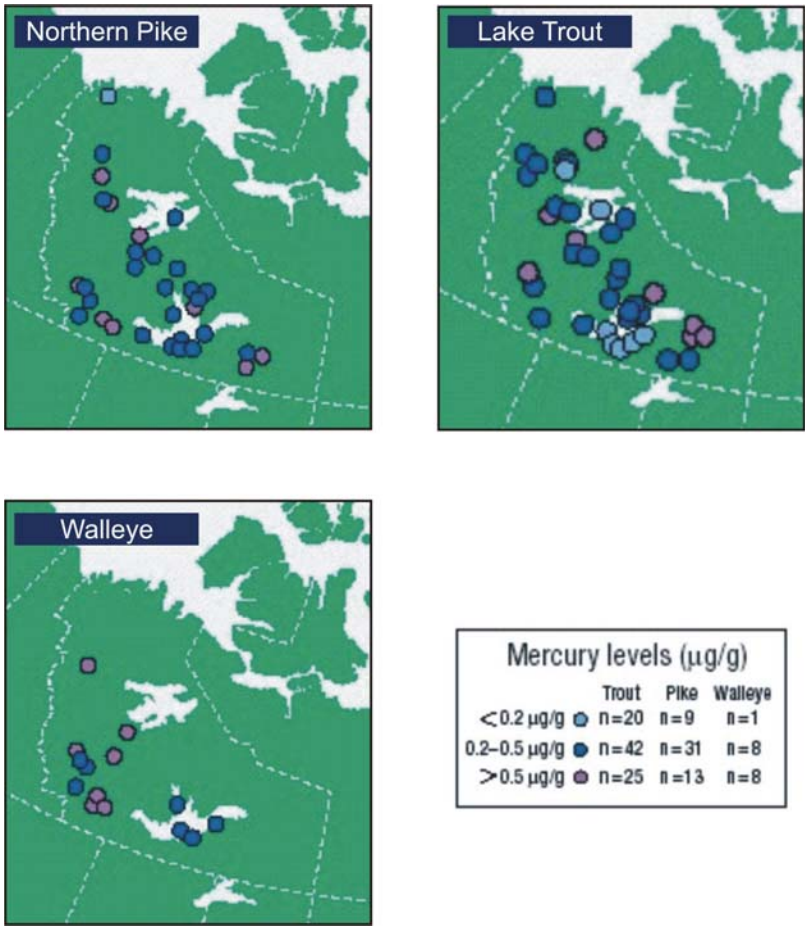
Health advisories for mercury have been issued for some fish species, including northern pike, lake trout, burbot, whitefish and suckers, in several NWT lakes (INAC 2005). Some of these lakes may have naturally high mercury levels (MRBB 2004, INAC 2005), while others are the result of anthropogenic sources. An example of the latter situation is the ban that was put in place in 1978 on consumption of fish from Giauque Lake, which was impacted by mercury leaching from tailings at Discovery Mine (MRBB 2004).

Fish exposed to high mercury levels suffer damage to gills, sense of smell, blindness and a decreased ability to absorb nutrients through the intestine (AMAP 2002). Grayling embryos exposed to mercury may have decreased growth and decreased ability to capture prey later in life thereby decreasing their ecological fitness. Similar results were observed for juvenile walleye (AMAP 2002). Cadmium exposure can interfere with calcium metabolism. In lake trout, poorer foraging behaviour was displayed, along with a decrease in prey capture success, as well as a decrease in thyroid function after exposure (AMAP 2002).

Mercury is the only contaminant that is consistently greater than guideline limits for consumption (<0.2 µg/g (wet weight) by people who eat large amounts of fish) or commercial sale (<0.5 µg/g (wet weight)) (INAC 2003). Evans *et al*. (2003) report that between 88 and 91% of lakes surveyed in the Mackenzie River Basin have mean mercury levels in predatory fish above the 0.2 µg/g guideline and some 25 to 45% have mean mercury levels above the 0.5 µg/g. Figure 3.3-10 presents mercury concentrations for northern pike, walleye and lake trout found in the NWT.

A survey of lakes in the Deh Cho and Sahtu settlement regions found mercury levels between the 0.2 and 0.5 µg/g guideline values in 60% of lake trout lakes, 50% of northern pike lakes and 42% of walleye lakes (Evans *et al*. 2003). Another 27% of lake trout lakes, 38% of northern pike lakes and 40% of walleye lakes had mercury levels above the 0.5 µg/g guideline. Evans *et al*. 2003 report that consumption advisories have been issued on 16 of 29 lakes in these regions.

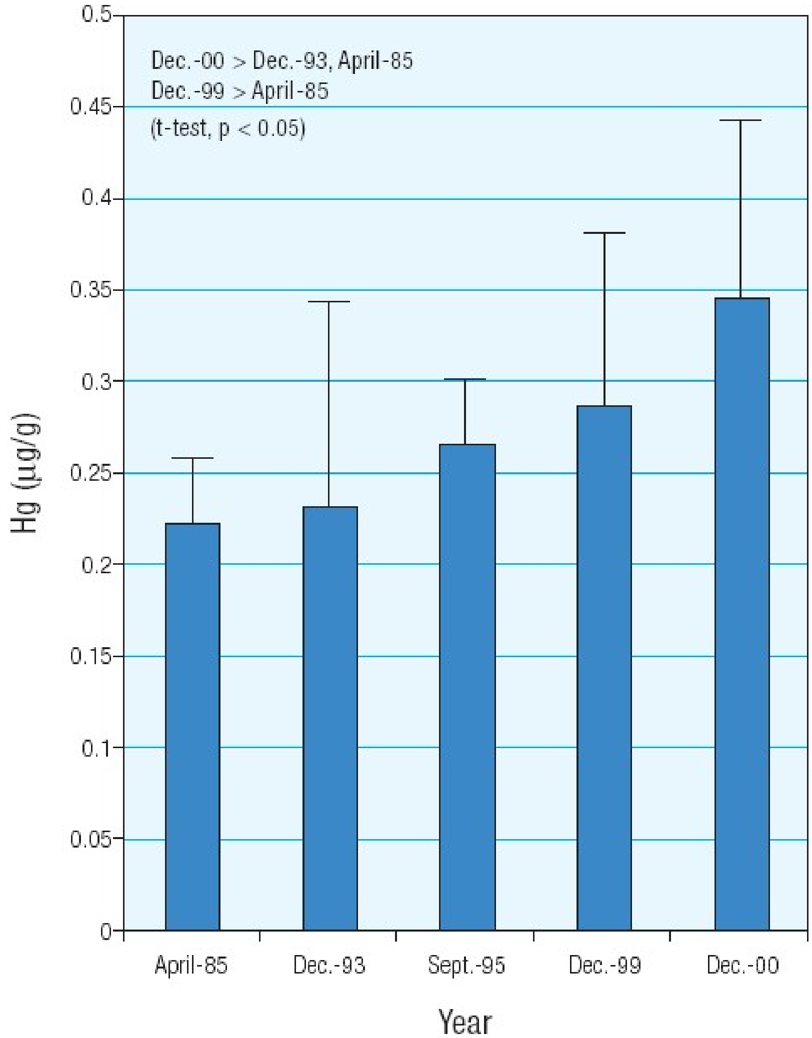
FIGURE 3.3-10
MERCURY CONCENTRATION IN NORTHERN PIKE, LAKE TROUT AND WALLEYE IN NWT LAKES



Source: INAC 2003.

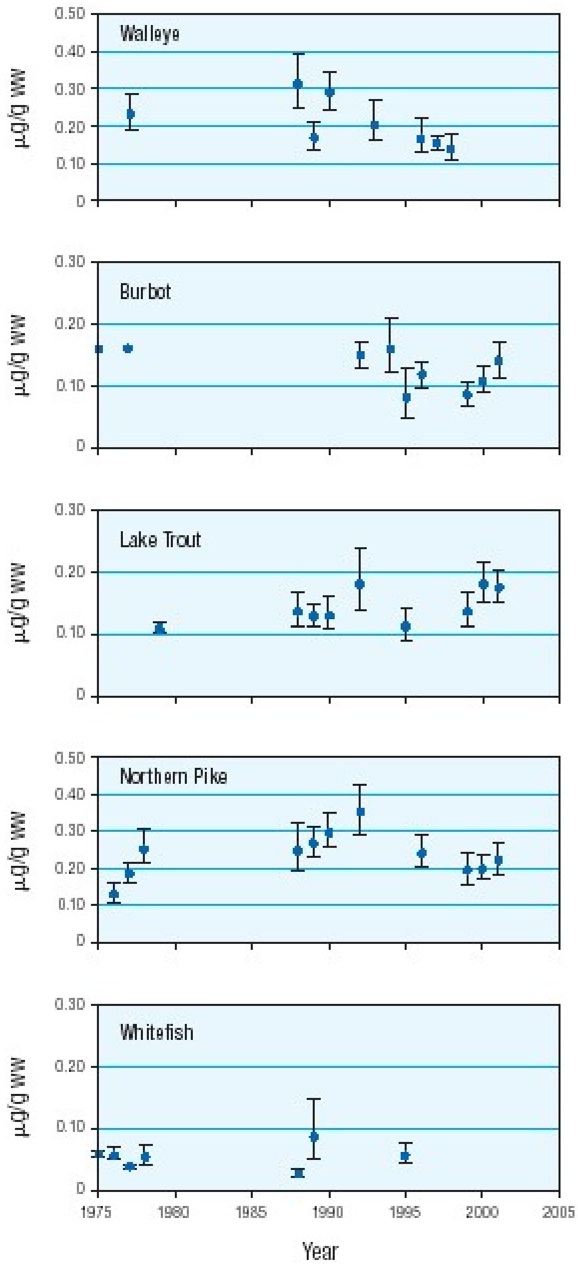
Figure 3.3-11 shows mercury concentrations in burbot livers from Fort Good Hope between 1985 and 2000 (AMAP 2002). The figure shows an overall increase of approximately 36% in mercury concentrations over the fifteen year time period. Similarly, Figure 3.3-12 presents temporal trends of mercury concentrations in walleye, burbot, lake trout, northern pike and whitefish from Great Slave Lake from the 1970s to 2001.

FIGURE 3.3-11
MERCURY CONCENTRATION IN BURBOT LIVER OVER TIME AT FORT GOOD HOPE, NWT



Source: INAC 2003.

FIGURE 3.3-12
MERCURY CONCENTRATIONS IN FISH MUSCLE
(GEOMETRIC MEANS ± 95% CONFIDENCE LIMITS)
FROM GREAT SLAVE LAKE

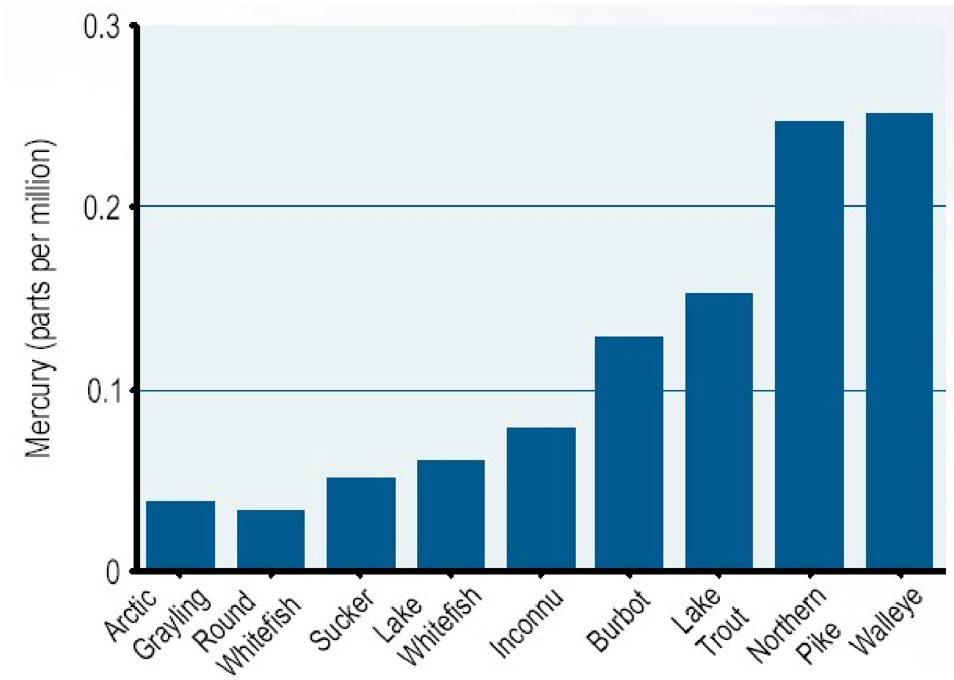


Source: INAC 2003.

Frequently, predatory fish like walleye, northern pike and lake trout have higher mercury levels because concentrations biomagnify through the food chain versus fish species that feed lower in the food chain such as lake whitefish, which mainly feed on zooplankton and benthos (AMAP

2002, INAC 2003). Figure 3.3-13 clearly shows biomagnification up the food chain in species from Great Slave Lake.

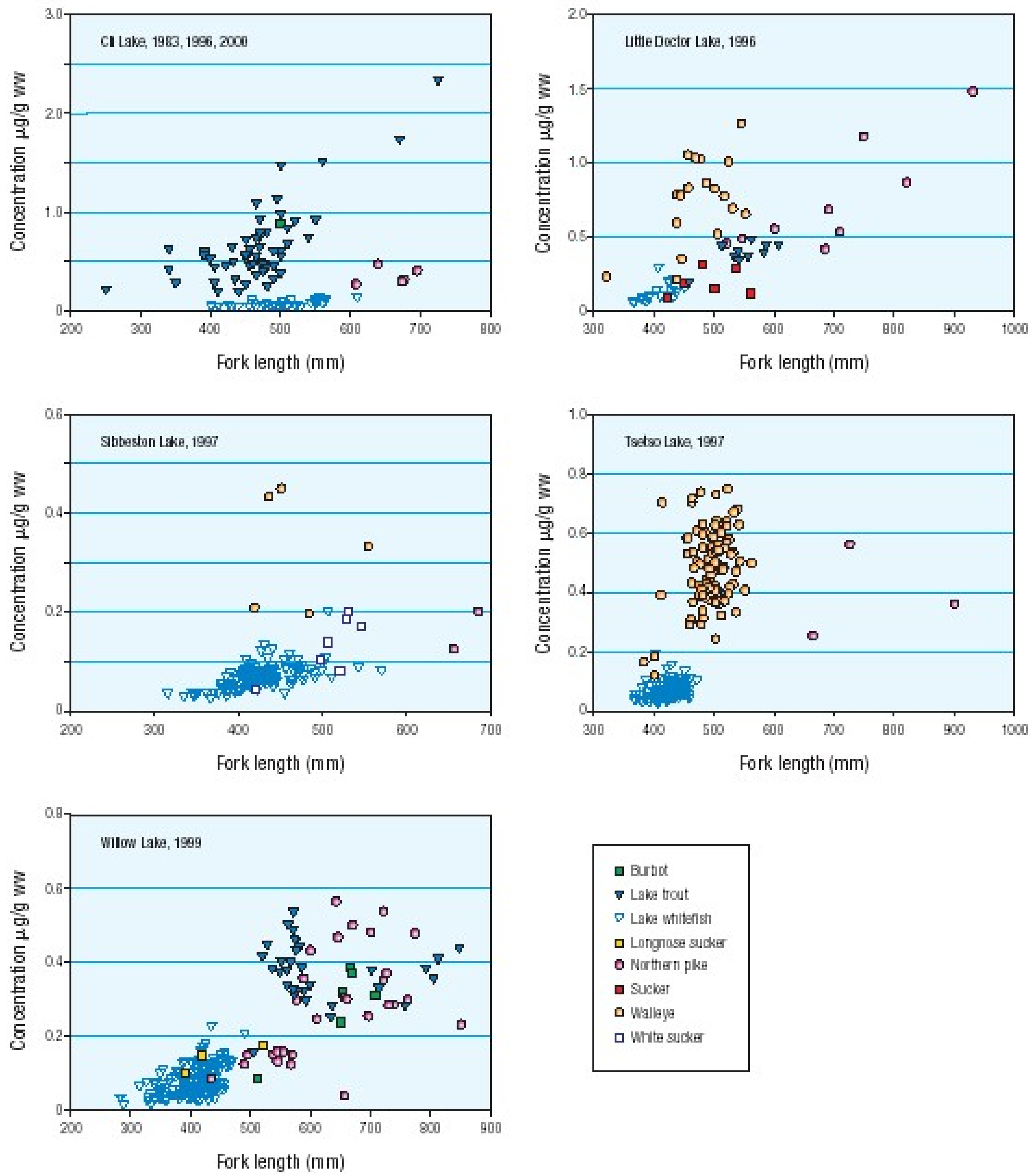
FIGURE 3.3-13
BIOMAGNIFICATION OF MERCURY IN PREDATORY FISH IN GREAT SLAVE LAKE



Source: Mackenzie River Basin Board 2003.

As a rule, high mercury levels are found to be associated with larger and older predatory fish, often more than 10 years in age. Figure 3.3-14 presents the relationship between mercury concentration and fish fork length from five lakes in the NWT.

FIGURE 3.3-14
MERCURY CONCENTRATION VERSUS FISH FORK LENGTH



Source:INAC 2003.

Different fish species and tissues within species contain varying heavy metal concentrations. For example, arsenic and cadmium concentrations tend to be higher in liver tissue versus muscle. At the species level, cisco had the highest arsenic concentrations whereas the highest cadmium concentrations were found in walleye liver (INAC 2003).

Water chemistry parameters, such as the humic content, and dissolved oxygen may also play a role in the uptake of mercury. Mercury in the water phase is bioavailable and is greater in streams with higher humic levels (INAC 2003).

One potential effect of global warming is an increase in water temperature, which would result in an increase in fish metabolic rates and therefore an increase in the volume of water passing across the gills. A consequence of such an increase in the metabolic rate would be an increase in the uptake of metals. This may be exacerbated by an increase in the bioavailability of mercury with an increase in water temperature (MRBB 2004).

<u>Persistent Organic Pollutants</u>: The same human health driver does not exist for POPs as it does for mercury although a health advisory for burbot from the Slave River near Fort Smith for toxaphene contamination was made in 1992 (MRBB 2004).

Dioxins and furans are among the most toxic POPs because they can affect health in so many ways including wasting, damage to the immune system and liver, endocrine disruptions and problems with fetal development. Because they tend to be fat soluble, they also biomagnify through the freshwater food chain causing higher concentrations in top predators like northern pike and lake trout.

Levels of chlorinated dioxins and furans in burbot showed a decrease in the early 1990s (Figure 3.3-15) as pulp mills located within the Mackenzie River Basin decreased effluent concentrations of these organic compounds (MRBB 2004).

A comparison of burbot livers from Fort Good Hope showed a slow decline in the major organochlorines and toxaphene from the mid-1980s to 1999 (Figure 3.3-16) (AMAP 2002). However, a study from 1993-1999 in Great Slave Lake showed that toxaphene levels in burbot exceeded levels associated with bone development effects in catfish (AMAP 2002).

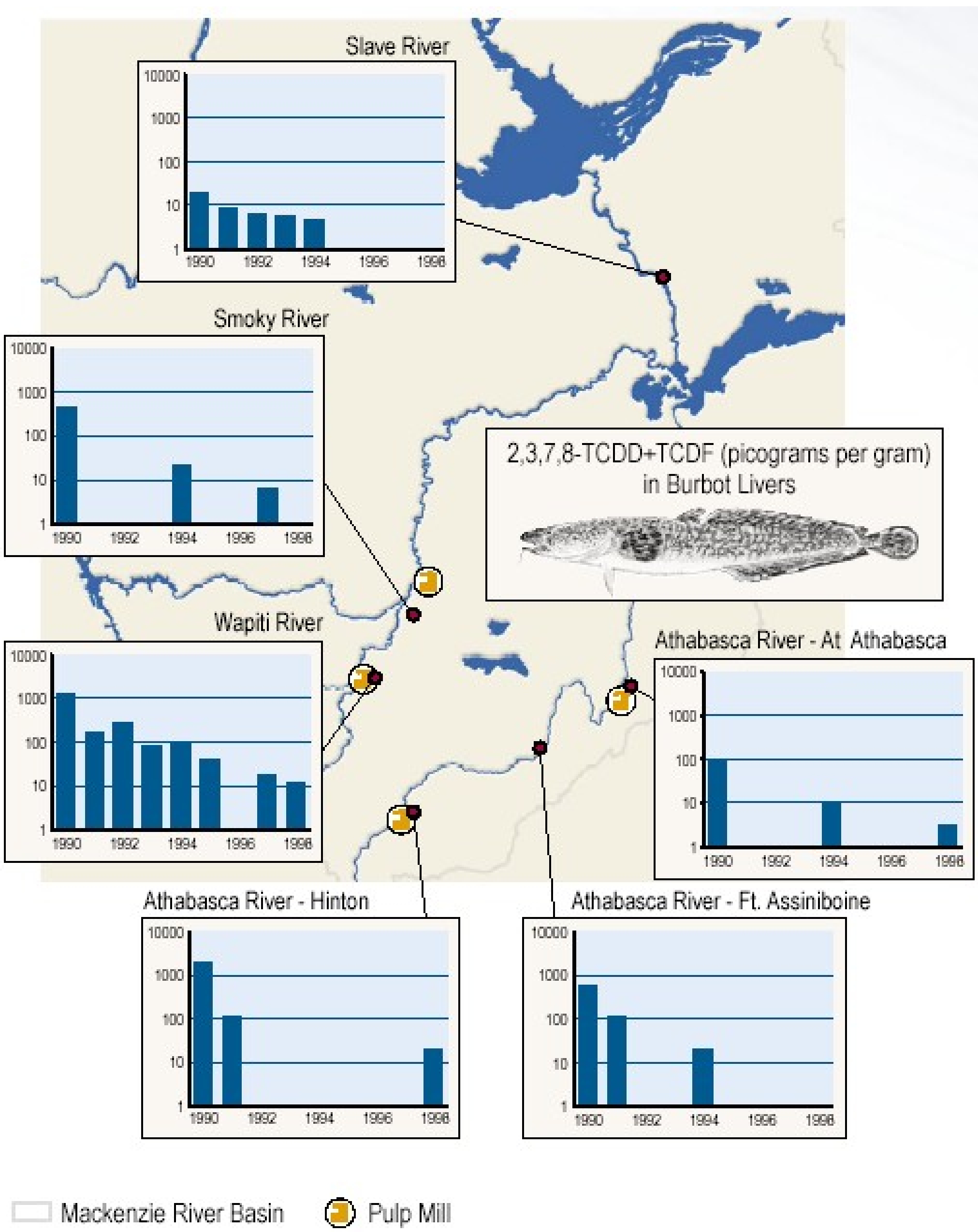
To accurately assess spatial and temporal trends of POPs, the length, age and growth rates of fish must be considered because each of these factors affects concentration (AMAP 2002). It is particularly important that these factors be taken into account when comparing studies between different lakes or rivers.

Based on the lack of EROD induction[6], the potential for POPs to be causing significant influences on fish health in NWT fish is low (INAC 2003). Nevertheless, monitoring of POP

[6] EROD induction refers to a test that measures the level of a biomarker that indicates the level of enzyme activity in breaking down compounds, specifically ethoxyresorufin in the EROD test. The presence of this activity is low, often undetectable, in uncontaminated organisms but highly activated in the presence of contaminants.

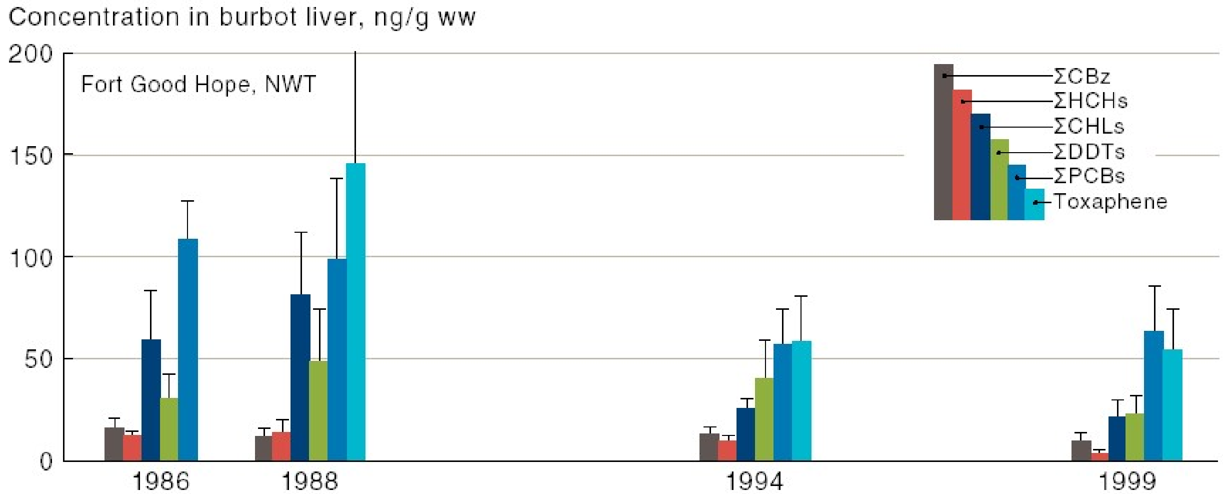
levels ensures that if levels become significant, they will be identified. Current research with respect to climate change impacts on POPs is focused on potential changes to pathways and not influences on individuals or populations.

FIGURE 3.3-15
DECLINES IN DIOXIN AND FURAN LEVELS IN BURBOT LIVERS NEAR PULP AND PAPER MILL SITES



Source: Source: Mackenzie River Basin Board 2004.

FIGURE 3.3-16
CHANGES IN POP CONCENTRATIONS IN BURBOT LIVER FROM THE FORT GOOD HOPE AREA



Source: AMAP 2002.

Radionuclides: Although the potential for human health impacts from radionuclide contamination of fish in the NWT exists, only limited data has been gathered on radionuclide levels in fish. An investigation of radionuclide levels in fish near the former Port Radium radium/uranium/silver mine site on Great Bear Lake showed low levels in lake trout and lake whitefish muscle and liver samples and herring whole body samples (SENES 2004). An assessment of the whole body dose to these species using measured levels in the lake water and sediment in combination with fish tissue data demonstrated that the combined dose from internal and external exposures were well below acceptable levels.

In the NWT, the lack of information about the rates of diseases and parasites in fish does not allow for analysis of changes in their occurrences. However, interviews with First Nations fishers indicated that parasites are more abundant in some areas of the NWT including the lower portion of the Laird Sub-basin. Residents along the Slave River reported a general decline in fish health with an increase in deformities and signs of disease (MRBB 2004). Fish in the lower Mackenzie River area are reportedly good with only a few incidences of parasites, soft flesh, poor liver quality or body marks like scabs (ABEKC 2003). Although it could be expected that climate change and the anticipated increase in water temperature could result in changes in occurrence of diseases and parasites, no studies to investigate this effect were identified for fish in the NWT.

iii) Why is it happening?

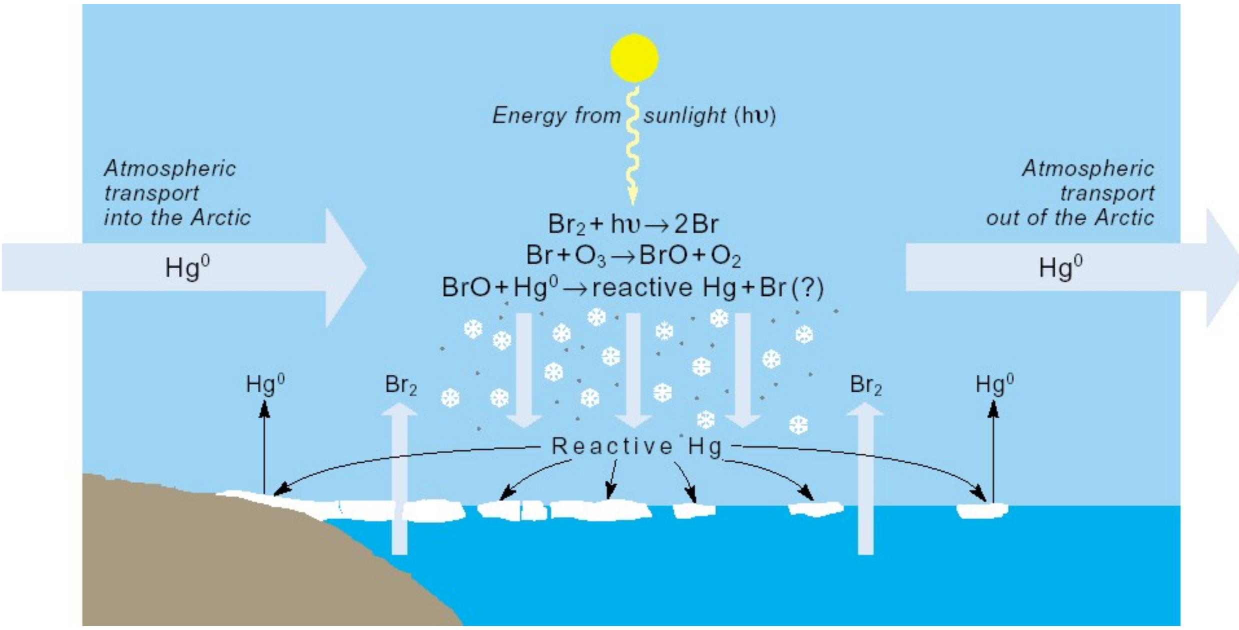
- Transport of contaminants to the Arctic includes atmospheric transport in both the gaseous phase as well as by particle adhesion and transport by both ocean currents and rivers (INAC 2003). For example, the transport of POPs to Great Slave Lake occurs from the south via the Peace River to the Athabasca River and finally through the Slave River (AMAP 2002). Once contaminants are present in the aquatic environment, accumulation of contaminants in aquatic plants and fish occurs. Fish exposure pathways include uptake through the gills, the skin and by direct digestion (INAC 2003).

Heavy Metals: *The sources and pathways of heavy metals other than mercury are not well known. In general, these sources are identified on an individual lake or system basis once contamination is found. For example, abandoned mine sites may be a source of several metals. Likewise, areas with natural outcropping of mineral deposits are potential sources of metals.*

By contrast, investigations into the sources and pathways of mercury have received much more attention. Long-range atmospheric transport has been identified as being a major source of mercury in the NWT. A simplified schematic of the reactions that occur and contribute to mercury deposition is presented on Figure 3.3-17.

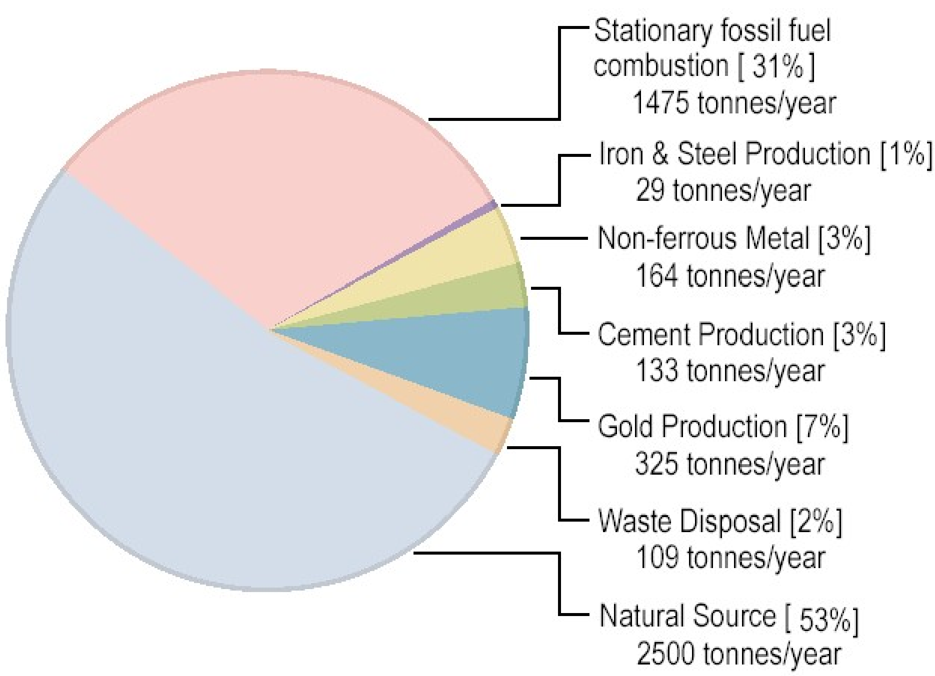
While initiatives have been taken to reduce mercury source emissions in North America and Europe, this has not translated into a reduction in the mercury level in the atmosphere over the Arctic. It may be that these recent reductions are offset by increases in emissions from Asia. Anthropogenic mercury is released to the atmosphere through coal burning, waste incineration and industrial processes. Natural atmospheric mercury is emitted from volcanoes and forest fires (AMAP 2002). Figure 3.3-18 shows a breakdown of atmospheric mercury sources. Unique pathways seem to concentrate mercury in bioavailable forms in the Arctic and NWT.

FIGURE 3.3-17
SCHEMATIC SHOWING REACTIONS THAT CAUSE DEPOSITION OF ATMOSPHERIC MERCURY



Source: AMAP 2002.

FIGURE 3.3-18
SOURCES OF ATMOSPHERIC MERCURY, BOTH ANTHROPOGENIC AND NATURAL



Source: Source: Mackenzie River Basin Board 2004.

Persistent Organic Pollutants*: POPs provide the best evidence that pollution in the NWT is primarily from the south because they are not typically used locally in large amounts (Macdonald 2000). POPs tend to be anthropogenic in origin, persistent in remaining in their original or stable form for decades, bioaccumulate throughout the life cycle of a fish, and they tend to be toxic at low concentrations. Levels of POPs are mostly due to past emissions but, new POPs have been found as well. POPs are generally man-made chemicals with applications as insecticides and in industrial processes.*

Radionuclide*: In the NWT, radionuclide sources include natural deposits, atmospheric fallout from nuclear weapon testing conducted from the 1940s through 1980, transportation accidents and industrial process by-products (for example testing during the laying of pipe). However, the most common source of radionuclides in any Arctic environment is through accidents resulting in releases including those involving stockpiles of radioactive waste (AMAP 2002). While it is unclear how much radioactivity is distributed through the environment in the NWT, radioactivity levels measured in terrestrial animals and fish indicate that radioactivity is not a concern.*

Parasites and diseases may be transported in the holds of ships destined for the NWT. Although the majority of fish parasites and diseases are endemic to the NWT, as water temperatures increase, the range of parasites may change and stress may increase the incidence of disease.

iv) What does it mean?

Contaminant levels in fish are affected by not only the concentrations found in lake or river water but also the type of fish, where it lives in the system, how old it is and what it eats. Older fish may have higher levels of contaminants such as mercury which bioaccumulate in species higher in the food chain. Predatory fish, those that primarily eat other fish, like northern pike, walleye and lake trout, typically have the highest levels of contaminants.

As well as being important culturally for many NWT inhabitants, fish are generally an inexpensive, readily available and generally healthy source of protein (MRBB 2004). To protect the health of people living in the NWT, health advisories for mercury have been issued respecting certain species of predatory fish on twelve lakes in eth NWT (Giauque Lake, Lac Ste Therese, Lac Tache, Little Doctor Lake, Lac a Jacques, Thistlewaite Lake, Keller Lake, Cli Lake, Turton Lake, and Manuel Lake) (INAC 2005).

The presence of diseases and parasites can either make fish unsafe or, at best, undesirable for human consumption. This could impact the ability of NWT inhabitants to utilize this readily available source of food and could have other economic impacts, such as on tourism, if fish quality declines too far.

v) What is being done about it?

The first phase of the Northern Contaminants Program (NCP) began in 1991 and was completed in 1997. This phase focused on gathering data to determine contaminant levels, their geographic extent, sources of contamination in the northern atmosphere, environment and people as well as the expected duration of the problem. The results of this phase were synthesized in the 1997 Canadian Arctic Contaminant Assessment Report. The second phase began in 1998 and continued to March 2003. This phase identified three primary study interests: (1) survey, monitoring and temporal trends of traditional food sources and wildlife health, (2) impacts and risk of item 1 on human health, and (3) determining temporal trends of contaminants of concern in key Arctic indicator species and air (INAC 2003). As part of this program, the NWT Environmental Contaminants Committee provides northern residents with information about contamination so that informed choices can be made with respect to fish consumption.

The Arctic Monitoring and Assessment Programme (AMAP), a joint effort of eight Arctic countries, Arctic aboriginal organizations and other observer countries and organizations, began monitoring and assessing anthropogenic pollution in the Arctic in 1991 with a first report published in 1997. NCP is Canada's primary contribution to AMAP.

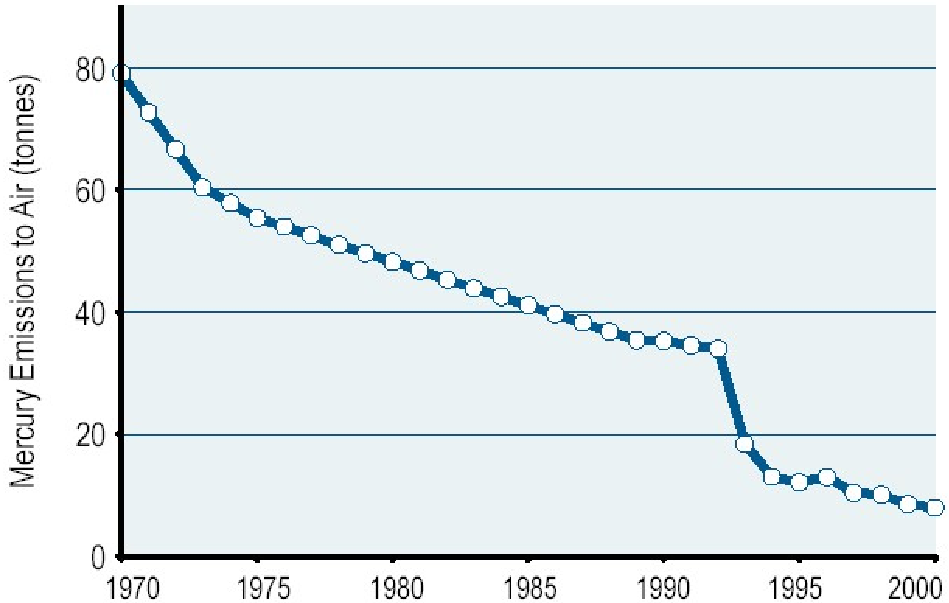
Current contaminant clean-up efforts in the NWT by the INAC and other federal departments are focused on priority abandoned mines. Industry and sewage treatment is also more closely regulated (MRBB 2004).

There are few guidelines for contaminant concentration levels designed to protect fish. Instead, guidelines are focused on the protection of consumers.

Heavy Metals. *Lead is a great example that demonstrates the effectiveness of pollution control. Emissions of lead in 1995 were nearly two thirds lower than those from 1983 (AMAP 2002). This decrease is primarily a result of restrictions of lead in gas.*

Government regulations, such as the Canadian Environmental Protection Act (CEPA), industry cooperation and technological advances have resulted in a decrease in anthropogenic mercury emissions (Figure 3.3-19). However, there is a need for continued international efforts to decrease mercury emissions.

FIGURE 3.3-19
DECLINE IN CANADIAN ANTHROPOGENIC MERCURY EMISSIONS BETWEEN 1970 AND 2000



Source: Source: Mackenzie River Basin Board 2004.

Persistent Organic Pollutants. *The largest contributor of dioxins and furans, pulp mills, are no longer permitted to emit these compounds in their effluent under the CEPA. The industry has implemented technological advances to meet these regulations (MRBB 2004).*

Along with ongoing studies to measure POPs like PCBs, DDT and toxaphene, an effort is being made to investigate new contaminants like brominated flame retardants, fluorinated organic compounds and chlorinated paraffines.

Radionuclides. *With little known about quantities of radionuclides in the NWT, clean up and regulation will continue as required when contamination is identified.*

Other than trying to prevent the introduction of new parasites and diseases, little is done and/or can be done to prevent the spread of fish diseases and parasites.

vi) What are the information gaps?

Identification of the impacts of climate change on contaminant pathways and effects: More research is needed to understand how climate change and variability will affect the ways in which heavy metals, POPs, and radionuclides are transported to, and within the NWT, as well as how they accumulate and impact biota. There is, as yet, not enough information collected to understand with any certainty how climate change will impacts contaminants and contamination in the NWT (AMAP 2002).

<u>Comprehensive monitoring of contaminants in fish (geographically and temporally):</u> Information regarding contaminant levels by species, types of contaminant and geographic areas (CIMP 2005) especially collecting data to elucidate temporal trends statistically (INAC 2003). Specific areas that require more information are Great Slave Lake and Great Bear Lake because of their importance with respect to human health risk (MRBB 2004) and the Slave River to monitor upstream impacts (Sanderson *et al.* 1998). There is also a need for larger numbers of samples so that statistical comparisons can be made between age and size differences (INAC 2003).

<u>Improved understanding of the biological impacts of contaminants on NWT fish:</u> There is an overall lack of information with respect to biological effects of contaminants on the NWT fish. Furthermore, there are few guidelines set for the protection of fish (INAC 2003), particularly with respect to body burden versus levels found in water and sediment. Specific research needs to determine threshold effects for NWT fish species rather than comparison of burden levels to laboratory studies on non-Arctic species (INAC 2003).

<u>Improved understanding of the pathways and distribution of mercury:</u> A better understanding is needed of the pathways and processes that influence mercury distribution in the Arctic, as well as that for other metals. The relative importance of freshwater and sediment sources versus atmospheric sources has not been determined (AMAP 2002). More information is required to determine the relative contribution of natural versus anthropogenic sources (INAC 2003).

<u>Identify all heavy metals of concern:</u> Consideration should be given to heavy metals that have not, as yet, received attention including platinum, palladium, rhodium and thallium (AMAP 2002, INAC 2003).

<u>Identify effects, sources and prevalence of cadmium:</u> The sources and biological effects of cadmium require more study and in particular, the role that soil and rock plays as a natural source of cadmium (AMAP 2002).

<u>Monitor POP levels and effects (geographically and temporally):</u> Studies should continue to monitor trends in POP levels, as well as to increase the ability to detect effects at the individual and population levels (AMAP 2002).

Ensure early identification of new POPs: Research must be directed at ensuring our ability to detect new and currently used POPs to stay ahead of emerging issues rather than responding once impacts have been observed (AMAP 2002, INAC 2003). Research should also involve the archiving of tissue, so that as new chemicals are identified, archived tissue can be analyzed to establish baselines (INAC 2003).

Identification of POP sources and particularly local sources: Although it is commonly believed that most POP contamination has its origin outside of the NWT, limited information is available regarding the contribution of local contamination such as from burning municipal waste and the DEW-line sites (INAC 2003).

Improved understanding of the presence, quantification and distribution of radionuclides in the NWT: More research is needed to understand the vulnerability of the NWT and potential impacts from radionuclides. There is also a need to look at the remobilization of radioactive compounds from sediment (AMAP 2002). It is unclear if the extent of radioactive contamination in the NWT has been quantified.

Quantification of dose levels and effects on NWT fish: Up-to-date information is needed with respect to the effects of radiation on fish to minimize uncertainties (AMAP 2002).

Development of fish specific guidelines for dose levels: Past dose limits have been focused on human (AMAP 2002). There is a need to develop limits for the protection of fish during all life-history stages. This is particularly important at chronic low-dose levels.

Conduct surveys to catalogue and document the levels of fish diseases and parasites found in the NWT.

Monitoring of diseases and parasites as indicators of fish quality: This type of investigation could be performed on a need basis, or as part of general monitoring added to community and contaminant monitoring efforts (CIMP 2005).

3.4 CONCLUSIONS AND RECOMMENDATIONS

Based upon the review of previously completed studies looking at components of the freshwater aquatic environment, the current conditions and trends for the NWT were found to be for the most part favourable. For some indicators the condition and/or trends were identified as unfavourable or deteriorating at a local scale, or, for the whole of the NWT, uncertain. Regarding the latter, such a finding was generally the result of inadequate monitoring data from which to draw conclusions, and in other instances uncertainty was associated with difficulty predicting actual impacts of climate change.

Recommnedations specific to the components assessed in this review are identified below:

Surface Water Quality

- Future monitoring of surface water quality needs to be maintained as it will be useful in determining changes in water quality as they relate to climate change effects.
- The number of long-term monitoring stations in the NWT is limited in comparison to the geographic size; therefore, expanding the current regional surface water quality monitoring to include key locations in unmonitored watersheds would be beneficial.
- Integration of more intensive local research (e.g., mine-specific aquatic effects monitoring) into the long-term monitoring network database would be another means of expanding the water quality database.

Sediment Quality

- Information on PCBs, pesticides, polycyclic aromatic hydrocarbons, dioxins and furans, and heavy metals in sediments is very limited with the exception of specific investigations on the Slave River at Fort Smith and the Liard River above Kotaneelee River. Regional monitoring would be useful.
- Long-term monitoring of river sediments and periodic collection of lake sediment core samples is required to better understand the fate of contaminants in the benthic environment.

Surface Water Quantity

- Future monitoring of surface quantity needs to be maintained to measure the effects of climate change on long-term average flows, extreme flow events and timing of snow melt and freeze over.

Ice Phenology

- Climate warming is anticipated to increase the frequency of interruption of the ferry service due to more frequent ice jams and reductions in water flow.
- Continued monitoring of river flows, frequency and timing of ice jams and days of operation of the ferry and ice bridge services will be important for determining the effects of climate change.

Fish Habitat

- There is only limited data to define baseline habitat conditions in the NWT.

- Aside from fish habitat assessments near residential, transportation, and industrial sites, fish habitat information is not commonly collected in the NWT. Within government agencies with objectives to protect and enhance aquatic ecosystems, there has been no consolidation of programs or data, which would allow for an assessment of parameters as indicators of well-functioning aquatic ecosystems over time.
- There is a need to compile data on various fish habitats for Great Slave Lake and Great Bear Lake, as they relate to fish harvest data. These data should reach a level of detail that would be useful for future comparisons.
- Archiving of high-resolution satellite images of the NWT would allow future comparison of changes in the physical environment that could potentially affect freshwater habitat.

Fish Population

- The data available to define baseline conditions in the NWT are limited.
- Great Slave Lake fish are exploited by several types of fisheries activities, which can affect and deplete populations and stocks. It is therefore imperative to manage the fisheries with proper planning and regulations, record and monitor harvests, and assess the stocks.

Fish Harvest

- Data from fish harvests could be useful to derive population and stock parameters relating to: (1) Energy Use; growth and reproductive investment, (2) Survival; age structure and length frequency analysis, and (3) Energy Storage; condition. Sufficient information appears available to derive new data, even assess trends at some local and regional levels within the NWT.
- Fish stock assessment studies are needed on Great Slave Lake to determine the current status of lake trout as well as other important fish species throughout the lake.
- On Great Slave and Great Bear lakes the fisheries need to be looked at closely and managed to ensure sustainability of stocks overtime. Detailed information is required about fish populations and stocks in order to achieve a corresponding good level of fisheries management.
- On Great Slave Lake, additional information is needed on the subsistence and sport fisheries to complete the understanding of the fisheries resources.
- In the Mackenzie Great Bear Sub-basin, subsistence, sport and commercial fishing are most important. Broad whitefish and lake whitefish remains the most important catch. Harvest status on these species is unknown and needed.

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4.0 MARINE ENVIRONMENT

4.1 INTRODUCTION TO THE MARINE ECOLOGY

Marine research in the southeastern Beaufort Sea-Amundsen Gulf area began in earnest in 1896 with an expedition from Stanford University to Herschel Island, and continued with an expedition from the American Museum of Natural History (1908) and the Canadian Arctic Expedition (1913-1918). However, regular studies in the Canadian Beaufort Sea-Amundsen Gulf area did not begin until the mid-1950s, when the Arctic Biological Unit of the Fisheries Research Board began a long series of marine biology and ecology studies. This work consisted largely of baseline and distributional studies and continued for over two decades.

Since the early 1970's, marine research efforts in the region have been closely tied to the level of interest in hydrocarbon development. Sampling efforts increased ca. 1972, in response to oil exploration and associated activities, such as seafloor dredging and artificial island construction. Most of this work consisted of environmental impact studies with a large, baseline/distribution or life history component. Both Government and Industry conducted these studies, some of which provide baseline data suitable for monitoring comparisons, but few lasted over 4 years. Hydrocarbon exploration activity in the region decreased in the mid-1980s, and with it the associated environmental research. Interest increased again in the mid-1990s and various environmental impact assessment studies are ongoing (e.g., Devon Canada Corp. 2004; http://www.mackenziegasproject.com).

Extensive, multi-disciplinary, marine research programs were carried out by scientists from the Department of Fisheries and Oceans (DFO) from 1984 through 1990, with funding from the Northern Oil and Gas Action Program (NOGAP) (e.g., Bond and Erickson 1989; Hopky *et al*. 1994; Chiperzak *et al*. 2003). This and other work formed the basis for the Beaufort Environmental Monitoring Project (BEMP), which began in 1983 and considered hypotheses related to the potential impacts of hydrocarbon development in the Beaufort Sea (ESL and Seakem 1989). A similar project, the Mackenzie Environmental Monitoring Project (MEMP) was initiated in 1985 for the Mackenzie Delta, including coastal areas of the Beaufort Sea (LGL *et al*. 1988).

The NCP is also conducting long term monitoring of contaminants in beluga, ringed seal, polar bear and anadromous char in and around the Beaufort Sea. Details of the plan can be found in the NCP Blueprint for research under the Environmental Trends subprogram.

While there have been many studies of the marine environment of the Beaufort Sea – Amundsen Gulf Area, remarkably few have provided trend-over-time data useful for monitoring environmental health. Key reasons for this deficiency include: 1) the high cost and difficulty of working in the region; 2) the short duration (<4 y) of the studies, most of which were designed to collect basic information on the environment or for environmental impact assessment; 3) the incomparability of data among studies, due to differences in the location, design, and/or methodology; and 4) the incomparability of data within longer-term studies due to changes over time in response to changing information requirements, improved understanding (e.g., the existence of separate populations), or technological advances (e.g., satellite technology). The comparability and repeatability of much of the research work conducted in the Canadian Beaufort Sea prior to ca. 1985-1993 was assessed by the Arctic Data Compilation Program (ADCAP) (oceanography: Cornford *et al*. 1982; Thomas *et al.* 1982, 1990; plankton: Woods and Smiley 1987; zoobenthos: Wainwright *et al*. 1987; fish: Ratynski *et al*. 1988; Stewart and Ratynski 1995; seals: Harwood *et al.* 1986; whales: Norton *et al*. 1987). This program also described marine industrial activity in the region (Taylor *et al*. 1985; Brouwer *et al*. 1988; ESL 1991).

Most of the sampling effort has been expended in the Mackenzie Estuary and on the Beaufort Sea shelf, typically within the 10 m isobath. This is primarily a function of the small boats used for sampling and because deep water is far offshore in most areas. Seal and polar bear surveys excepted, most sampling has been conducted during the open water period from July to October. Offshore research conducted in 1997-98 on the Surface Heat Budget of the Arctic Ocean (SHEBA) is an exception (e.g., Macdonald *et al.* 2002).

Two new research initiatives should provide valuable information on the oceanography of the Beaufort Sea-Amundsen Gulf area. In 2002, the Canadian Arctic Shelf Exchange Study (CASES) began a multi-year research program on the functioning of the Mackenzie Shelf ecosystem (http://www.cases.quebec-ocean.ulaval.ca/science.asp). The central hypothesis of this Canadian-led international program is: "The atmospheric, oceanic and hydrologic forcing of sea ice variability dictates the nature and magnitude of biogeochemical carbon fluxes on and at the edge of the Mackenzie Shelf." The CCGS Amundsen, formerly the icebreaker CCGS Sir John Franklin, has been refitted to provide a research platform capable year-round operation in the Arctic. The scientific studies will examine:

1. Atmospheric and Sea Ice Forcing of Coastal Circulation;
2. Ice-Atmosphere Interactions and Biological Linkages;
3. Light, Nutrients, Primary and Export Production in Ice-Free Waters;
4. Microbial Communities and Heterotrophy;
5. Pelagic Food Web: Structure, Function and Contaminants;
6. Organic and Inorganic Fluxes;
7. Benthic Processes and Carbon Cycling;
8. Millenial-Decadal Variability in Sea Ice and Carbon Fluxes; and
9. Coupled Bio-physical Models of Carbon Flows on the Canadian Arctic Shelf.

Another co-operative, multidisciplinary, multi-year research program in the Beaufort Sea is Theme 1 of ArcticNet. It began in 2004 and will document the links between environmental change, health and economy along the contrasted East-West gradient of the Canadian High Arctic (http://www.arcticnet-ulaval.ca/index.php?fa=ArcticNet.showArcticNet). Key indicators of change in the coastal environment and its inhabitants will be measured annually to gather the time-series data required to separate irreversible change from natural variability. Theme 1 results will contribute to the formulation of policies and adaptation strategies to help answer the specific needs of stakeholders in the fields of health, economy, geopolitics and industry. ArcticNet research programs will be supported by CCGS Amundsen, but will include a larger coastal component than the CASES research. Studies will be undertaken to assess:

- 1.1 Warming Coastal Seas & Shrinking Sea Ice;
- 1.2 Coast Vulnerability in a Warming Arctic;
- 1.3 Contaminant Cycling in the Coastal Environment; and
- 1.4 Marine Productivity & Sustained Exploitation of Emerging Fisheries.

Carmack and Macdonald (2002) provide a clear, readable overview of oceanographic processes on the Canadian shelf of the Beaufort Sea. The following report describes the Marine Environment adjacent to the Northwest Territories (NWT), with particular emphasis on:

- current monitoring/research programs and data;
- trends in the data and the significance of these trends; and
- information gaps and recommendations for additional monitoring/research.

4.2 MARINE STRESSORS

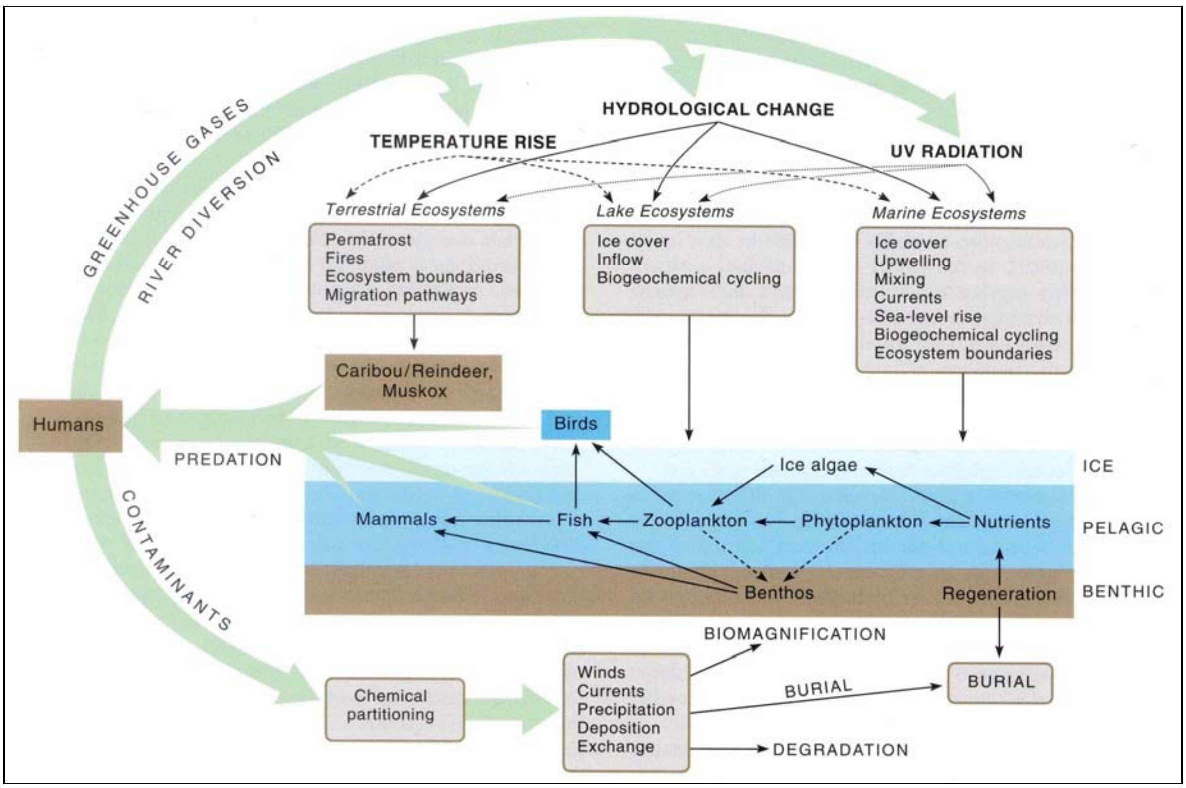
Marine ecosystems offshore of the Northwest Territories are vulnerable to a wide range of anthropogenic and natural stressors, each with the potential to affect the ecology in different ways. Chief among these stressors, but listed in no particular order, are:

- contaminants,
- harvesting,
- habitat disruption,
- disturbance,
- species invasions, and
- climate change.

4.2.1 Contaminants

Contaminants are transported to the region over long distances by marine currents, air currents, freshwater runoff from the land, and migratory biota (Figure 4.2-1) (Macdonald 2000, CACAR II 2003; Macdonald *et al.* 2003a,b; AMAP 2002, 2004). These long-range transport mechanisms carry a wide range of pollutants over the pole in seawater, ice, or air; from the Mackenzie Basin and other smaller Arctic watersheds upstream; and from habitats throughout North and South America, and disperse them throughout the region. Toxic, persistent substances that tend to accumulate in biota are of particular concern, including heavy metals such as mercury and cadmium, and organochlorine compounds such as PCBs, chlordane, and toxaphene. The risk they pose to Arctic marine systems is predicated on a conspiracy between physical, chemical, and biological processes that produces relatively high concentrations in apex feeders far from known sources. Radionuclides are not generally considered a threat in this region but Cesium-137, which was produced primarily by nuclear tests in the 1960's, does provide an excellent tracer of ocean pathways.

FIGURE 4.2-1
CONTAMINANTS PATHWAYS TO AND FROM THE ARCTIC MARINE ECOSYSTEM



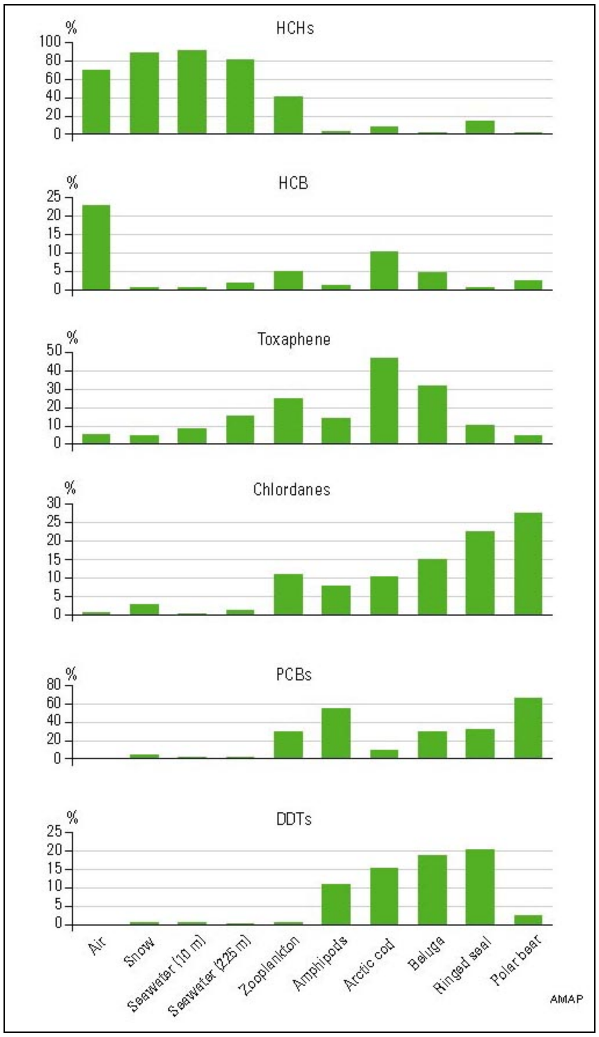
Source: Macdonald et al. 2003b, p. 48).

Contaminants are also transported directly to, or mobilized from, the local environment by human activities. While they may eventually disperse widely, these substances emanate from point sources that can be identified. PCB contamination at DEW Line Sites (CACAR II 2003), and nutrients and contaminants from sewage disposal and landfill sites at the communities, are examples of existing point sources. The potential for oil spills or natural gas leaks from hydrocarbon developments is significant in the region, and is likely to increase if hydrocarbon developments proceed. Shipping tracks are one of the few line-sources of contaminants entering the Arctic marine environment, and may increase in importance over time, with predicted longer ice-free shipping seasons resulting from climate warming.

Marine organisms accumulate contaminants from their environment and their diet. The types and body burdens of contaminants they accumulate reflect their habitat use, movements, diet, age, and metabolism (Figures 4.2-2, and 4.2-3) (AMAP 2002, 2004; CACAR II 2003; Macdonald *et al.* 2003a,b; Hoekstra *et al*. 2003). Some contaminants are metabolized, while others such as chlordanes and mercury accumulate over the life of the organism and can be present in increasingly high concentrations moving up the food web. As technology changes, new types of synthetic contaminants are constantly being made. Brominated flame-retardants, like polybrominated diphenyl ethers (PBDE), are one class of these compounds that has been identified in the past decade and is accumulating in Arctic marine biota (Ikonomou *et al*. 2002). Their biological effects on marine biota are largely unknown.

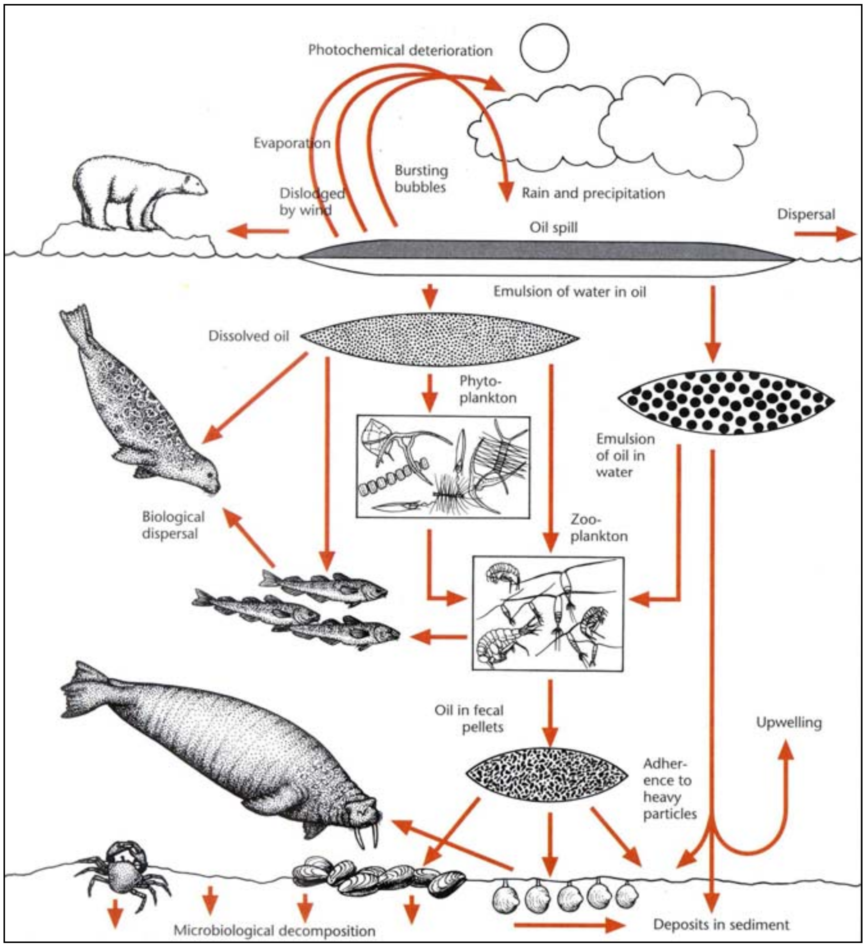
It is important in any monitoring program to differentiate between concentrations of contaminants in biota, which may be of direct concern to humans that eat these animals, and the health effects of contaminants on the biota themselves. Contaminants that are metabolized quickly may only be present at low levels, whereas their effects on the animal's health may be significant and lasting. These health effects can be a better indicator of the importance of the contamination than the contaminants levels themselves.

FIGURE 4.2-2
DISTRIBUTION OF ORGANOCHLORINE CONTAMINANTS IN ARCTIC AIR, SNOW, SEAWATER, AND THE MARINE MAMMALS FOOD CHAIN



Source: de March et al. 1998, after Norstrom and Muir 1994.

FIGURE 4.2-3
OIL DISPERSAL PATHWAYS IN THE ARCTIC MARINE ENVIRONMENT



Source: Born and Bocher 2001, p. 391.

Climate change could significantly alter the availability of contaminants to Arctic biota. Changes associated with ice and precipitation, and with the trophic structure of ecosystems have the greatest potential to alter contaminant pathways and exposure (Macdonald *et al*. 2003b).

4.2.2 Harvesting

The Inuvialuit have a long tradition of harvesting animals from the Mackenzie Delta/Beaufort Sea/Amundsen Gulf area for food and materials (Farquharson 1976; Usher 1976; Smith 1987; Byers and Roberts 1995; Inuvialuit Harvest Study 2003). These harvests have provided many of the necessities of life and continue to be economically and socially important.

Most marine fishing efforts have been concentrated on obtaining anadromous fishes, particularly: Dolly Varden (*Salvelinus malma*), Arctic char (*Salvelinus alpinus*), lake whitefish (*Coregonus clupeaformis*), broad whitefish (*Coregonus nasus*), inconnu (*Stenodus leucichthys*), and ciscoes (*Coregonus* spp.). These species typically spawn and winter in fresh water and feed at sea in the summer. Where salinity and temperature conditions are favourable, some species may remain in the river plumes over winter.

Anadromous species are attractive to harvesters because they are predictably available during migration in the coastal rivers, and in summer along the coasts. They are tasty, tend to grow faster than their non-anadromous counterparts due to the relatively rich feeding opportunities in the coastal waters, and they shed most of their parasites on entering the marine environment or re-entering freshwater. Depending upon their seasonal movements, some of these fish stocks may be vulnerable to capture at various locations along seacoast and in fresh water. Some inconnu, for example, migrate over 1000 km inland in the Mackenzie River watershed (DFO 1998). There are quotas on the commercial harvests and catch and possession limits on the sport fisheries, but none on the subsistence harvests.

While the anadromous fishes are harvested for subsistence, commercial sale, and sport, relatively few truly marine species of fish or invertebrates are harvested (Stewart *et al*. 1993; Inuvialuit Harvest Study 2003). Pacific herring (*Clupea harengus*), Arctic cod (*Boreogadus saida*), saffron cod (*Eleginus gracilis*), and sculpins (*Myoxocephalus* spp.) are caught in small numbers, primarily for use as dog food. To date none of the marine fish or invertebrate species identified from the region has demonstrated the potential to support an economically viable marine commercial fishery, including species that are commercially harvested elsewhere such as Pacific herring and Greenland halibut (*Reinhardtius hippoglossoides*). Difficult working conditions, high costs, and a limited resource base hamper these fisheries.

The harvest of marine mammals is also socially and economically important for the Inuvialuit. Ringed seals (*Phoca hispida*), bearded seals (*Erignathus barbatus*), beluga whales (*Delphinapterus leucas*), bowhead whales (*Balaena mysticetus*), and polar bears (*Ursus maritimus*) are the main species targeted (Inuvialuit Harvest Study 2003). Southern Beaufort Sea populations of these species, with the possible exception of bearded seals, undertake extensive seasonal westward movements that can make them vulnerable to harvest along the Alaskan or Siberian coasts (Richard *et al*. 2001; Harwood *et al*. 2002; Stirling 2002). There are no quotas on harvests of seals or belugas by Inuvialuit or Alaskan Inupiat for subsistence, but there are quotas on the harvest of polar bears. Inuvialuit require a special licence from the Minister of Fisheries and Oceans to harvest bowhead from the Western Arctic Population, which COSEWIC designated as endangered in 1986 and is listed in Schedule 2 of the Species at Risk Act. The species' status is currently being reassessed. Single animals were harvested in 1991 and 1996

(P. Hall, DFO Winnipeg, pers. comm. 2005). Walruses (*Odobenus rosmarus*) and other seals or whales are seldom harvested.

A variety of waterfowl that use coastal marine environments are harvested for subsistence. Those that make the greatest use of marine resources are the king and common eider ducks (*Somateria spectabilis* and *S. mollisima*), longtailed duck (i.e., oldsquaw; *Calangula hyemalis*), surf and white-winged scoters (*Melanitta perspicillata* and *M. fusca*), brant geese (*Branta bernicula*), and red-throated loons (*Gavia stellata*). There are no limits on the subsistence harvests of these birds by Inuvialuit.

4.2.3 Habitat Disruption

Bottom disturbance and sediment release from removal and placement activities have the potential to disrupt local habitat (Taylor *et al.* 1985; ESL and Seakem 1989). These activities can be related to the maintenance or construction of shoreline facilities such as harbours, or to offshore oil development. Transportation over the sea ice, and ice breaking in support of shipping activities, can also disrupt habitats by altering the ice surface or creating temporary leads. Ringed seal habitat in the landfast ice is that most likely to be affected.

4.2.4 Disturbance

Visual and noise disturbances related to coastal and offshore development activities can disturb animals in the region (Brouwer *et al.* 1988; ESL and Seakem 1989). Many species will acclimate to these disturbances, provided they are not associated with harvesting or injury. Walrus, however, may stampede at haulouts if they are disturbed, and sometimes trample smaller animals to death. They tend to leave areas disturbed by humans. Walruses are not common in the Canadian Beaufort Sea. Disturbances that cause animals and birds to enter the water when they are moulting and less well insulated may have a greater effect than during other seasons. The effects of seismic testing are intensified under the ice due to reflectance of pressure waves off its bottom surface (Wright 1982; Wright and Hopky 1998; Cott *et al.* 2003). This can physically harm marine biota or cause them to avoid areas near seismic tests.

4.2.5 Species Introductions

Species introductions can occur naturally in response to environmental changes that create favourable conditions in new areas, or with human assistance. Invasive species transported to the Great Lakes in ship bilges are one example of the latter; another is the downstream movement of an anadromous species such as rainbow smelt when it is introduced to a new watershed (e.g., the Nelson River) (Stewart and Lockhart 2005). Recent observations of an increasing variety of salmon species that in the past have seldom been reported from the Beaufort Sea, suggest that they may be moving north more often to feed (Babaluk *et al.* 2000). Introduced species need not become established to cause harm if they successfully vector a new disease or parasite that affects the indigenous species.

4.2.6 Climate Change

Climate change has the potential to profoundly alter the marine ecology by changing the volume and seasonality of freshwater runoff from the land, reducing or eliminating seasonal ice cover, and altering ocean currents and weather patterns (Mysak 2001; Carmack and Macdonald 2002; Macdonald 2003b; Loeng 2004). Predictions vary widely on how quickly and to what extent climate may change, and on the extent to which observed warming trends are driven by human activities (e.g., Mysak 2001; Parkinson 2000a,b; IPCC 2001; Curry *et al*. 2003; Curry 2004; Johannessen *et al.* 2004). A significant warming trend that reduces sea ice cover has the potential to alter the biological communities in and around the Beaufort Sea, from the bottom up by affecting nutrient availability and light conditions (Carmack and Macdonald 2002).

While biological productivity may increase over the long term, the direction and degree of change at any time during the transition is impossible to predict (Carmack and Macdonald 2002; Macdonald 2003b). Shifts may occur within and among communities and species, and the overall marine production will rise and fall until stability is regained. Species that cannot adapt to changes in habitat or food resources will be selectively eliminated. The effects on each species may depend in large part on how they use and interact with the ice environment, and on how plastic that use is. Ice-adapted species such as ice algae, sympagic amphipods, polar bears, and ringed and bearded seals, would likely be most affected by climatic warming. Indigenous, Arctic adapted species would probably face increasing competition from Pacific species that invade as conditions ameliorate.

Climate change also has the potential to fundamentally alter the local marine environment and resource base of communities such that traditional knowledge is no longer applicable, and to change patterns of northern development and marine transportation (Maxwell 1997; Duerden 2004).

4.3 MARINE ENVIRONMENTAL QUALITY (MEQ) INDICATORS

Indicators of marine environmental health can be drawn from the physical, chemical, and biological oceanography. The list of potentially useful indicators is very long but at present few offer data sets that are comparable for a period of over 3 years, and fewer still are repeatable for future comparison (see ADCAP reports).

A "top-down" approach, whereby large predatory species such as the polar bear, beluga whale, ringed seal, and anadromous char (i.e., Arctic char and Dolly varden) are examined offers perhaps the best potential for monitoring cumulative impacts on the marine environment at present. As high-level consumers, these species are integrators of change in the food web which itself responds to a myriad of stressors. This makes them particularly vulnerable to environmental perturbations, and to the accumulation of persistent contaminants. As large, predictably available species they are also very important to the Inuvialuit, who harvest them in quantity for food and materials. Consequently, government and other agencies have studied these animals over a longer period and in greater detail than most other species.

Changes in the composition of marine communities, in the seasonal abundance or availability of species, and in their quality and/or health can be useful indicators of changes in marine environmental health. Because the Arctic food web is relatively simple, the loss of a species or introduction of another may have important consequences, particularly for higher-level consumers, such as bears and people (Welch *et al.* 1992). However, natural variability among geographical locations, habitat types, seasons and years reduces the sensitivity of community monitoring as a tool for assessing environmental change.

Species with hard parts that grow throughout their lives (e.g., teeth, otoliths, or shells) are particularly useful for monitoring purposes as these parts can be examined to estimate the individual's age. The results of these estimates are however sensitive to the structure and methods used for age determination, which can yield very different estimates. Among invertebrate species, clams such as *Mya truncata* and *Serripes groenlandicus* offer the best opportunities for monitoring as they are long lived and can be aged using shell growth. However, research in the eastern Canadian Arctic suggests that populations may follow an 8-10 year cycle of abundance (T. Siferd, DFO Winnipeg, pers. comm. 2005).

Subsistence harvesters rely on the predictable abundance of a small number of species for food and materials, and their harvests per unit of effort can provide a useful indicator of changing availability. Depending upon the year-to-year continuity of harvesting efforts, and on how the data are collected, harvest data can serve as an indicator of abundance. Abundant, widely distributed species, such as the ringed seal may be more useful indicators than species like the polar bear, which are harvested under quotas. Hunter experience and observations can also provide an important long-term indicator of abundance. However, this information may be confounded over time if climate change alters environmental conditions such that animals change their seasonal movements and traditional knowledge is no longer valid.

The quality and health of animals, prior to their harvest, is an important consideration for the people who eat them. Qualitative observations of whether animals are fat or skinny, whether they taste different, and are energetic or lethargic can be useful indicators of larger problems. Because harvesters handle many more animals than scientists each year, from a much wider area, they are also more likely to encounter diseased or parasitized animals, which can be reported and examined. They can also provide insight into why these changes may be occurring. Harvesters are also more likely to capture uncommon species, such as salmon, that may provide an early indication of changes in community structure.

Contaminant levels are an important aspect of the marine environmental health that affects humans directly through their diet. Trends in accumulation can be followed over time, provided variations related to geography and age and sex of the animal are understood. The value of marine bottom sediment as a record of contaminant deposition over time is limited by the reworking of these sediments by benthic infauna.

Understanding of key atmospheric and oceanographic processes and their linkages to the biological indicators is critical for accurate interpretation of trends in these indicators. Trends in sea ice and water column stratification are particularly useful. Changes in sea ice cover are climate driven and have major oceanographic and ecological implications. All but the ice thickness can now be measured remotely by satellite over the entire region and compared digitally to identify trends over time. Inuvialuit knowledge of sea ice conditions has an important contribution to make in the interpretation of ice data, particularly in the ground-truthing of remote sensing images for subtle changes in ice formation over time. Changes in the seasonal profiles of light penetration, temperature, salinity, nutrients, and chlorophyll ***a*** in the water column are also useful indicators of change. They can provide important information on freshwater inputs, mixing, and biomass.

To date, the only marine valued ecosystem components identified by CIMP (2005) are marine mammals. The key monitoring indicators identified were: body condition and reproductive status of seals and whales; disease and contaminants loads in individuals; age of first maturity and reproductive rate; and stock size and range. Some of these indicators work better for one species than another.

To correctly interpret trends in these indicators, data must also be collected on other aspects of their environment. Consequently, the quality, extent, and duration of sea ice cover; prey quantity and quality; and ambient and anthropogenic noise levels were also identified as key indicators (CIMP 2005).

The indicators identified by CIMP (2005) are appropriate for the marine mammals but leave gaps with respect to monitoring the cumulative effects of stressors on the marine environment as a whole. They do not, for example, consider the effects on the polar bear, which as the apex predator may be more sensitive to stressors such as climate change and persistent contaminants, nor do they consider the effects on marine birds, fishes, invertebrates, or plants except as food for whales and seals. Because of differences in their diet, habitat use, physiology, and life history the stressors acting on the region's marine environment may affect these species differently (Figures 4.2-2 and 4.2-3).

As consumers, the species listed below integrate the effects of environmental changes (Table 4.2-1). Each species is vitally important to the traditional economy, has been studied in the region, and may provide a useful indicator of the state of the environment through time. At present, few if any other species or parameters, with the exception of sea-ice cover, offer useful trend-through time data. Among the potentially useful indicators, only those with the most useful data records will be discussed further.

TABLE 4.2-1
RATIONAL FOR SELECTION OF SPECIES AND PARAMETERS AS POTENTIAL MARINE ENVIRONMENTAL QUALITY INDICATORS

VEC	Parameter*	Rationale
Mammals		
Polar bear	• **natality** • **sex and age composition of the harvest** • body condition • contaminants • population abundance	• High level consumer, eats primarily ringed seals • Widely distributed in winter; more concentrated distribution in summer; den mostly along the western and southern coasts of Banks Island and on multi-year pack ice • Bears from the three management populations (Southern Beaufort/Northern Beaufort/Viscount Melville Sound) remain within the Beaufort Sea/Amundsen Gulf/western M'Clure Strait area year round • Extensive database of monitoring and research • Sensitive to changes in the quality, distribution, and duration of ice cover • Particularly vulnerable to the accumulation of persistent contaminants that bioaccumulate in the food web • Important resource and source of income for residents
Beluga	• **composition of the landed harvest** • **contaminants**	• Mid-level consumer that eats fish and invertebrates and is eaten by polar bears • Widely distributed in summer • Important traditional food source for communities • Composition of the landed harvest and contaminants monitored; growth parameters difficult to obtain in sample sizes sufficient for comparison; migrate east to Lancaster Sound and west to the Bering Sea, making it harder to understand the factors underlying any trends • Returns to the same estuaries each year, making it vulnerable to over-exploitation, might be a useful integrator of the downstream effects of changes occurring in freshwater systems

TABLE 4.2-1 (Cont'd)
RATIONAL FOR SELECTION OF SPECIES AND PARAMETERS AS POTENTIAL MARINE ENVIRONMENTAL QUALITY INDICATORS

VEC	Parameter*	Rationale
Ringed seal	• **harvesting removals** • **body condition** • **ovulation rate** • **contaminants** • recent pups in the harvest • population density	• Mid-level consumer between fish and invertebrates and foxes, polar bears, and people • Widely distributed, year-round resident • Major traditional source of food and materials for Inuvialuit • Sensitive to changes in the ice environment • Reproduction, condition, and contaminants can be monitored cost effectively each year by community-based sampling of the harvest • Contaminants monitored in seals from Holman since 1971
	Birds	
red-throated loon	• surveys of nesting success • contaminants in chicks and eggs	• Mid-level consumer, eat small fish • Arrive in offshore leads in late May or early June and remain until nesting ponds have open water; these ponds winterkill so the loons must travel to the coast or a large lake to forage for fish to feed their young • Widely distributed and conspicuous nesting species in coastal areas in summer; typically nest within 8 km of the coast or a large lake • Young can be followed from egg to fledging unlike many other species with more mobile young and because they are fed local marine fish from an early age can be used to monitor local contaminants • Very vulnerable to oil pollution • Baseline data available on reproductive success; contaminants samples archived

TABLE 4.2-1 (Cont'd)
RATIONAL FOR SELECTION OF SPECIES AND PARAMETERS AS POTENTIAL MARINE ENVIRONMENTAL QUALITY INDICATORS

VEC	Parameter*	Rationale
Fish		
anadromous Dolly varden & Arctic char	• **population size** • **catch-per-unit effort** • **age at harvest** • **fish condition** • **harvest** • contaminants	• Low to Mid-level consumer, eats invertebrates and smaller fish and is eaten by ringed seals and belugas • Widely distributed in coastal areas in summer, winters in fresh water • Important traditional food source for residents and supports economically important commercial and sport fisheries • Individuals return to the same estuaries, rivers, and lakes each year, making populations vulnerable to over-exploitation • Population dynamics and fish condition monitored • May be vulnerable to environmental changes and fish species invasions
Environment		
sea ice	• **duration of ice cover** • **aerial extend to ice cover** • **ice thickness**	• Key determinant of Arctic marine processes at all levels of the ecosystem • Sensitive to climate change • Duration and extent of cover can be measured over the entire region by satellite; thickness and draft cannot • Important determinant of harvesting, transportation, and development activities

*key indicators are in bold type.

4.3.1 MEQ Indicator – Polar Bears

Polar bears (*Ursus maritimus*) are an apex consumer in the Arctic marine food web. They eat primarily ringed and bearded seals, and are eaten by humans. The species was chosen as a VEC because of its high trophic level, and its cultural and economic importance to the Inuvialuit.

Bears from three management populations (SB = Southern Beaufort, NB = Northern Beaufort, VM = Viscount Melville Sound) inhabit the Beaufort Sea/Amundsen Gulf/western M'Clure Strait area year round (Taylor *et al.* 2001). They are widely distributed on the sea ice in winter, with a more concentrated distribution in summer when sea-ice dissipates and they follow the receding ice edge to the permanent pack, or move ashore (Stirling 2002). The Southern Beaufort Population is shared with Alaska, and the others with Nunavut. Birthing dens have been found mostly along the western and southern coasts of Banks Island and on multi-year pack ice, although there are some on the northern coast of Yukon and Alaska.

Bears from these populations travel extensively but, with a few notable exceptions (Durner and Amstrup 1995), remain within their management areas (Amstrup *et al*. 2000; Taylor *et al*. 2001; Stirling 2002). Consequently, they are useful for monitoring environmental change and contaminants in these areas. Polar bears are very sensitive to changes in sea ice, which they use as a platform for travel and hunting seals (Stirling 2002; Derocher *et al.* 2004). The quality, extent, and duration of ice cover determine how successfully, where, and how long they can hunt seals in a particular area. It also determines where maternity dens can be constructed. As apex consumers, polar bears accumulate contaminants from both the benthic and pelagic food chains. They are particularly susceptible to the bioaccumulation of some persistent contaminants that are biomagnified by the food chain, including mercury and chlordane (CACAR I 1997; Norstrom *et al*. 1986, 1998), and may be useful for the early identification of new persistent contaminants.

i) What is being measured?

- **natality (birthrate)**
- **sex and age composition of the harvest**
- **body condition**
- **contaminants**
- **population abundance**

In the Canadian Beaufort Sea and Amundsen Gulf, research on polar bear populations and their ecological interrelationships with seals and sea ice conditions began in the fall of 1970 (Stirling 2002). Its purpose was to address worldwide concern about the conservation of polar bear populations, which had been severely over-harvested throughout the Beaufort Sea and

Amundsen Gulf area before quotas were established in Canada in 1968, and Alaska ceased all but subsistence hunting in 1972.

This research has involved the delineation of populations, population assessments, baseline studies of demographic and reproductive parameters, identification of maternity denning areas, studies of the ecological relationships between seals and polar bears, and the examination of data and specimens from the polar bear harvest (Stirling 2002). The Canadian Wildlife Service and NWT Department of Resources, Wildlife and Economic Development (RWED) have conducted much of this work, in cooperation with local hunters and researchers from Alaska and various universities.

Among the parameters measured, natality and the sex specific age structure of the harvest are perhaps the most immediately useful long-term indicators for monitoring purposes (Stirling 2002). Data on natality (the ratio of live births in an area to the population of that area) provides a measure of the reproductive rate and have been collected during mark-recapture surveys. Data on the age structure of harvested polar bears can reflect both short-term fluctuations in the ecosystem and the overall long-term status of the population in relation to harvesting (Stirling 2002; Derocher *et al*. 2004). Successful hunters must provide information about the hunt and submit proof of sex, the lower jaw or a premolar for aging purposes, and tags/tattoos of any marked bears. At the end of the year data from each population are compiled and reviewed by the Wildlife Management Advisory Committee (WMAC) to ensure that the annual harvest is sustainable. Body condition, contaminants, cub survival, and movement patterns may also provide useful indicators of environmental change (Derocher *et al*. 2004).

Fat samples have been collected from captured bears for contaminant analysis (Norstrom and Schweinsburg 1985; Norstrom *et al.* 1986, 1998). While higher levels of polychlorinated biphenyls (PCBs) have been found in the fat of bears from the Northern Beaufort Population than from populations elsewhere in Arctic Canada (Norstrom *et al*. 1986, 1998), too few of these samples have been analysed to assess trends in contaminant levels (Norstrom *et al.* 1998; CACAR II 2003). However, samples of bear fat have been archived for possible future examination (N. Lunn, EC, Yellowknife, pers. comm. 2005). At high levels, organochlorine contaminants can impair immune function (Lie *et al.* 2004, 2005) and may impair reproduction and cub survival (Skaare *et al*. 2002; AMAP 2002). Higher levels of mercury have been measured in the liver tissue of bears from the NWT than elsewhere in Arctic Canada (CACAR I 1997).

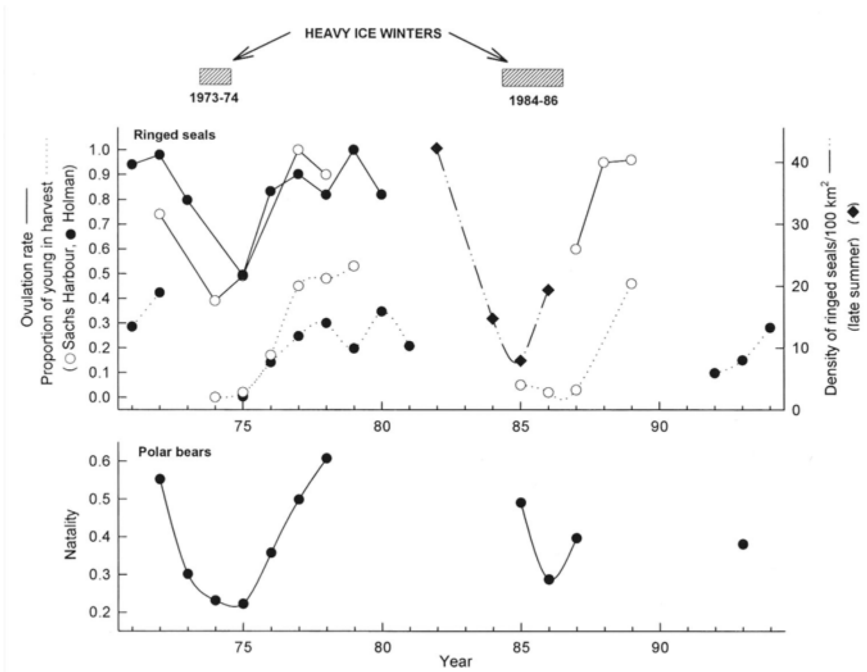
Population abundance estimates do not provide useful trend over time data at present. Initially, they were constrained by the inability to delineate populations. Studies in Canada and Alaska were conducted independently, until mark-recapture and satellite tracking studies demonstrated that the Southern Beaufort Sea population was shared. These estimates continue to be constrained by high costs and logistical difficulties, sampling biases (SB; Stirling 2002), the low density of bears (Lunn *et al*. 1995), and poor tag recoveries (Urquhart and Schweinsburg 1984). Harvest managers now rely on dated estimates from mark-recapture studies conducted in the late 1980s and early 1990s. During these studies, data are typically collected on the size, age (tooth), sex, reproductive state, and fatness of captured bears. Blood, fat and hair samples may also be collected for genetic and contaminants analyses.

Annual maternity denning surveys to estimate cub production are not feasible in the NWT as snow conditions make it difficult to find tracks and locate dens, and the distribution of dens is scattered (Urquhart and Schweinsburg 1984). Mean ashore dates, which are used in Hudson Bay, have less significance in the Beaufort where most bears summer in the permanent pack ice rather than onshore.

ii) What is happening?

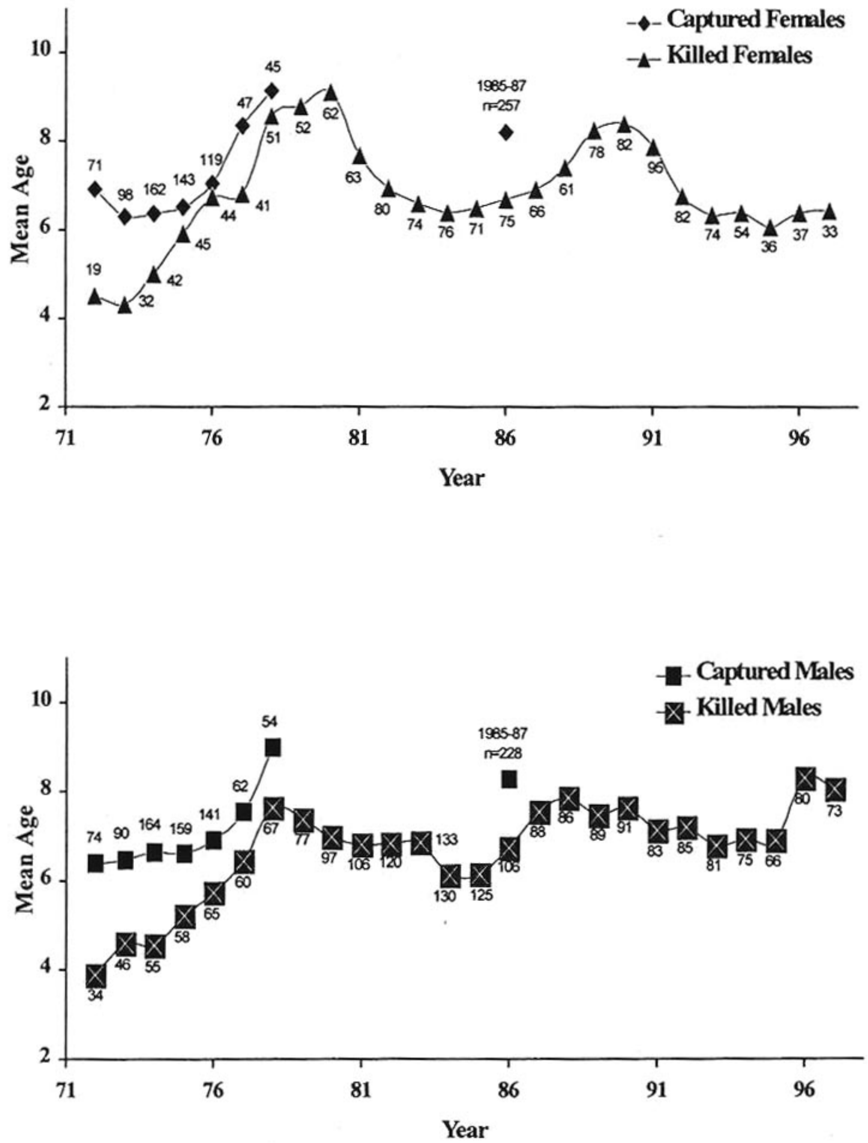
In the mid 1970s and again in the mid 1980s, significant declines were observed in the natality of polar bears and survival of subadults, after which both increased (Stirling 2002) (Figure 4.3-1). This pattern of fluctuations is also apparent in the mean sex-specific age of bears harvested by Inuit hunters over the same period (Figure 4.3-2). A substantial increase in the mean sex specific age of these bears was observed in the decade following the establishment of harvest quotas. The collection of these data has continued, but post-1996 data are not yet available.

FIGURE 4.3-1
CHANGES IN INDICES OF PRODUCTIVITY OF RINGED SEALS AND POLAR BEARS



Source: Stirling 2002.

FIGURE 4.3-2
AVERAGE AGES OF FEMALE AND MALE POLAR BEARS ONE YEAR OF AGE AND OLDER CAPTURED



Source: Stirling 2002.

iii) Why is it happening?

The factors underlying fluctuations in polar bear natality are uncertain, but they follow a pattern similar to that of ringed seal productivity (Stirling 2002). The declines in seal productivity that were observed in the mid 1970s and again in the mid 1980s appear to be related to heavy ice conditions (Figure 4.3-2). Polar bear populations are closely dependant upon ringed seal productivity because the bears eat mostly ringed seals (Stirling and Øritsland 1995).

Quota implementation enabled bear populations to recover from over-harvesting. The average age of harvested bears increased in the decade following these harvest reductions as more bears lived longer before being harvested (Stirling 2002). Subsequent declines in the average age were due to an influx of young bears, rather than an absence of older animals. These influxes occurred in response to increases in ringed seal productivity that followed the heavy ice years and supported higher bear natality and the increased survival of younger bears. The drop in the average age of bears taken did not approach the low levels of the early 1970s when the population was being over-harvested. The pattern was more pronounced in female than male bears because older males tend to stay further offshore and are less vulnerable to harvest.

iv) What does it mean?

The polar bear populations in the NWT are believed to be stable, and hunting rates are believed to be sustainable. The apparent sensitivity to changes in the ice environment makes it important, with the threat of global warming, to re-establish baseline parameters for polar bears and their prey that will permit scientists to evaluate change and develop appropriate responses for conservation and management of marine mammals in the Beaufort Sea (Sterling 2002).

v) What is being done about it?

Ongoing studies that began in Alaska in 2001, were expanded to Canada in 2003, and may continue into 2006, should improve understanding of bear movements in the region and generate much better estimates of the Southern and Northern Beaufort Sea populations.

Harvests of bears from the NWT populations are now being jointly managed with Alaska or Nuanvut to avoid over-harvesting of bears that are vulnerable to harvest in several jurisdictions. In 1988, the Inuvialuit Game Council and North Slope Borough of Alaska implemented the Polar Bear Management Agreement for the Southern Beaufort Sea (Brower *et al*. 2002). It established a total annual harvest quota that, in March 2000, was revised to 80 bears, shared equally between the two jurisdictions. Kills of problem bears and research handling deaths are included in the harvest, of which no more than 27 animals can be female. A review of this agreement in 1998 concluded that it has been successful in limiting the total harvest and proportion of females in the harvest within sustainable limits. It highlighted the need to improve awareness of the need to prevent over-harvesting of females, and the need for better harvest monitoring in Alaska.

vi) What are the information gaps?

Temporal trends in the abundance of bear populations are uncertain. New population estimates should be generated based on ongoing research to facilitate harvest management. These estimates should be updated using comparable research at intervals of 15 years to facilitate population management and trend assessment, sooner if other indicators suggest the need.

The underlying causes of short-term fluctuations in natality and condition remain uncertain. This limits the ability of scientist to accurately predict how bear populations may be affected by long-term trends in sea ice cover. Linkages to other monitoring research on seals and sea ice should be continued and augmented to improve understanding of the how changes in these parameters affect bear populations.

Little is known of trends in contaminant accumulation by bears in the NWT, or of how different levels of these substances affect these animals. The analysis of archived samples might establish trends in contaminant accumulation over time that could be followed on an ongoing basis. The effects of high contaminants levels on the health and reproductive success of polar bears are not well understood.

4.3.2 MEQ Indicator – Beluga

The beluga whale is a mid-level consumer that eats fish and invertebrates and is eaten by polar bears and people. Whales from the Eastern Beaufort Sea stock undertake very extensive seasonal movements that can take them from wintering areas in the Bering Sea to eastern Viscount Melville Sound (Richard *et al.* 2001; Harwood *et al*. 2002). They follow ice leads eastward into the Amundsen Gulf area in May and June from wintering areas in the Bering Sea. As soon as ice conditions permit they move into the Mackenzie Estuary, where they remain until mid-July or early August. Females with calves then make a circuit or two around Amundsen Gulf before returning to their Bering Sea wintering areas. Males and resting females move offshore to the north of Banks Island and into Viscount Melville Sound, before returning west in September and then through Bering Strait in November and December to their wintering areas. The beluga's use of the Mackenzie Estuary makes them vulnerable to harvesters and perhaps to other stressors.

Belugas are an important traditional food source for Inuvialuit living in communities on the NWT mainland (Byers and Roberts 1995; Harwood and Smith 2002; Inuvialuit Harvest Study

2003). Each summer hunters and their families from Inuvik, Aklavik, and Tuktoyaktuk travel to traditional hunting camps along the eastern Beaufort Sea coast (Harwood *et al*. 2002). Most hunting takes place in July in the Kugmallit Bay, Beluga Bay, and Shallow Bay areas of the Mackenzie Delta (Norton and Harwood 1986). Inuvialuit at Paulatuk and Holman also have a tradition of harvesting belugas, usually in late July or August as they pass near the community, although few belugas are harvested in the Holman area (Farquharson 1976; Inuvialuit Harvest Study 2003). Harvested animals likely all belong to same stock, but are taken after the animals leave the estuary and move offshore to feed (Richard *et al*. 2001).

While the beluga stock is believed to be large, population estimates are difficult to obtain due the large geographical extent of their summer range. Monitoring contaminant accumulation by belugas is important, as the Inuvialuit eat these whales in quantity. However, extensive movements by the belugas make it difficult to relate contaminant levels in belugas to contaminants in the Beaufort Sea.

vii) What is being measured?

- **composition of the landed harvest**
- **contaminants**

Hunter-based monitoring programs have collected data on the number of belugas harvested and the efficiency of hunts in the Mackenzie Delta and Paulatuk areas since 1973 and 1989, respectively (Harwood *et al*. 2002). Since 1980, data on the standard length, fluke width, sex, and age of the landed whales have also been collected. These "on-the-beach" observations produced somewhat higher counts of landed whales than the recall surveys used for the Inuvialuit Harvesting Study (2003). Since 1972, tissue samples have been obtained from harvested belugas for contaminant analyses (de March *et al.* 1998).

Studies of trends in the prevalence of disease among belugas have been ongoing since 1999 (Nielsen *et al.* 2004; Philippa *et al*. 2004; O. Nielsen, DFO, Winnipeg, pers. com.). Preliminary results suggest that there has been an increase of 4-5 times in the prevalence of the Brucella virus since 2000, for unknown reasons. This virus causes Brucellosis, which can affect humans. The morbillivirus (distemper), which affects ringed seals and foxes, has not been found in belugas. This suggests that they either are not susceptible to infection or have not been exposed to the virus, which is a concern as this family of viruses can cause high mortality among whales (Nielsen *et al*. 2000). These disease studies rely on year-to year funding from the FJMC for continued operation.

viii) What is happening?

The number of belugas landed each year appears to be declining, despite increases in the human population (Harwood *et al*. 2002). The removal of belugas from the Eastern Beaufort Sea stock, including those landed by Alaskan harvests, is estimated at 189 per year. Harvest efforts are directed mostly at adult male animals (92% >10 years old; 2.3 males/female)

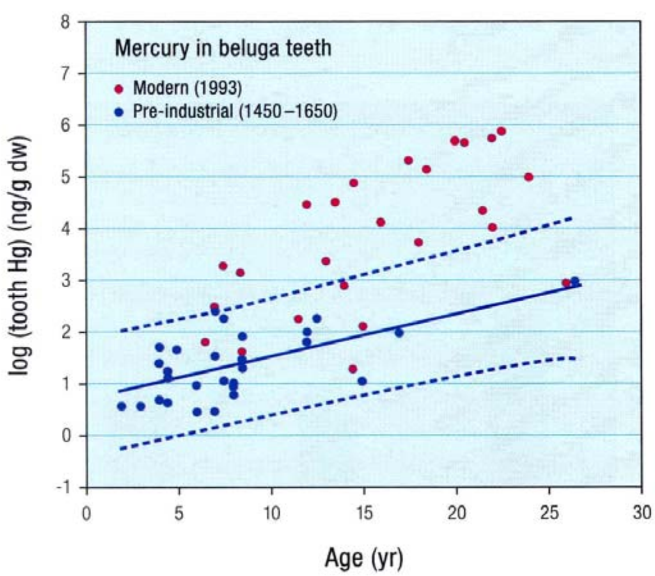
TABLE 4.3-1
BELUGA HARVEST DATA

Period	Average number of belugas harvested annually	Standard Deviation (SD)	Total landed harvest over 10 year period
1970-79	131.8	26.5	1337
1980-89	124.0	23.2	1240
1990-99	110.0	19.0	1110

Source: ***Harwood et al. 2002.***

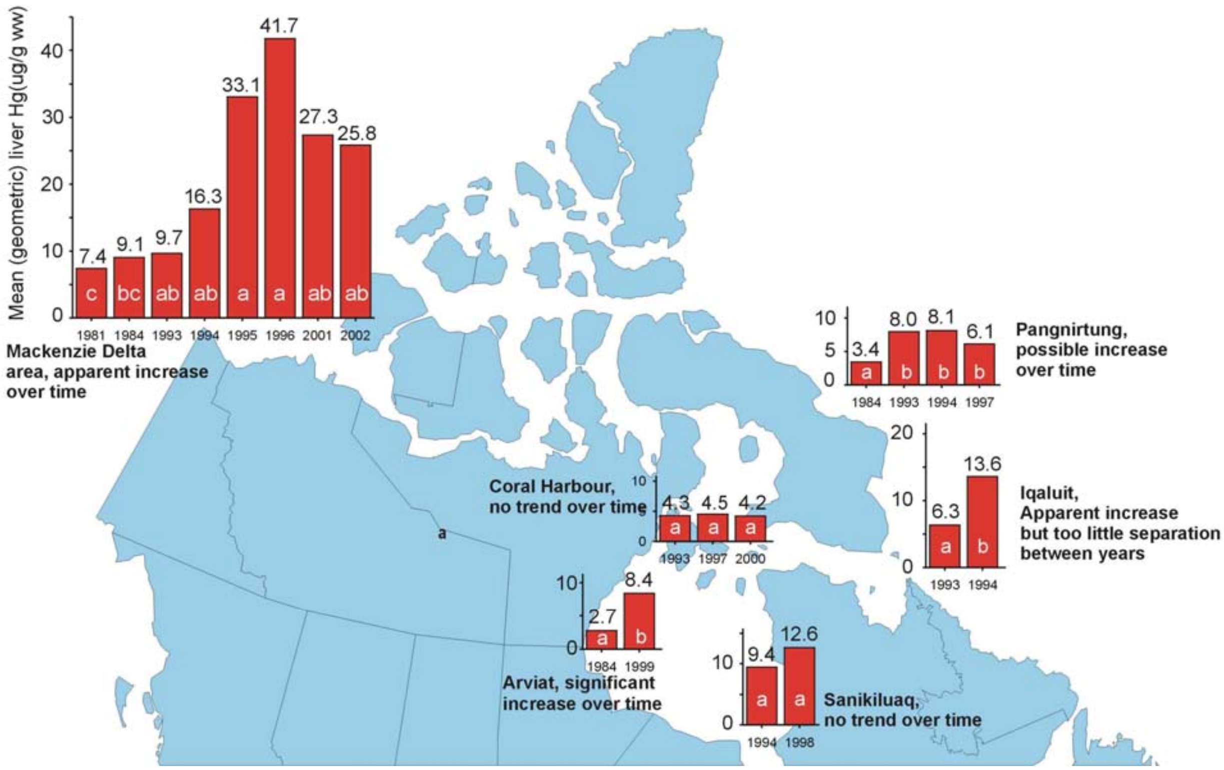
Studies of beluga teeth suggest that industrialization has led to a substantial increase in mercury accumulation by beluga whales that summer in the estuary of the Mackenzie River (Figure 4.3-3). Levels of mercury in the liver of belugas in this area are higher than those found elsewhere in the Canadian Arctic, and appear to have increased since 1981 (Figure 4.3-4).

FIGURE 4.3-3
MERCURY IN MODERN AND PRE-INDUSTRIAL TEETH OF BEAUFORT SEA BELUGA WHALES
(Outridge *et al*. 2002)



Source: CACAR II 2003, p. 80.

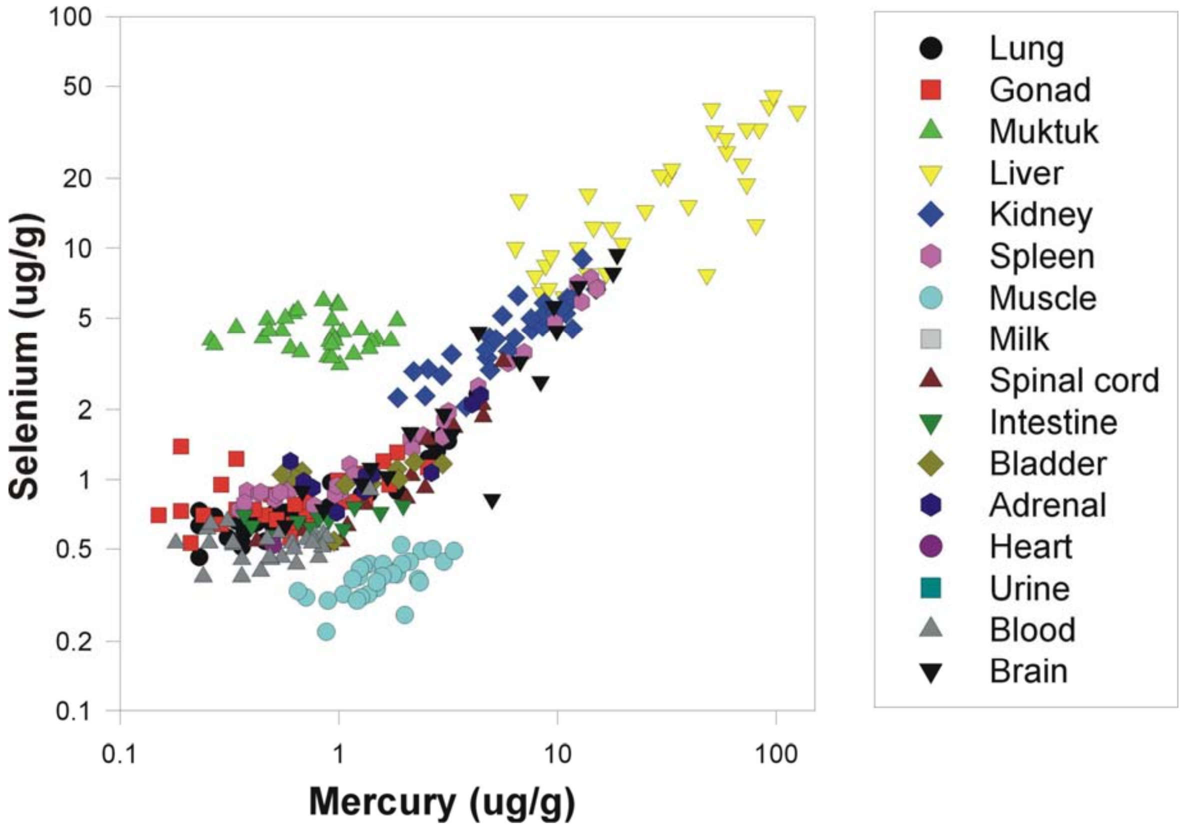
FIGURE 4.3-4
MEAN TOTAL MERCURY CONCENTRATIONS IN BELUGA LIVER



Source: Stewart and Lockhart 2005).

The levels of mercury and selenium vary greatly among different organs of belugas from the Mackenzie Delta (Figure 4.3-5). Mercury concentrations were considerably higher in liver than in other organs, and the level of selenium relative to mercury was relatively low in muscle and high in muktuk. The relationship between mercury and selenium may be important because the presence of selenium can ameliorate the toxicity of mercury (Eaton *et al.* 1981). Only about 6% of the total mercury in liver tissue is present as neurotoxic methylmercury (Lockhart *et al.* 1999). However, other tissues, such as muscle, can have a much higher proportion of methylmercury (Wagemann *et al.* 1998). Some belugas may contain sufficient mercury in their tissues that is could pose a toxicity risk to them (CACAR II 2003).

FIGURE 4.3-5
TOTAL MERCURY AND SELENIUM (µg/g WET WEIGHT)
IN ORGANS OF BELUGA WHALES



Source: Hyatt et al. 1999.

While belugas accumulate high levels of persistent organic pollutants in their blubber (e.g., PCBs from 3500 to 6000 ng/g), typically intermediate between those found in polar bears and ringed seals, temporal trends have not been found (de March *et al.* 1998; Macdonald 2000). Much lower levels are found in the muktuk.

ix) Why is it happening?

The rate of removal of belugas from the Eastern Beaufort Sea stock is small in relation to the expected maximum net productivity rate of this stock, which has an index of abundance of 19,629 belugas (Harwood *et al.* 1996). It is also smaller than historical harvests (Nuligak 1966). However, the annual harvest rate can vary by a factor of two from year to year (Harwood *et al.* 2002). There are no trends in the size of males or females in the harvest over the 30-year period of monitoring.

The accumulation of mercury by belugas is likely related to industrial development (Outridge *et al*. 2002). Pathways by which mercury and manmade organic pollutants enters the Arctic marine food chain are complex and likely to change with shifts in industrial activities and environmental conditions (Macdonald *et al*. 2003b).

x) What does it mean?

Current beluga harvests are believed to be sustainable (DFO 2000; Harwood *et al*. 2002). The low rate of removal, continued availability of large and old individuals after centuries of harvesting, and the apparent stability of the size and age structure of the catch in recent years, support this conclusion. Annual fluctuations in the harvest are likely related to a variety of factors, including changes in the need for beluga products and weather, but these have not been quantified.

Mercury concentrations observed in the meat and muktuk of belugas exceed the Health Canada human consumption guideline of 0.5 µg/g (ww) for commercial fish and 0.2 µg/g (ww) for subsistence fisheries (Macdonald 2000). There is also potential for the dietary intake of muktuk to exceed recommended daily intake levels of various organic contaminants, including PCBs.

xi) What is being done about it?

The Inuvialuit hunters and Canada Department of Fisheries and Oceans prepared the Beaufort Sea Beluga Management Plan (FJMC 1998) to address the management and conservation of belugas in the Canadian Beaufort Sea. Under the Inuvialuit-Inupiat Beaufort Sea Beluga Whale Agreement (2000), Canadian and Alaskan hunters have agreed to share information and co-manage the harvest to conserve the Eastern Beaufort Sea stock.

Work is ongoing internationally to reduce the use of persistent organic pollutants and to identify and reduce levels of new contaminants (AMAP 2004). There are a number of initiatives under the Northern Contaminants Program to inform consumers about the results of contaminants studies and to gather further samples (http://www.ainc-inac.gc.ca/ncp/).

xii) What are the information gaps?

The size of the Eastern Beaufort Sea beluga stock is unknown, so the rate of removal must be estimated. However, stock size is probably much larger than the index of abundance, which is currently used to assess rate of removal. Data are needed on the range, movements, site fidelity, stock structure, and reproductive potential of these belugas (DFO 2000; Harwood *et al.* 2002; CIMP 2005). These data are necessary for developing population models and assessing sustainable harvest potential. Harvest monitors could gather data on the reproductive status and history of harvested belugas that would be useful for assessing the reproductive potential of the population. Little is known of the biological effects of contaminants on belugas, or about temporal trends in their accumulation of persistent organic contaminants in the Beaufort Sea region.

4.3.3 MEQ Indicator – Ringed Seal

The ringed seal (*Phoca hispida*) is smaller and more common and numerous in coastal waters of the Beaufort Sea and Amundsen Gulf than the bearded seal (*Erignathus barbatus*), which is the only other seal species common in the Beaufort Sea (Stirling *et al.* 1977; Smith 1987). As a mid-level consumer, it is a keystone species in the Arctic food web between fish and invertebrates, and foxes, polar bears, and people. Inuvialuit harvested an average of 1085 ringed seals annually over the period 1988 to 1997 (Inuvialuit Harvest Study 2003).

Ringed seals can maintain breathing holes through the landfast ice (Smith 1987; Reeves 2001). This enables them to inhabit nearshore habitats year-round, and to use the more stable ice as a birthing platform. Birth lairs are built in snowdrifts on the ice. Melting conditions that cause the lair to collapse or ice to dissipate before the pups are ready to leave the lair and feed on their own may increase mortality from predation, thermal stress, and starvation (Harwood *et al*. 2000; Stirling and Smith 2004).

Because individuals are present year-round in the coastal waters the ringed seal has been considered a sedentary species, well suited for local contaminants monitoring. In reality, individual seals are very mobile. Animals tagged near Holman Island range northeast to M'Clintock Channel, southeast to Bathurst Inlet, and southwest to Cape Bathurst; those tagged at Paulatuk range west into the Bering and Chukchi seas, some 2625 km (http://www.beaufortseals.com/telemetry.htm). These movements may confound the interpretation of population surveys and contaminants data.

Its widespread occurrence, importance to humans, availability from the harvest, and sensitivity to change in the ice environment makes the ringed seal a useful and cost-effective species for monitoring environmental productivity and the effects of climate change (Stirling and Oritsland 1995). These animals are also useful for monitoring contaminant bioaccumulation, although the sources of these contaminants may be obscured somewhat by their movements.

xiii) What is being measured?

- **body condition**
- **ovulation rate**
- **contaminants**
- **recent pups in the harvest**
- **population density**
- **harvesting**

The annual seal harvest has been estimated from commercial sales records and harvest studies (Stewart *et al.* 1986; Reeves *et al*. 2001; Inuvialuit Harvest Study 2003; Stephenson 2004). While not always directly comparable, these data do provide a rough estimate of the trend over time in harvest removals over the past 50 years. The seal harvest was not monitored in 1998-2001, but since 2002 has been monitored by DFO (Stephenson 2004).

Ringed seals taken in the subsistence harvest at Holman have been sampled annually since 1992 (Harwood *et al.* 2000; L. Harwood, DFO Yellowknife, pers. com. 2005). About 100 animals are examined each year to assess their body condition (fatness) and two parameters of seal reproduction, ovulation rate and recent pups in the harvest. These parameters were selected because they varied with changes in the seal population during work in the same area in 1971-78 (Smith 1987), and because it was possible and practical to monitor these aspects over the long-term through a harvest-based study in the community of Holman (Harwood *et al.* 2000; (http://www.beaufortseals.com/monitoring.htm). Teeth are collected from the seals for aging, and tissue samples have been collected periodically since 1972 for contaminant analyses (e.g., Smith and Armstrong 1975, 1978; Addison and Smith 1998; Stern and Addison 1999; CACAR II 2003). The Holman samples represent the most complete temporal data set for contaminants in seals in the Canadian Arctic (CACAR II 2003), and a valuable source of data for monitoring ocean health (Strain and Macdonald 2002). Studies to collect similar data have been undertaken at the other NWT coastal communities, but do not as yet provide a time series sufficient for useful trend analysis.

Systematic aerial surveys of the distribution and abundance of ringed seals hauled out on the ice of the Beaufort Sea and western Amundsen Gulf were conducted in 1974 through 1979 (Stirling *et al.* 1977, 1982). They are being repeated in the area of the Devon Nearshore Lease, using the same flight paths, each June from 2003 through 2007 (Smith and Harwood 2004). The value of these surveys for long-term monitoring is limited by the wide variability introduced by differences in the ambient weather conditions, timing of breakup, and other factors (Moulton *et al.* 2002). They do provide useful seasonal information on seal densities among areas and habitats, but further work is required before temporal trends can be assessed.

xiv) What is happening?

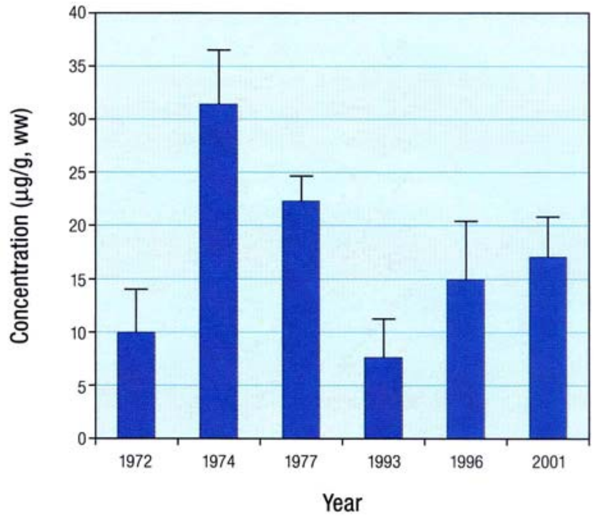
Despite an increase in the human population, the harvest has declined over the past 50 years. Annual removals were probably highest in the 1960s and 1970s, a period when sealskin prices were high (Stewart *et al.* 1986; Reeves *et al.* 2001). At Holman, for example, an average of 2,324 (STD 1312; n = 8 years) sealskins were traded annually to the Hudson Bay Company over the period 1961-74, with an unknown number of animals harvested for subsistence (Reeves *et al.* 2001). Harvests declined substantially in the 1980s following a collapse in sealskin prices related to the 1982 European ban on the import of skins from newborn harp and hooded seal pups. A strong subsistence harvest has continued, but there is no longer a substantial harvest of seals for the commercial sale of pelts. Over the period 1988-97, Holman hunters harvested 839 animals on average annually for subsistence (Inuvialuit Harvest Study 2003).

In the mid 1970s significant declines were observed in seal ovulation rate and proportion of young seals in the harvest at Holman and Sachs Harbour, after which they increased at both areas (Stirling 2002) (Figure 4.3-4). The body condition of adult female seals ($\geq$ 7 years of age) at Holman was poorest in 1974, which was a particularly heavy ice year (Harwood *et. al*. 2000; Stirling 2002). Fewer than half of the adult females examined that year were reproducing, compared to normal years when most reproduce. A widespread decline in the seal population of the Beaufort Sea-Amundsen Gulf area was also observed between 1974 and 1975 (Stirling *et al.* 1977), and again in the mid 1980s concurrent with heavy ice conditions (Stirling 2002). A similar decline may have occurred in the mid-1960s (Stirling *et al.* 1977). In contrast, 1998 was a year with a particularly early breakup and long period of open water (Harwood *et al*. 2000; http://www.beaufortseals.com/monitoring.htm). Many starveling pups were found while the older animals were in good condition. Apparently the early breakup provided favourable energetic conditions for the older animals but caused some pups to be weaned before they were ready, particularly those at the periphery of the seal breeding habitat.

The proportion of pups in the harvest fluctuated markedly and was not closely matched to ovulation rate the previous year (Harwood *et al.* 2000). The harvest is sensitive to weather and ice conditions that influence the availability of pups to hunters at breakup. Consequently, the proportion of pups in the harvest may not be a particularly good measure with which to assess population status or recruitment.

Average mercury concentrations in Holman ringed seals varied significantly over the 30-year period 1972-2001 (CACAR II 2003) (Figure 4.3-6). Higher concentrations were found in 1974 and 1977 (Smith and Armstrong 1978) compared to 1993 and 1996 (Wagemann *et al*. 1996). Results from 2001 were also significantly higher than in 1993 (Muir *et al*. 2002).

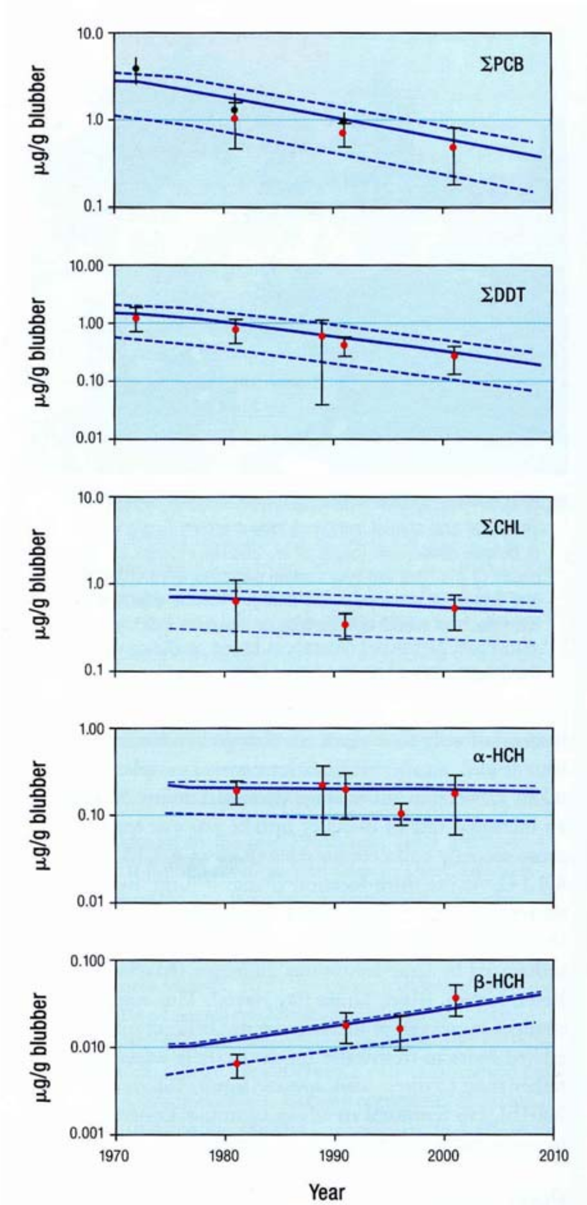
FIGURE 4.3-6
TEMPORAL TRENDS IN TOTAL MERCURY IN THE LIVER OF RINGED SEALS AGED 5 – 15 YEARS FROM HOLMAN, NWT (1972-2001)



Source: CACAR II 2003, P. 79.

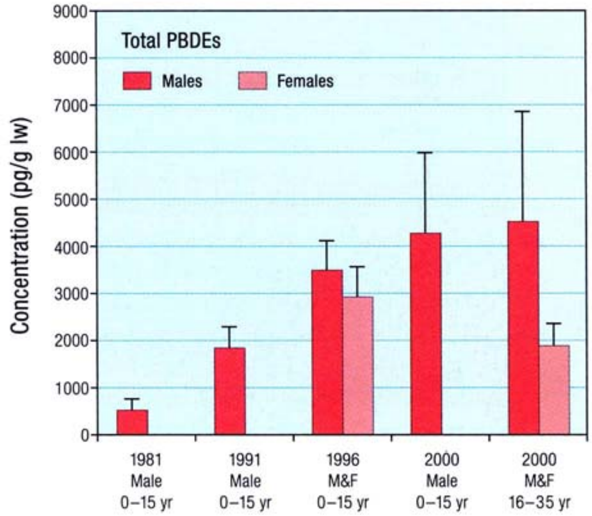
The levels of persistent organochlorine contaminants in the blubber of ringed seals from Holman are changing over time (Figure 4.3-7). The direction of change varies with the class of contaminant. Significant declines in the concentrations of polychlorinated biphenyls (∑PCB) and dichloro-diphenyl-trichloromethane (∑DDT) have been observed; chlordanes (∑CHL) and hexachlorocyclohexanes (∑HCH) have not changed significantly, but the α-HCH : β-HCH ratio has decreased since the early 1980s (CACAR II 2003; AMAP 2004). The change in ratio is a direct result of cessation of technical HCH use and the relative persistence and lag in delivery of β-HCH compared to α-HCH. Sample archiving has enabled researchers to revisit samples taken from ringed seals in the 1980s and 1990s, to establish that there has been a dramatic increase in the concentrations of polybrominated diphenyl ethers (PBDEs) in ringed seal blubber over the past two decades (Figure 4.3-8).

FIGURE 4.3-7
OBSERVED AND PREDICTED TRENDS OF POPS CONCENTRATIONS FOR RINGED SEALS FROM HOLMAN ISLAND



Source: CACAR II 2003, PG. 82 After Hickie 2002.

FIGURE 4.3-8
INCREASING CONCENTRATIONS OF TOTAL BR2-BR7 PBDE CONGENERS IN RINGED SEAL



Source: Macdonald et al. 2003a, p. 77, after Ikonomou et al. 2002)

xv) Why is it happening?

Changes in the ice environment have been linked to drastic changes in seal populations and reproduction over periods of several years at intervals of about 10 years. These population changes are likely related directly or indirectly to short-term changes in the ice environment, but disease and migration may also be contributing factors (Stirling *et al*. 1977).

Higher mercury levels in the western Arctic than in the eastern Arctic have been attributed to differences in the natural background concentrations (Wagemann *et al*. 1995, 1996), but factors underlying temporal differences in mercury concentrations are not well understood.

Body burdens of persistent organic pollutants reflect changes in the global use patterns of these chemicals--albeit with some time lag, and differences in their availability to the food web (Addison and Smith 1998; CACAR II 2003; AMAP 2004). The relatively recent development and use of fire retardant compounds in manufacturing has led to a global increase in the emissions of PBDEs. These persistent organic contaminants reach the Arctic by long-range transport mechanisms, and have increased sharply in Arctic biota over the past several decades.

xvi) What does it mean?

Ringed seals appear to be very sensitive to changes in their ice environment, which is a key determinant of their energetics and reproductive success. This makes them a very useful indicator of climate change. Their contaminants levels provide a good indication of trends in the bioaccumulation of some toxic substances by the pelagic food web, and in the exposure of polar bears and people to these persistent contaminants.

xvii) What is being done about it?

Studies are underway under CACAR (CACAR II 2003), AMAP (AMAP 2004), and the Northern Contaminants Program (http://www.ainc-inac.gc.ca/ncp/summ0405/nt_e.html) to identify emerging contaminants and to assess their impacts on marine biota. The main objective of the Northern Contaminants Program is to reduce and, wherever possible, eliminate contaminants in traditionally harvested foods, while providing information that assists informed decision making by individuals and communities in their food use (http://www.ainc-inac.gc.ca/ncp/index_e.html).

Continued community-based monitoring through harvest-based projects has been recommended as a good method for gathering data on trends in seals (CIMP 2005). These studies collect biological data that are otherwise difficult and expensive to gather, and provide more useful information than studies that simply enumerate the harvests.

xviii) What are the information gaps?

DFO has identified the need for data and information on the range, movements, site fidelity and stock structure of ringed seals, and on the impacts of climate change related to reduced ice cover (CIMP 2005). Better understanding of seal movements is needed to determine whether animals in the Beaufort Sea belong to a single population or several populations, and the extent to which seals in the Holman area represent those elsewhere in the NWT. The biological implications to ringed seals of the contaminants they accumulated are not well understood. The species' ability to adapt to changes in the ice environment is unknown, and a very important information gap.

Seals collected at Holman have been aged by counting growth rings in the dentine (Smith 1987; L. Harwood, DFO Yellowknife, pers. comm. 2005). This method tends to underestimate seal ages, particularly those of older animals with worn teeth (Stewart *et al.* 1996). It limits the comparability of data with that from elsewhere, and its use for age-specific determinations. Aging seals using growth rings in the tooth cementum provides a better record of age (Stewart *et al*. 1996). Consideration should be given to aging seals in future using both dentine and cementum to facilitate comparison and age-specific analyses.

4.3.4 MEQ Indicator – Red-throated Loon

Red-throated loons (*Gavia stellata*) arrive at offshore leads in the Beaufort Sea - Amundsen Gulf area in late May or early June (Dickson 1992, 1993, 1994; Dickson and Gilchrist 2002). They remain there until the shallow tundra ponds they nest beside have open water. These birds are a widely distributed, conspicuous nesting species near the coasts in summer. They typically nest within 8 km of the coast or a large lake and, because the shallow nesting ponds winterkill, those near the coast travel there to forage for fish to feed their young. The young remain at the nest until they are fledged, longer than most other marine bird species in the region. Because they migrate, the value of adult loons for local contaminant monitoring is limited. However, because of their coastal diving habit they are very vulnerable to local oil pollution.

The Canadian Wildlife Service studied the abundance, breeding effort, and breeding success of the red-throated loon along the mainland NWT coast between 1985 and 1989 (Dickson 1992). The species was identified as suitable for monitoring environmental changes caused by offshore oil and gas development in the Beaufort Sea. Little inter-annual variation was observed in the number of loons with breeding territories or in breeding effort, but there was wide variation in breeding success. Breeding success was recommended as the key indicator for monitoring purposes. However, due to wide natural inter-annual variability, only large changes in productivity (31-43%) will be detectable with statistical certainty (95%). This may make human-induced change difficult to identify, and necessitates long-term study to identify natural trends. The 1980s surveys have not been repeated, so trend over time in this indicator cannot be established.

Females pass very little in the way of contaminants on to their eggs, but feed the chicks almost entirely on small coastal marine fish (L. Dickson, CWS, Edmonton, pers. com. 2005). Consequently, contaminants accumulated by the young before they leave the nest originate from the local marine environment, making them a useful indicator of the local availability of contaminants to fish-eating marine birds. However, the available data are insufficient to assess trends over time.

4.3.5 MEQ Indicator – Anadromous Dolly Varden and Arctic Char

Anadromous Dolly Varden (*Salvelinus malma*) and Arctic char (*Salvelinus alpinus*) spawn and winter in fresh water but feed at sea during the summer. The two species are often confused with one another. Dolly Varden typically occurs west of the Mackenzie, while fish to the east and on the Arctic islands are typically Arctic char (Reist *et al*. 1997). These fish are low to mid-level consumers that eat freshwater and marine invertebrates and smaller fish, and are eaten by ringed seals, belugas, and people.

Both species show a high degree of fidelity to their natal spawning and over wintering areas, and because of their extensive seasonal movements a particular wintering stock may be vulnerable to harvest at numerous locations. Dolly Varden from the Rat and Big Fish rivers, for example, are vulnerable to capture along the Yukon coast, near Shingle Point, in the Mackenzie mainstem, and in their individual river systems (DFO 2001). This predictability makes them attractive to harvesters and vulnerable to over-harvesting. These fish are harvested in quantity for subsistence, sport and commercial sale, and are important to the culture and economy of the Inuvialuit (Stewart *et al*. 1993; Inuvialuit Harvest Study 2003; Stephenson 2004) and Gwich'in (Stewart 1996; MacDonald 1998a,b; http://www.grrb.nt.ca/Harvest_Study.html). Arctic char tagged at the Hornaday River system show very strong fidelity to that system (DFO 1999). They feed along the nearby coast and winter in the river system, and tagging studies have not found strays entering other systems. They appear to be vulnerable to harvest only by the Inuvialuit from Paulatuk.

Arctic char have been recommended as an ideal species for assessing the impacts of climate change on Arctic fishery resources (Reist *et al*. 2004). Char populations may become more productive over the short term in response to increased nearshore production, but over the long term may be replaced by other salmonid species that move northward to take advantage of increasingly favourable habitats.

xix) What is being measured?

- **population size**
- **catch per unit effort**
- **age at harvest**
- **fish condition**
- **harvest**
- **contaminants**

Most studies to assess the health of these fish populations have subsampled commercial, subsistence, or sport harvests for data on growth, reproduction, population structure, and condition (Ratynski *et al*. 1988; Stewart and Ratynski 1995; Stewart 1996). Some of these studies have provided tissue samples for contaminant analysis; others have estimated population size based on mark-recapture studies or counts at weirs. Typically, the annual harvest of fish from a particular population is uncertain and difficult to establish, due in part to the species' extensive movements. The sampling programs often have been undertaken in response to community concerns over resource depletion or fish quality. Studies conducted at the Rat (DFO 2001), Big Fish (DFO 2003), and Hornaday (DFO 1999) rivers are examples of this, but are unusual in their longevity and continuity. Populations in other rivers such as the Kagloryuak, Kuujjua, Kuuk, and Nalaogyok have also been studied. While some data are available on contaminants of the fish in these systems, they are too few to provide a useful assessment of the trend of accumulation over time (Macdonald 2000).

At the Rat River, annual harvest estimates are available beginning in 1986, with some earlier data back to 1972 (DFO 2001). Timing of the peak of the fishery at various locations has been recorded since 1996. Sex, maturity and catch-per-unit-effort (CPUE) data are available from the subsistence fishery since 1989. Mark-recapture estimates are available for the population in 1989, 1996, and 1998.

Population estimates based on mark and recapture studies (Peterson method) and weir counts are available for Dolly Varden in the Big Fish River in 1972, 1984, 1987, 1988, 1991, 1993, and 1998 (DFO 2003). Not all of these studies are directly comparable.

Data are available on the annual harvest of Arctic char from the Hornaday River since 1968 (DFO 1999; Stephenson 2004). Data on the catch-per-unit-effort by the fishery, mean age of male and female fish, and the condition of fish in the harvest were also collected between 1990 and 1998.

xx) What is happening?

At the Rat River, harvest levels appear to have been reduced since the 1970's (DFO 2001). This decline may be related to closure of the commercial fishery in 1985. The CPUE has fluctuated about an average of 38 fish/100 net m/24 h since 1986; the use of smaller gillnets (89 mm stretched measure) was discontinued by 1998. There were no trends in mean age over time, and the absence of smolts in the harvest after 1998 is likely related to the change in mesh size of the gillnets used in the fishery.

At the Big Fish River, abundance estimates suggest that the population was reduced substantially between 1972 and 1988, and has not recovered (DFO 2003). Over the five-year period ending in 1998 with the most recent population estimate, the number of adult fish in the population appears to have remained relatively stable at about 4000 fish.

The Paulatuk fishery removes the larger char from the Hornaday River stock (DFO 1999). While fish are now harvested only for subsistence, there was a substantial commercial harvest until 1986, when commercial fishing was suspended in response to concern that the stock was being over-harvested. Harvests peaked over the period 1976 to 1984, and since then have declined slowly, except in 1995 when there was a particularly large harvest (DFO 1999; PCWG 2002; Stephenson 2004). Both the CPUE and mean age of harvested fish were low from 1995 through 1997, but have recovered somewhat since then (DFO 1999; PCWG 2002). The condition of fish has varied among years, but was particularly good in 1993 and 1998, which were both years of light regional sea-ice conditions and early breakup.

xxi) Why is it happening?

In the Rat River stock, fluctuations in CPUE may be correlated with timing of the run, with unusually high CPUE in 1998 when the run was three weeks earlier than usual and unusually low in 2000, when the run was three weeks later than usual (DFO 2001).

The apparent lack of recovery of the Big Fish River stock, despite closure of the fishery in 1987, may reflect habitat changes rather than harvesting pressures (DFO 2003). The water level of the fish hole is much lower than in the 1960s and 1970s; salinity of this spring-fed pool has declined; and the mean annual air temperature in the area has been increasing. Seismic events in the region may have reduced the rate of groundwater flow into the site.

The Hornaday River stock does not appear to be capable of sustaining harvests of the magnitude taken in 1995 (DFO 1999). Changes in the data suggest that the subsistence harvest in 1995 removed a substantial proportion of the older fish in the population, and that it took several years for the stock to recover. Light ice conditions may result in better coastal feeding conditions.

xxii) What does it mean?

Results from the harvest monitoring suggest that the Rat River Dolly Varden stock is stable and sustaining the present harvest level (ca. 2000 AD) (DFO 2001). The timing of the run varies considerably in response to environmental conditions.

While empirical evidence is lacking, both fishers and scientist agree that habitat changes may be limiting the recovery of the Big Fish River Dolly Varden stock (DFO 2003). These changes must be taken into account in management of this fishery, which is further complicated by the vulnerability of this stock to harvest by mixed-stock fisheries along the coast and in the Mackenzie River system.

While the sustainable harvest level for the Hornaday char stock cannot yet be determined, care must be taken to avoid over-harvesting. There may be important linkages between sea ice cover and the condition of anadromous fishes.

xxiii) What is being done about it?

Working groups have been established to coordinate fishing pressure on these shared populations and prevent over-harvesting. A community based fishery plan has been in place at Aklavik and Fort McPherson for the Rat River since 1995, and community-based sampling program has monitored the fishery since 1989 (DFO 2001; http://www.fjmc.ca/rat_river_charr.htm). The fishery plan recommends that the annual harvest of Dolly Varden by the food fishery not exceed 2000 fish and specifies the number of nets, their size, and depth restrictions.

The West Side Working Group (WSWG) made up of fishers from Aklavik, community elders, biologists, and managers is working to develop a long-term, objectives-based Fisheries Management Plan for the Big Fish River and other rivers between the Mackenzie River and the Canada/Alaska border (DFO 2003). In addition, the Aklavik Inuvialuit Community Conservation Plan has designated the Fish Hole and riparian areas of the Big Fish River as Management Category E to protect them from development.

Char in the Hornaday River are now managed under the Paulatuk Char Management Plan, which was developed by the Paulatuk Char Working Group (PCWG) (DFO 1999; PCWG 2002). This plan has recommended the closure of Fish Holes between Coalmine and Aklak Creek to fall and winter fishing and a limit of 2000 on the total annual harvest of char from the river (PCWG 2002). The community does not have an alternative source of anadromous Arctic char nearby (MacDonell 1989), and wishes to conserve the stock and ensure its long-term well being (DFO 1999). Consequently, fishing for alternate species has been encouraged and fishers will be supported if they fish at alternate locations.

Completion of the Inuvialuit Harvesting Study in 1997 left a void in harvest monitoring that has been partially filled for fish and seals by DFO (Stephenson 2004). The department has made a number of recommendations for future harvest monitoring programs, including:

- their incorporation in any future fishing management plans; and that they
- document the harvest of specific stocks at specific locations or times;
- inquire about the capture of rare or unusual species;
- use door-to door rather than written surveys;
- be conducted co-operatively by several government departments;
- focus on the period(s) of highest harvesting activity in their area; and
- target sensitive species or areas, particularly those at the greatest risk of impact from increasing oil and gas activity.

xxiv) What are the information gaps?

Information is not currently collected on smolts from the Rat River population. Their collection would provide more information on recruitment, but would also increase mortality. Linkages between habitat changes and the failure of the Big Fish River population to recover are uncertain. If habitat changes are limiting the fishery, knowledge of the mechanisms by which they act could improve the ability to manage regional fisheries in response to changing climatic conditions.

Sustainable harvest levels, the vulnerability of stocks at various locations, and the reasons for declining harvests are uncertain for most stocks. Linkages between sea ice cover and the condition of anadromous fishes have not been examined, but may be important determinants of the sustainable harvest level.

4.3.6 MEQ Indicator--Sea Ice

Changes in the ice cover have major implications for the Beaufort Sea/Amundsen Gulf area. The reduction or loss of seasonal ice cover would reduce or eliminate an important component of the freshwater budget (i.e., sea ice melt) and threaten existing ecosystems (Carmack and Macdonald 2002; Macdonald *et al*. 2003b). How changes in the ice environment affect each species will depend very much on the exact way in which the animal or plant uses ice, and on the plasticity of that use.

A reduction or elimination of seasonal ice cover would:

- initially increase and eventually reduce or eliminate polynya and ice edge habitats that are important areas for the exchange of energy between ecosystems;
- alter seasonal tidal spectrums by reducing or eliminating the damping effects of ice cover;
- reduce or eliminate coastal ice scour and the redistribution of sediment and other material trapped within the ice or carried on its upper or lower surface;
- increase surface salinity by reducing or eliminating the release of fresh water at the surface by melting sea ice. With a thinner layer of low salinity water at the surface, and longer open water period, wind mixing should make more nutrients available to primary producers in the upper water column (Dunbar 1993).
- make more light available to primary producers;
- increase surface water temperature and reduce or eliminate freezing of macrophytes;
- reduce or eliminate ice habitats, their associated biota and seasonal biological production; and
- trigger trophic changes, from the bottom up and top down (Macdonald *et al*. 2003b).

A shorter duration of ice cover when coupled with stronger winds may:

- increase re-working of coastal habitats by wave action, leading to increases in longshore sediment transport and changes in spit and delta formation;
- increase winter mixing and upwelling, and thereby the nutrients available to phytoplankton (Carmack and Macdonald 2002);
- favour more severe wave development and more frequent storm surges; and
- lead to warmer temperatures and earlier melt in coastal areas. The rate of evapotranspiration would increase and could lead to drying of wetlands and lengthening of the growing season.

These changes are not necessarily linear and there may be a few threshold responses and non-linear surprises. There may also be unexpected cumulative effects when impacts of climate change interact with those from other environmental stressors.

xxv) What is being measured?

- **duration of ice cover**
- **areal extent of seasonal ice cover**
- **ice draft**

Satellite passive-microwave observations have proven tremendously valuable for monitoring the duration and extent of sea ice coverage. Observations of Arctic ice began in December 1972, following the launch of the Electronic Scanning Microwave Radiometer (ESMR) on board NASA's Nimbus 5 satellite (Parkinson 2000b). The ESMR provided good-quality data for most of the period from January 1973 through October 1976, but had only one channel so the accuracy of derived ice concentrations was ±15% and ice types could not be distinguished from one another. Since October 1978, more advanced passive-microwave instruments aboard subsequent U.S., Canadian, and European satellites have provided a record of ice concentrations that is more accurate and distinguishes between different types of ice (Parkinson 2000b; Parkinson and Cavalieri 2002; http://ice-glaces.ec.gc.ca).

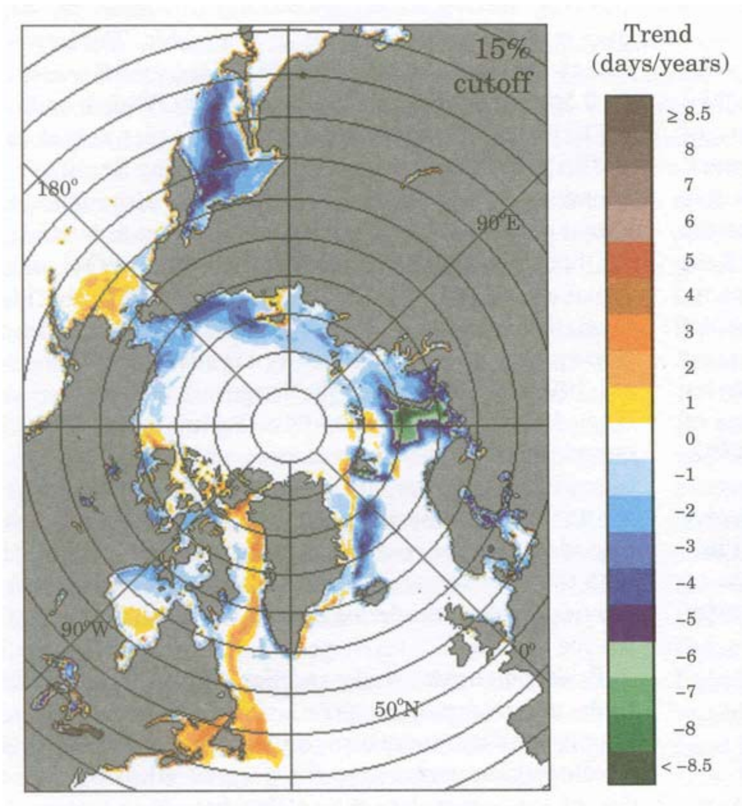
Ice draft has been measured since the late 1980s in the Beaufort Sea area using upward-looking sonar moored to the bottom of the ocean (Melling and Riedel 2004; http://www.aslenv.com/iceprofiler.htm), and using submarine-based upward looking sonars (Winsor 2001). Sea ice draft is a measure of the subsurface ice thickness, whereas the total thickness also includes the above-surface freeboard which accounts for about 10% of the ice thickness. In the past, the Canadian Ice Service also collected ice thickness data manually at stations along the NWT coast (http://ice-glaces.ec.gc.ca/). The length of the data record varies with station: Sachs Harbour (1956-86), Mould Bay (1949-97), Holman (1960-69), Cape Parry (1959-92), and Tuktoyaktuk (1971-77).

xxvi) What is happening?

The results of ice cover studies vary somewhat depending upon the area, parameters, and length of the observation record examined. Satellite observations suggest that there has been a general decrease in the duration and areal extent of the Arctic sea ice cover since the mid-1970s (Parkinson *et al*. 1999; Serreze *et al*. 2003; Johannessen *et al*. 2004). This is consistent with observations in Amundsen Gulf and the western Beaufort Sea, whereas the duration of sea ice cover increased slightly in the eastern Beaufort Sea (1979-96; Figure 4.3-9), as did the average sea ice concentration (1979-2000; Barber and Hanesiak 2004). Over the period 1978-2003, there was a slight decrease in the mean winter (March) ice concentration in the southeastern Beaufort Sea, but a slight increase in summer (September) (Johannessen *et al*. 2004). The increasing trend in ice concentration was greater over the period 1979-1996 than it was from 1979-2002 (Figure 4.3-10) (Rigor and Wallace 2004). This was due, at least in part, to record minima in the extent of the sea ice cover in September of 1998 and 2002 (Serreze *et al.* 2003). Since that analysis was completed, low sea ice cover was also reported in September of 2003 and 2004 (Stroeve *et al*. 2005).

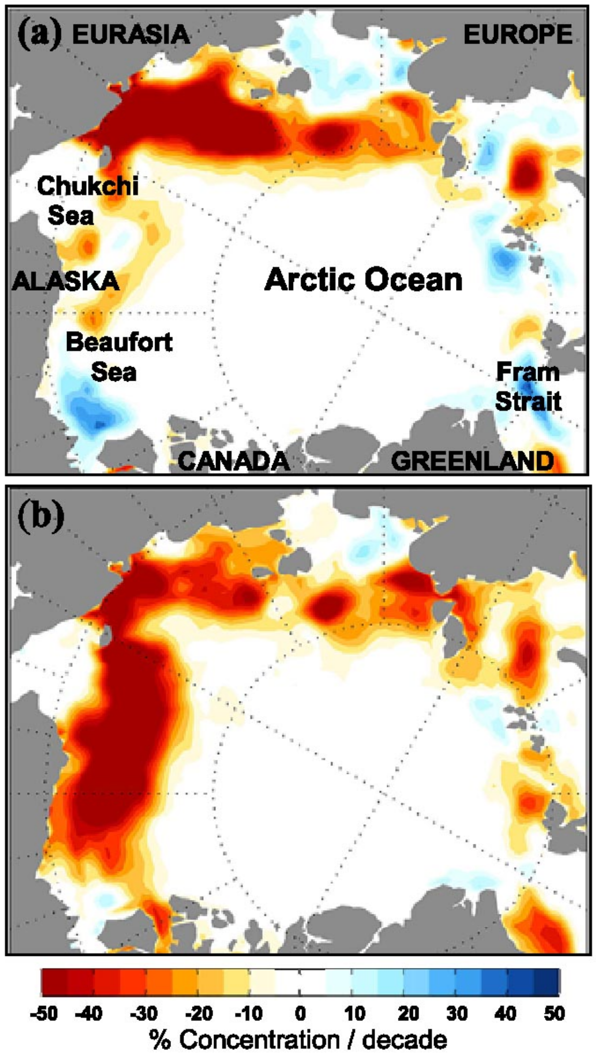
Between September 1991 and March 2003, a small thinning trend (0.07 m/decade) was found in ice draft at a site over the Mackenzie Shelf of the Beaufort Sea (Figure 14) (Melling et al. in press). The net change did not exceed the accuracy of measurement (±0.1 m), and was not statistically significant since seasonal and inter-annual variability are large. Ice was unusually thin during 1997-98. The trend toward greater ice concentration (0.12 m/decade), meaning more ice in summer, was significant at the 93% level. Data from conventional ice reconnaissance suggest that there has been little net change in ice conditions over the Beaufort shelves during the past 36 years, despite dramatic a decrease in summertime ice over the south-western Canada Basin to the northwest and a significant (1.6±0.4°C at 95% confidence) increase in air at Tuktoyaktuk, 100 km to the south (Melling et al. in press) (Figure 15).

FIGURE 4.3-9
TRENDS IN THE LENGTH OF THE SEA ICE SEASON FROM 1979 THROUGH 1996



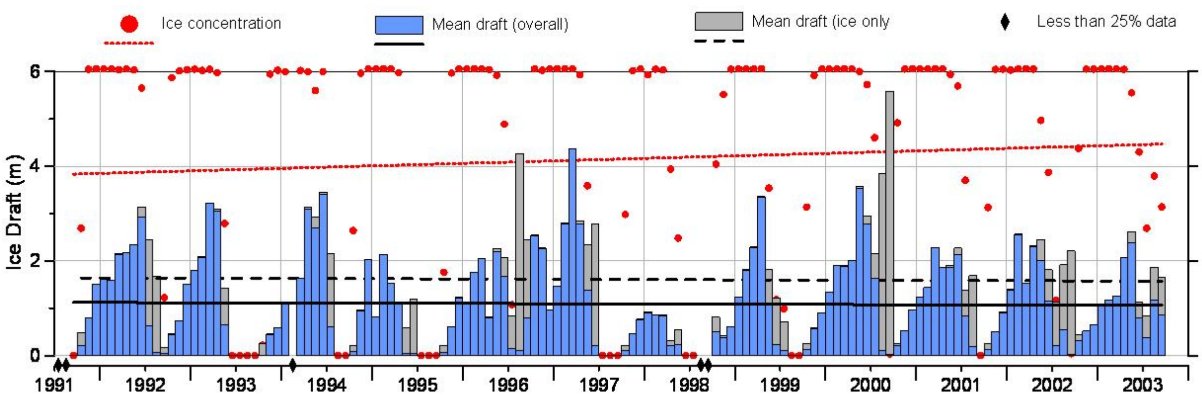
Source: ***From CACAR II 2003, (P. 79)***.

FIGURE 4.3-10
TRENDS IN SEPTEMBER SEA-ICE CONCENTRATION FROM MICROWAVE SATELLITE DATA FROM 1979-1996 (A) AND 1979-2002(B)



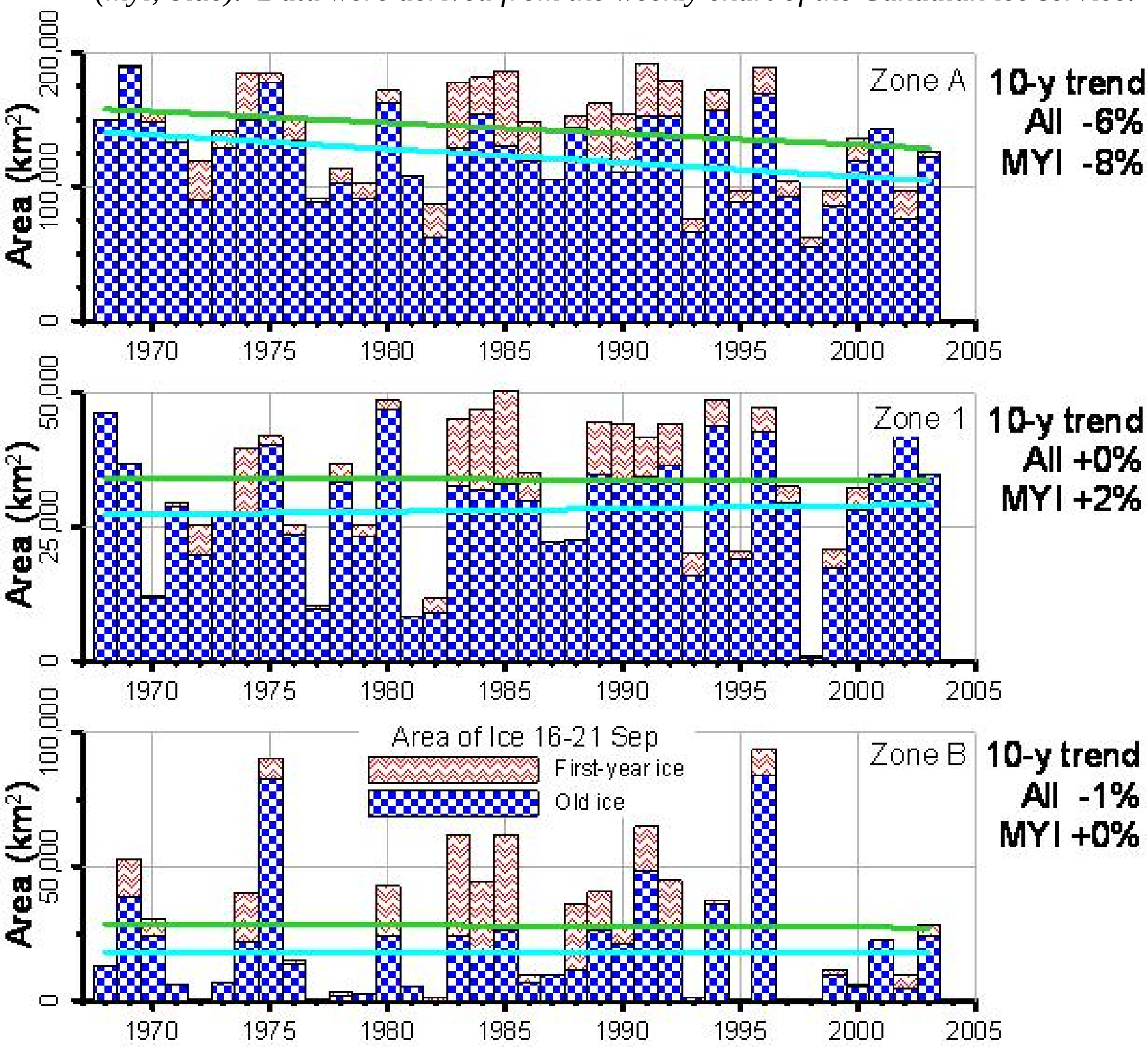
Source:Rrigor and Wallace 2004,(p. 2).

FIGURE 4.3-11
MONTHLY AVERAGE CONCENTRATION AND DRAFT OF PACK ICE ON THE MACKENZIE SHELF OF THE BEAUFORT SEA, 1991-2003.



Source: Figure courtesy of H. Melling, DFO Sidney, pers. com. 2005.

FIGURE 4.3-12
AREA COVERED BY SEASONAL AND MULTI-YEAR PACK ICE IN THE BEAUFORT SEA IN MID-SEPTEMBER, 1968-2003.
Zone a (top) is the domain of perennial pack ice in the Canada basin, zone 1 (middle) is the eastern continental shelf west of banks island, and zone b (bottom) is the southern continental shelf west of Cape Bathurst. Trend lines are shown for all ice (green) and for multi-year ice (myi; blue). Data were derived from the weekly chart of the Canadian ice service.



Source: Figure courtesy of H. Melling, DFO Sidney, pers. com. 2005.

xxvii) Why is it happening?

While the satellite sea ice data show changes in the sea ice, they do not explain their causes or predict future changes (Parkinson and Cavalieri 2002). If the recent observed changes are tied most closely to Arctic warming (Martin *et al*. 1997; Serreze et al. 2000; Johannessen *et al.* 2004) that continues, then the ice cover should continue to decrease; but, if the sea-ice changes are tied more closely to oscillatory changes in the climate system, such as the North Atlantic Oscillation and the Arctic Oscillation (Deser *et al.* 2000; Morison *et al*. 2000; Parkinson 2000a), then sea ice cover will likely fluctuate (Parkinson and Cavalieri 2002). Local, regional, and internal processes may play a more significant role in shaping the persistence of Arctic change than has previously been recognized (Barber and Hanesiak 2004; Overland and Wang 2005). Changing snow cover, ice circulation and ice deformation may obscure the direct effects of warming on seasonal pack ice (Melling et al. in press).

xxviii) What does it mean?

Uncertainty in the underlying causes of changes in sea ice cover means that extrapolations of recent sea ice conditions into the future should be done with caution (Parkinson 2000a).

xxix) What is being done about it?

There is intense concern over the potential impacts of significant changes in the ice cover on the Arctic ecosystem and on human activities. Large-scale research programs such as CASES and Arctic Net, which were described above, are underway to improve monitoring capabilities and assess changes in the sea ice. The results of these and other studies feed into programs such as the International Program for Climate Change (IPCC) and Arctic Monitoring and Assessment Program (AMAP), which consider their implications.

xxx) What are the information gaps?

While synoptic data are available for the duration and extent of ice cover, they are not available for ice thickness. This is a very important gap in the information necessary to understand changes in ice cover and develop predictive climate models (Laxon *et al.* 2003). The factors underlying natural variability of the sea ice cover, atmospheric couplings, and linkages between changes in sea ice and other aspects of the marine ecosystem are also uncertain. These information gaps limit the ability to predict how ice cover may change over time, and how species and biological communities may respond over the short or long term, and from one area to another. Longer time series are needed to detect and understand changes in the sea ice (Melling et al. in press). The role of sea ice in moving contaminants from one part of the environment to another also needs to be better understood.

4.4 RECOMMENDATIONS

Effective monitoring for changes in the health of the marine environment caused by human activities will not be possible until the natural variability of the indicators used for environmental

monitoring has been established. Many natural cycles in the Arctic are affected by the dramatic climatic shifts associated with the Arctic Oscillation, which follows a 5 to 7 year cycle. Only once the effects of these cycles, and of other environmental linkages, are understood will it be possible to differentiate changes that occur naturally in a healthy marine environment from those that are caused by human activities.
Lack of information on natural variability affects all types of monitoring, even that of contaminants and sea ice. The contaminants, because variability related to age of capture and diet is not well understood; the sea ice, because it may follow a cycle of natural variability that exceeds the length of our comparable records. Short-term (<5 y) research programs of the sort used to gather baseline environmental data for impact studies cannot properly assess natural variability, nor can collecting samples every 5 years circumvent the problem.

The solution to this problem lies in the design and completion of elegant long-term (>10 y) research designed to develop appropriate monitoring strategies, and the implementation of these strategies over the long term. Effective monitoring requires the proper choice of monitoring parameters; well-designed studies that are repeatable reliably over time; long-term support and continuity; the cooperation and participation of local communities, to ensure the integrity and success of sampling programs; and competent personnel.

Government scientists are often best equipped to conduct this research, and to provide the resources, expertise and long-term stability required for this work. However, fiscal planning must extend past the next fiscal year or next election. Otherwise the existing, short-sighted planning horizon that has failed to provide adequate resources for environmental monitoring will continue. This short-term approach simply does not support the type of science required for environmental monitoring, particularly cumulative impact assessment, and the problem is too important to ignore. New, ongoing research by the CASES and Arctic Net projects may provide the data necessary to establish natural variability, but only if their support base is maintained over the long term.

At present, community-based harvest sampling programs are the cornerstones of work to assess temporal trends in the marine environment of the NWT. This top-down approach may be a cost effective method of identifying that change is occurring, but it does not provide the information necessary to understand why change is occurring. Linkages between trends in these harvested species and their environment, and between contaminant burdens and species' health must be established. The applicability of these relatively local studies to other geographical areas, populations, or biota in the region must also be established. Establishing linkages between the quality, extent and duration of sea ice cover and biological indicators may be particularly important for understanding natural trends and assessing the effects of any climate change. The archiving of aging structures and banking of tissue specimens will be critical to future retrospective work on temporal trends in contaminants.

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5.0 TERRESTRIAL ENVIRONMENT

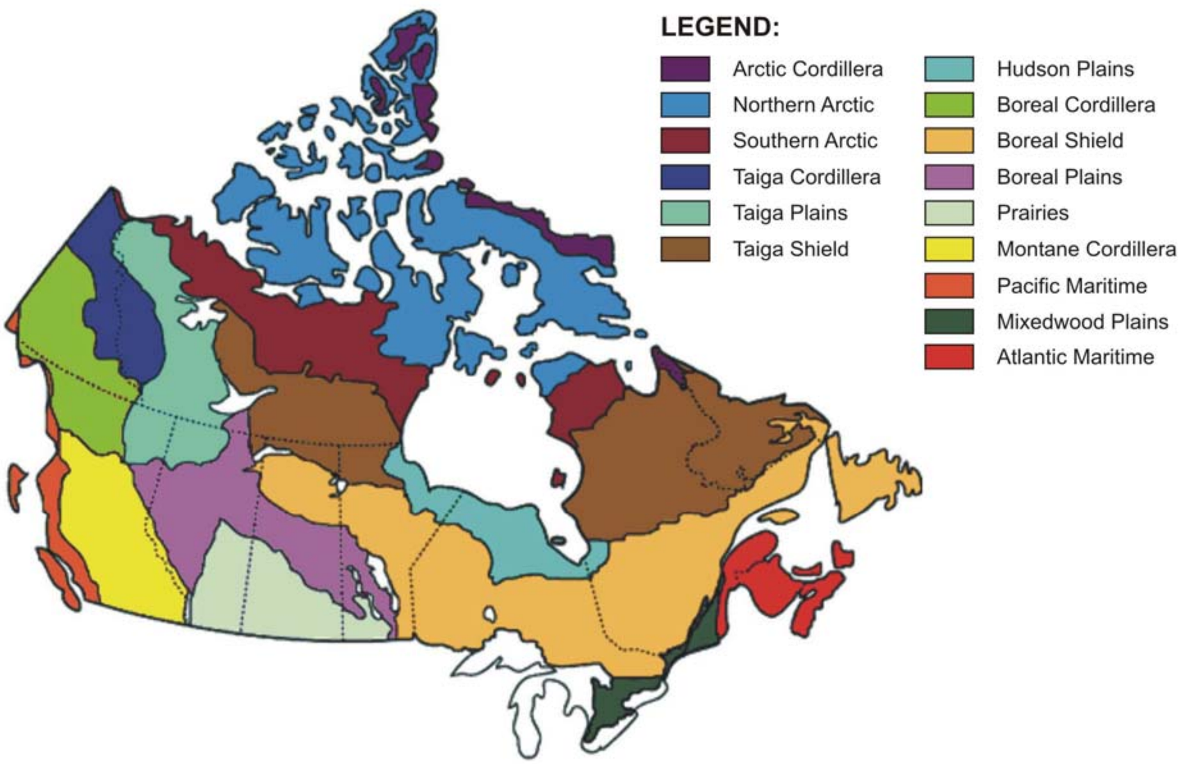
5.1 TERRESTRIAL ECOLOGY OF NWT

The Northwest Territories cover an area of 1.2 million square kilometres or approximately 13% of the land mass of Canada. Given the large size of the NWT, it is not surprising that it comprises a variety of habitats, each with its own distinct natural landforms, geology and biodiversity. The main features of these ecozones are described below. In addition, a brief overview of monitoring and research work that has been, or is being carried out, is provided. More detailed information on the findings of monitoring activities are presented in subsequent sections.

5.1.1 Ecozones of the NWT

Of the 15 separate terrestrial ecozones which have been defined for Canada using the national land classification framework (Wiken 1996), 6 ecozones cover parts of the NWT. The aerial extent of these ecozones is demonstrated on Figure 5.1-1.

FIGURE 5.1-1
ECOZONES OF CANADA



(Source: Parks Canada Website 2004)

Northern Arctic Ecozone

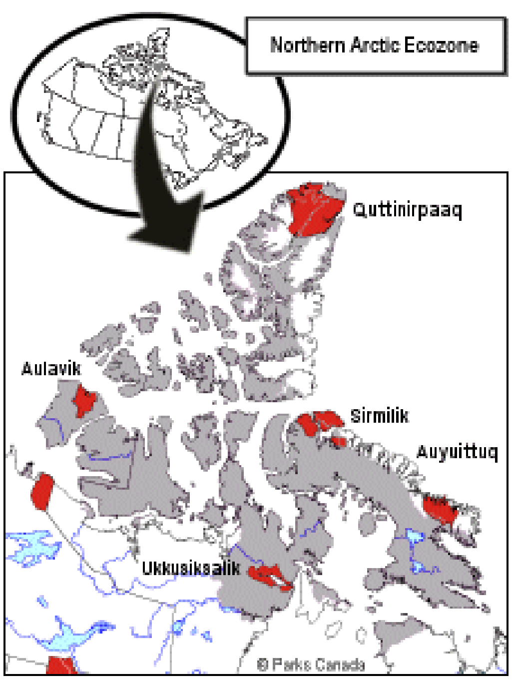
The Northern Arctic Ecozone encompasses most of Nunavut and a portion of both the Northwest Territories and northern Quebec (see Figure 5.1-2). Physically, it extends over most of the nonmountainous areas of the arctic islands and the western portion consists mostly of lowland plains covered with glacial moraine.

The climate is very dry and cold. Mean daily January temperatures ranges from -30ºC to -35ºC in the long winters and the daily July temperatures are between 5ºC and 10ºC in the short summers. The annual precipitation ranges from 100 mm to 200 mm. Snow may fall any month of the year and usually remains on the ground from September to June. Herb and lichen dominated communities constitute the main vegetation cover.

Mammals of the Northern Arctic Ecozone include Peary and barren-ground caribou, muskox, wolf, arctic fox, polar bear, arctic hare, and brown and collared lemmings.

Some representative birds include red-throated loon, brant, oldsquaw, gyrfalcon, willow and rock ptarmigan, and snowy owl.

FIGURE 5.1-2
NORTHERN ARCTIC ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

Southern Arctic Ecozone
The climate is typically arctic with long, cold winters and short, cool summers. Mean daily July temperatures tend to be cool (about 10ºC). Winter temperatures are highly variable, but the mean daily January temperature tends to be about -30ºC. Mean precipitation north-south ranges between 200 mm and 400 mm.

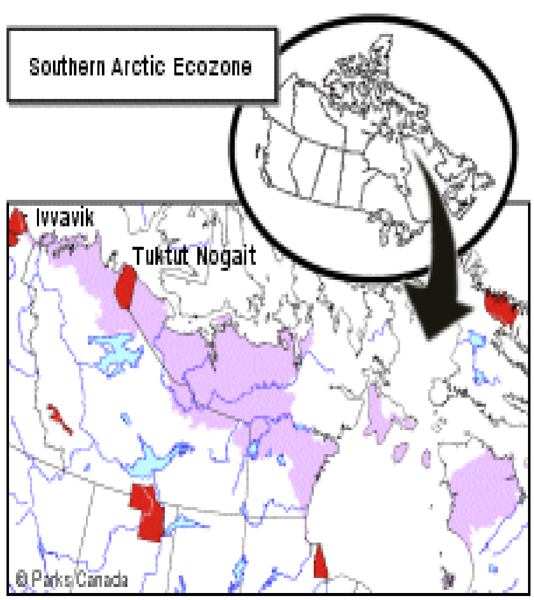
This ecozone represents a major area of vegetation transition and contains the major shrublands in the tundra.

Typical shrubs include dwarf birch, willows and heath species; these are commonly mixed with various herbs and lichens.

Characteristic mammals of the Southern Arctic Ecozone include moose, muskox, wolf, arctic fox, grizzly and polar bears, and arctic hare. The area also includes the major summer and calving grounds of two of the largest caribou herds.

The area is also a major breeding and nesting ground for a variety of birds. Representative species include yellow-billed, arctic and red-throated loon, whistling swan, snow goose, oldsquaw, gyrfalcon, willow and rock ptarmigan, northern phalarope, parasitic jaeger, snowy owl, hoary redpoll and snow bunting.

FIGURE 5.1-3
SOUTHERN ARCTIC ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

Taiga Shield Ecozone

The Taiga Shield ecozone lies on either side of Hudson Bay, as shown on Figure 5.1-4. The western segment includes portions of northern Manitoba and Saksatchewan, a portion of southern Nunavut, and the south-central area of the Northwest Territories.

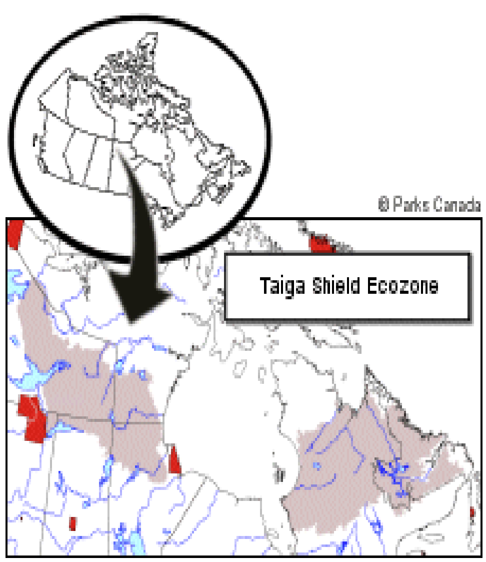
The climate is subarctic continental. Precipitation is low (from 175 mm to 200 mm). The mean daily January temperature ranges from -17.5ºC to -27.5ºC, with the mean daily July temperatures ranging from 7.5ºC to 17.5ºC.

The Russian term "taiga" refers to the northern edge of the boreal coniferous forest. In northern Canada, much of this forest rests on the Canadian Shield, the bedrock heart of the continent. Along the northern end of this ecozone, the poleward limits of tree growth are reached. The forest stands are open and form lichen woodlands which merge into areas of open arctic tundra. The central portion contains relatively unproductive and commonly stunted coniferous and deciduous stands, including open, stunted black spruce, accompanied by alders, willows and tamarack in the fens and bogs, and open, mixed wood associations of white spruce, balsam fir and trembling aspen.

Characteristic mammals of the Taiga Shield Ecozone include barren ground and some woodland caribou, moose, wolf, snowshoe hare, arctic fox, black and grizzly bears and lynx.

Representative birds include arctic and red-throated loons, northern phalarope, tree sparrow and grey-cheeked thrush.

FIGURE 5.1-4
TAIGA SHIELD ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

Taiga Plains Ecozone

The Taiga Plains Ecozone is an area of low-lying plains centred on Canada's largest river, the Mackenzie, and its many tributaries. As demonstrated on Figure 5.1-5, the plains are mainly located in the southwesterly corner of the Northwest Territories; however, they also extend into northeastern British Columbia and the upper margin of Alberta.

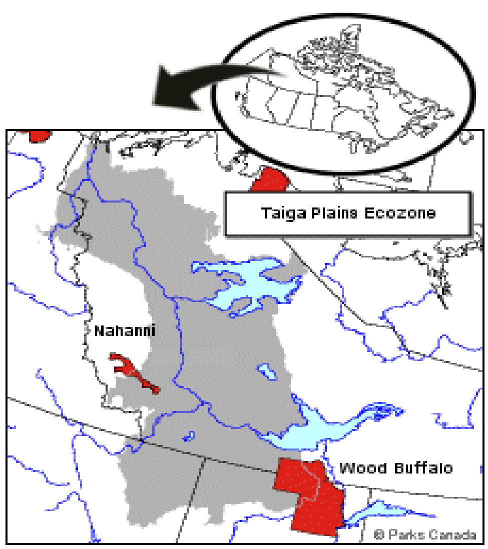
The climate is semi-arid and cold. Annual precipitation ranges from about 400 mm in the south to about 200 mm in the north. The mean daily January temperature ranges from -22.5ºC to -35ºC, while the mean daily July temperature ranges from 10ºC to 15ºC.

Dwarf birch, Labrador tea, willows, bearberry, mosses and sedges are associated with the arctic tundra environment. Upland and foothill areas and southerly locales tend to be better drained and warmer. The mixed wood forest is characterized by white and black spruce, tamarack, white birch, trembling aspen, balsam poplar and lodgepole pine.

Characteristic mammals of the Taiga Plains Ecozone include moose, woodland caribou, bison, wolf, black bear, marten and lynx. The southern portion is home to the world's largest Wood Bison herd.

Some representative bird species include red-throated loon, northern shrike, and common redpoll. The southern area contains the only known nesting site of the endangered Whooping Crane, and encompasses the sprawling Peace-Athabasca Delta, a wetland habitat of global significance.

FIGURE 5.1-5
TAIGA PLAINS ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

Taiga Cordillera Ecozone

The Taiga Cordillera is located along the northern extent of the Rocky Mountain system (see Figure 5.1-6). It covers segments of the Yukon Territory and the southwestern portion of the Northwest Territories. "Cordillera" refers to the series of mountain ranges and valleys that form this ecozone's rugged interior. This ecozone hosts some of Canada's largest waterfalls, deepest canyons, and wildest rivers.

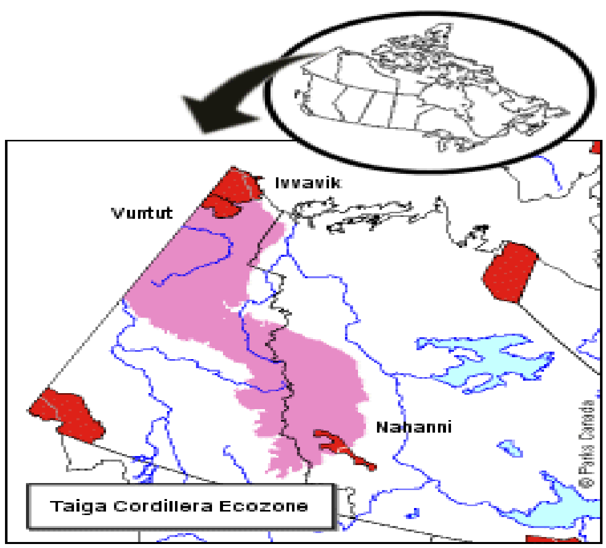
The climate is generally dry and cold. Total precipitation averages about 300 mm per year. The mean daily January temperature ranges from about -25ºC to -30ºC, with the mean daily July temperature ranging from 12ºC to 15ºC.

Steep, mountainous topography, consisting of repetitive, sharply etched ridges and narrow valleys, predominates. The Arctic tundra formations are more common in the north, the alpine tundra in areas of higher elevations and the taiga in the south.

Characteristic mammals of the Taiga Cordillera Ecozone include Dall's Sheep, woodland and barren-ground caribou, moose, mountain goat, black and grizzly bears, lynx, arctic ground squirrel, American pika and wolverine.

Gyrfalcon and willow ptarmigan are representative bird species.

FIGURE 5.1-6
TAIGA CORDILLERA ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

Boreal Plains Ecozone

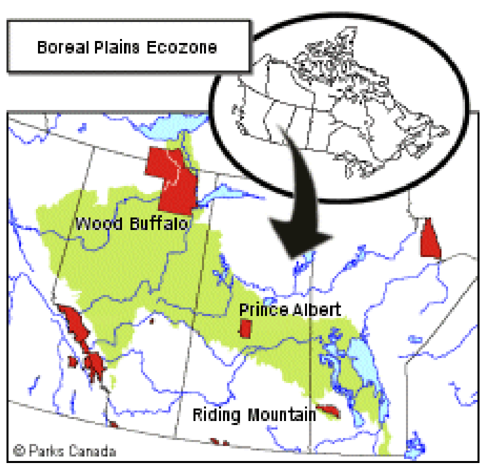
The Boreal Plains Ecozone extends as a wide band from the Peace River country of British Columbia in the northwest to the southeastern corner of Manitoba (see Figure 5.1-7). The ecozone extends along the Slave River to the southern perimeter of Great Slave Lake.

The moist climate is typified by cold winters and moderately warm summers. Precipitation is about 400 mm over much of the ecozone, nearing 500 mm along the southern boundary. The mean daily January temperature ranges from -17.5ºC to -22.5ºC, with the mean daily July temperature ranging from 12.5ºC to 17.5ºC.

White and black spruce, jack pine and tamarack are the main conifer species. Nevertheless, there is a wide distribution of broadleaf trees, particularly white birch, trembling aspen and balsam poplar. Characteristic mammals of the Boreal Plains Ecozone include woodland caribou, mule deer, bison, coyote, fisher and least chipmunk.

Representative birds include boreal owl, great horned owl, blue jay, evening grosbeak and brown-headed cowbird.

FIGURE 5.1-7
BOREAL PLAINS ECOZONE
[Areas in red are Canadian National Parks]



Source: http://www.parkscanada.ca/

5.1.2 Monitoring and Research Activities

Several monitoring and research programs are ongoing in the NWT, and elsewhere in the world, for species found in the NWT. Federal and territorial agencies have the ongoing mandate to conduct research and monitor individual species. Co-management boards, Hunters and Trappers

Associations and Renewable Resource Councils also provide continuing assessments on resources of concern to them.

A key theme in evaluating the status of the terrestrial ecosystem is the maintenance of the biodiversity, which generally refers to the maintenance of the individual species of plants and animals, and their genetics, within the current system. The NWT has extensive research, monitoring and assessment programs to monitor biodiversity, both independently and in conjunction with federal agencies and non-governmental organizations. Most of the programs are conducted under goals and objectives defined under the Northwest Territories Biodiversity Action Plan[1] (NWT Biodiversity Team 2005). The results of many of these programs can also be used in order to help determine the current status of the terrestrial system. For example, the list of programs identified under the Biodiversity Action Plan (Appendix A) provides useful information on a broad range of agencies, co-management boards and wildlife monitoring research activities.

This assessment for the terrestrial ecosystem was conducted by reviewing the scientific literature, reports, scientific and government on-line resources and through discussions with key researchers. The objective of the review of background material was to develop a consensus from several perspectives of the status of the indicators and to determine the methods and state of knowledge used in other jurisdictions for the same indicators.

The quality of the data in the reports was screened before using the information in the assessment. The highest credibility was given to scientific papers because the manuscripts are reviewed by other scientists before publishing, which removes many of the errors and poorly-designed studies. Some jurisdictions are maintaining bibliographies of research of immediate relevance to their area (WMACNWT 2003) or general bibliographies of wildlife and habitat that include the NWT (e.g., Yukon Renewable Resources)[1] and provide good source material.

This assessment also made a concerted effort to include traditional knowledge in the determination of the status of indicator species and to determine how prevalent the use of traditional knowledge is in monitoring programs. Although the incorporation of traditional knowledge into environmental assessments and environmental management programs has been recognized as a formal requirement for some time, the organization of the knowledge into a useable form by project proponents and regulators has made its use difficult (Usher 2000). Recently there has been a trend towards publishing traditional knowledge studies in the scientific literature (e.g., Lyver and Lutsel K'e First Nation (2005), Parlee *et al.* (2005)), making it easier to access during assessments. This type of widespread distribution of traditional knowledge is

[1] http://www.nwtwildlife.rwed.gov.nt.ca/Biodiversity/news.htm

encouraging because it helps First Nations, Inuit and Métis contribute important information to the review process in an accessible way. This has changed considerably over the last ten years and is an encouraging trend.

5.2 TERRESTRIAL ENVIRONMENT STRESSORS

Terrestrial ecosystems in the Northwest Territories are vulnerable to a wide range of anthropogenic and natural stressors, each with the potential to affect the ecology in different ways. Chief among these stressors, but listed in no particular order, are:

- climate change;
- contaminants;
- development (habitat disruption); and,
- harvesting.

5.2.1 Climate Change

Several comprehensive assessments have been written on the present and future effects of a warming climate on northern terrestrial systems. Groups such as the Intergovernmental Panel on Climate Change (IPCC)[2] and the Arctic Climate Impact Assessment (ACIA 2004) of the Arctic Monitoring and Assessment Program (AMAP)[3] have considered the evidence of climate change on a global scale and explicitly consider the effects to the northern landscape. International teams of scientists made up of several disciplines, including meteorologists, geologists and biologists, conducted these assessments. The teams used data collected over the last several decades to document ongoing changes and used computer models to predict the extent of changes over the next few decades. Summaries of the assessments are available at their websites. A major Canadian document on climate change by Natural Resources Canada primarily addresses changes to southern Canada and places little emphasis on the northern terrestrial system (CCIAP 2004)[1].

The most likely driving force behind the increasing temperatures is the accumulation of the greenhouse gases carbon dioxide, methane and nitrous oxide that cause heat to be retained in the atmosphere. Although effects from changing climate have been observed around the globe, the greatest effects are found in the higher latitudes, where melting ice and large tracts of drying tundra cause significant changes to the natural hydrologic cycle and carbon exchange. Overall, it has been estimated that the air temperature over the arctic landmass has increased at a rate of 0.40°C per decade since the 1960s. ACIA (ACIA 2004) reports that average winter temperatures

[1] http://www.yukia.ca/libraries20/renres.cfm
[2] http://www.ipcc.ch/
[3] http://www.amap.no/acia/index.html

in the western Canadian Arctic have increased by 3 to 4°C in the last 50 years, and that precipitation appears to have increased by 8% across the Arctic. ACIA predicts that total annual precipitation will increase by 20% in the Arctic by the end of the century. These prolonged changes to the climate are expected to have major effects on the northern terrestrial biological community.

Although the largest effects to birds and mammals are expected in the marine system with the loss of sea ice and elevated sea levels, major changes are also predicted for terrestrial plants and wildlife, primarily due to changes in the hydrologic cycle. A warming climate would result in eroding permafrost, erosion of soils and thermokarst and the possibility that wetlands and lake levels will be reduced (IPCC 2001a). The IPCC concludes that significant erosion of permafrost has already occurred in some areas of the north. This erosion of permafrost will lead to changes in surface water drainage and an increase in the active growth layer (i.e., the layer between permafrost and ground surface). Increases in the melting of snow and ice could cause the ponding of surface waters in some areas, but drying out of wetlands in other areas because of increased evaporation and transpiration. IPCC (2001b) cite studies in which the area of tundra is predicted to decrease by as much as two-thirds of its present size. The new environment will result in new assemblages of plant species.

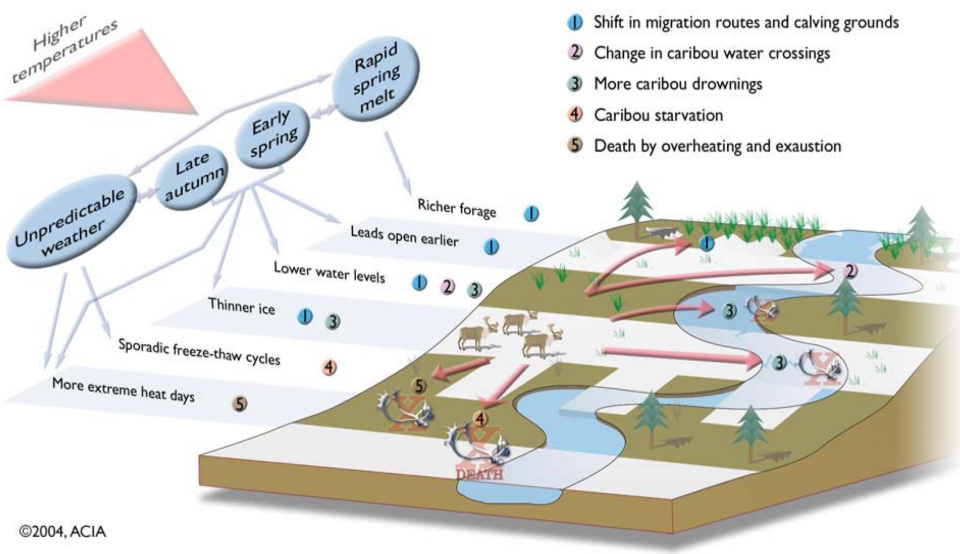
The exact nature of the changes to terrestrial wildlife in light of changes in climate, hydrology and plant communities is difficult to predict. Current predictions suggest that the overall effects to the terrestrial wildlife are a balance between plant and animal species that benefit from the warming temperatures and changes in surface water drainage and those species that will be negatively affected. Greater snow depth in winter, one of the consequences of higher air temperatures and higher moisture levels in the atmosphere, would make access to food difficult for resident birds and mammals, and make large-scale movements more difficult for species like caribou. Several times over the past decades, deep snow in spring has slowed migration of the Porcupine herd to the extent that calves were born in suboptimal habitat during the migration. This caused very low calf survival rates for those years (Russell and McNeil 2002). Similarly, freezing rain events on Banks Island appear to have been a major factor in the decline of the Peary caribou herd during the 1990s by forming an impenetrable barrier over lichen during much of the winter (Miller and Gunn 2003). Significant changes to the landscape could also influence millions of nesting waterfowl that rely on open water for nesting, and landbirds that require insect food sources at specific times during their breeding cycle.

Several studies predict impacts of climate change on caribou in northern Canada. The Kitikmeot Inuit used traditional knowledge to predict the impacts on the breeding cycle of a caribou herd

[1] http://adaptation.nrcan.gc.ca/perspective_e.asp

(Figure 5.2-1). Changes were predicted for the migration route and on the calving grounds, major river crossings, and possible death of caribou from starvation, overheating and exhaustion (ACIA 2004). An increase in freeze-thaw cycles and freezing rain would have a major impact on the herd condition, particularly during late winter and spring when the pregnant females require sustained nutrition. ACIA (2004) also reported a summary of changes expected to occur in the Porcupine herd with climate change (Table 5.2-1). The changes are a combination of positive (e.g., faster plant growth, higher pregnancy rates) and negative effects (e.g., extreme weather events, higher predation rates), but ultimately it is predicted that the herd will decline. Note that none of the predictions can be made with much certainty and that research and monitoring of the physical and biological components of the environment must continue.

FIGURE 5.2-1
SUMMARY OF ENVIRONMENTAL CHANGES THAT COULD IMPACT A CARIBOU HERD, AS PREDICTED BY THE KITIKMEOT INUIT



Source: ACIA (2004).

Scientists are also trying to assess how the northern species will react to the changing conditions by predicting how they will adapt to the new climate regimen (IPCC 2001b). In general, the IPCC authors note that natural systems in polar regions are highly vulnerable to climate change and have low adaptive capacity. Adaptation is expected to occur by the migration of species within the ecosystem and changing species assemblages (IPCC 2001a). IPCC has predicted with a high level of confidence that physical changes in the environment will affect the distributions, the population size, densities and behaviour of bird and mammal species as vegetation changes.

TABLE 5.2-1
POTENTIAL CHANGES IN THE PORCUPINE CARIBOU HERD AND ITS HABITAT FROM A WARMING CLIMATE

Climate Change Condition	Impact on Habitat	Impact on Movement	Impact on Body Condition	Impact on Productivity	Management Implications
Earlier snow melt on Coastal Plain	Higher plant growth rate	Core calving ground move further north	Cows replenish protein reserves faster	Higher probability of pregnancy	Concern over development on northern portion of present core calving area
		Less use of foothills for calving	Higher calf growth rate		
			Lower predation risk	Higher June calf survival	
Warmer, drier summer	Earlier peak biomass	Movement out of Alaska earlier in season	Increased harassment resulting in lower body condition	Lower probability of pregnancy	Protection of insect relief areas important
	Plants harden earlier	More use of coastal zone when in Alaska			
	Reduction in mosquito breeding sites	More dependence on insect relief areas, especially from mid- to late July			
	Significant increase in oestrid activity				
	Greater frequency of fire on winter range				
	Few "mushroom" years				
Warmer, wetter autumn	Deeper denser snow	Increased use of low snow regions	Greater over-winter weight loss	Maternal bond broken earlier	
		Later to leave winter range			
Warmer spring	More freeze/thaw days, snow forms ice layers	Move to windswept slopes	Accelerated weight loss in spring	Higher wolf predation due to use of windswept slopes	Concern over timing and location of spring migration in relation to harvest
	Faster spring melt	Faster spring migration			Lower productivity due to high spring mortality
Overall effect	Calving range improves, summer, autumn and winter ranges probably lower quality	Seasonal distribution less predictable, timing less predictable	Improves June condition but later summer condition reduced, more rapid weight loss in winter and early spring	High pregnancy rates but overall survival and recruitment; Shift mortality later in year (late winter, early spring); Herd more likely to decline	Need to assess habitat protection in relation to climate trends
	Extremes (such as very deep snow or very late melt) hard to adapt to)				Need to factor climate change on harvest levels
					Need to communicate impacts of climate on harvest patterns and timing
					Need to set up monitoring programs

Source (ACIA 2004)

Arctic mammal species have special adaptations for survival in the extreme northern climate but they cannot compete with temperate species that move north with the moderating climate. The arctic species would tend to move to new areas that are being formed further north.

Another issue that is similar to climate change, but occurs through a different mechanism, is the increase in ultraviolet radiation exposure in the terrestrial system caused by the thinning of the stratospheric ozone layer. The thinning of the ozone layer, which absorbs UV-B radiation, is caused by the emission of chlorofluorohydrocarbons (CFCs) that have eroded the ozone layer over the last 50 years. In general, the thinning of the ozone layer is at its maximum in the spring. The effects of this increased UV radiation to the terrestrial system could be extensive. Some plant species can create more pigmentation to reduce the effects of the radiation, while other plant species may die-off. Most effects to date have been described in the lower trophic systems and the impact to wildlife and bird species is largely unknown.

5.2.2 Contaminants

The presence of contaminants in Arctic wildlife has been the focus of extensive research since organochlorines were first reported in ringed seals in the ISR in the early 1970s (Bowes and Jonkel 1975). These observations ultimately led to two 5-year phases of DIAND's Northern Contaminants Program (NCP) beginning in 1992 that was dedicated to understanding the sources, transport and spatial and temporal trends of synthetic contaminants in traditional foods in the NWT and Nunavut. The goal of Phase II was to take action that would lead to the reduction of the chemicals in the environment of the north. The results of the program have been published in the Canadian Arctic Contaminants Assessment Reports (Jensen *et al.* 1997, DIAND 2003) and have been summarized in several scientific papers. The summary papers for the terrestrial system are presented in Thomas *et al.* (1992) and Braune *et al.*(1999).

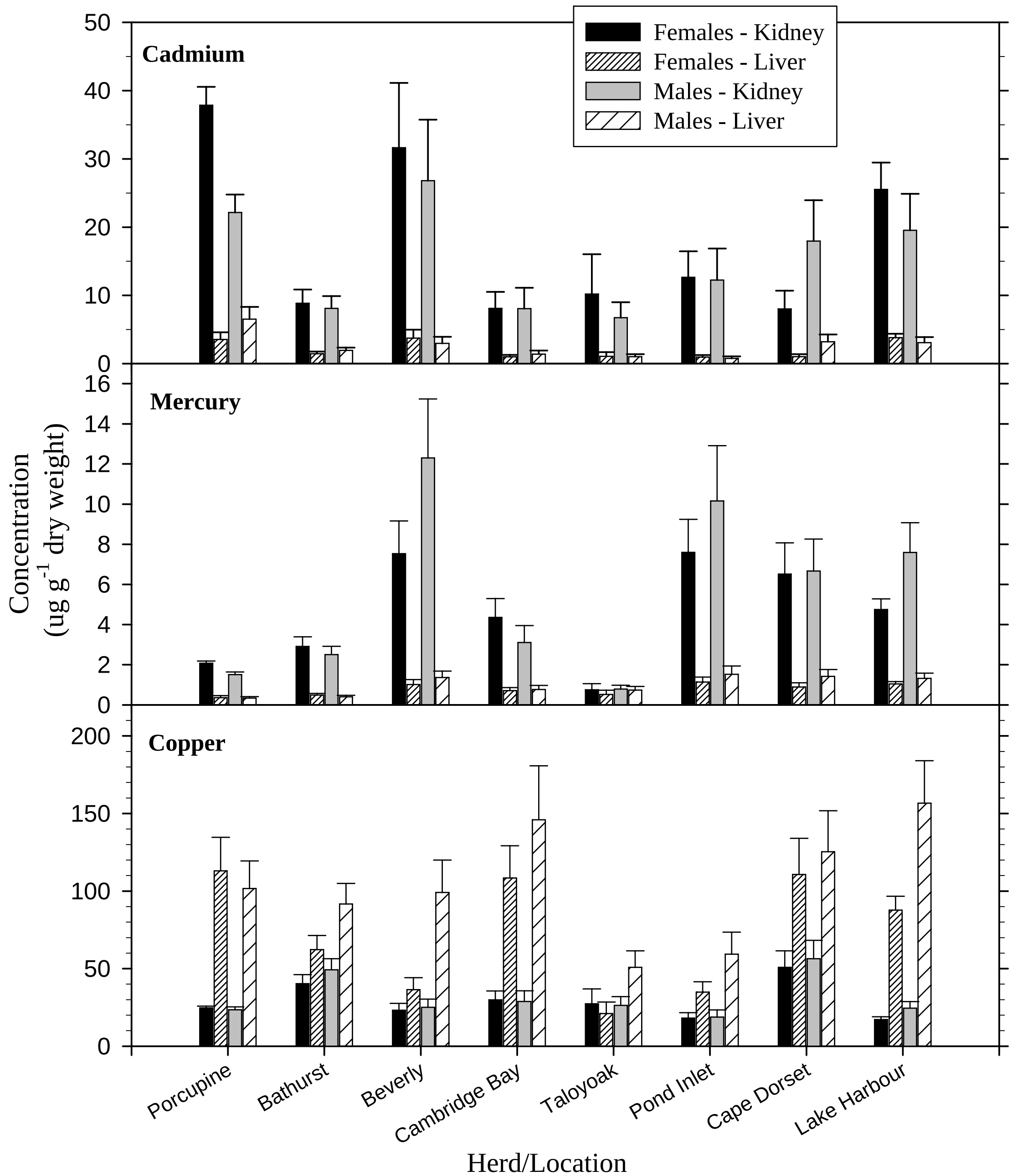
The consensus from two or more decades of research indicates that organochlorine contaminants, which reach levels of concern in marine wildlife and some freshwater fish species, remain at very low concentrations in terrestrial biota. This is largely due to the short food chains in the northern terrestrial food web. The concentrations of major contaminants such as PCBs, DDT, toxaphene and chlordane are at or below detection limits in caribou in the NWT and Nunavut (Elkin and Bethke 1995).

Metals and radionuclides occur naturally in the environment and many are present in all biological material. Some metals, such as copper, molybdenum and zinc, are important micronutrients for humans and wildlife and are required for the maintenance of health. In general, the highest concentrations of metals are in liver and kidney, with very low levels found in wildlife meat. The higher concentrations observed in liver and kidneys are typical of all organisms because of the mechanism of accumulation in these tissues.

A review of metal concentrations in caribou (Macdonald et al. unpublished MS) summarized the extensive data set of metals in caribou from the NWT and Nunavut generated by Environment and Natural Resources in a multi-year project partially funded by the NCP (Elkin and Bethke 1995). The program consisted of sampling from 10 to twenty caribou collected in community hunts and analyzing muscle, liver and kidney for a broad range of metals using high resolution chemical analysis. The age-corrected concentrations of some metals varied between herds, but the variation was attributed to normal biological variation (Figure 5.2-2). Cadmium, total mercury and copper accumulated with the age of the animals. There was no indication of consistent large-scale contamination for any of the metals tested and the concentrations of the metals tested were consistent with other caribou and reindeer studies from Europe and Alaska.

Radionuclide levels in the caribou were at natural levels, and the concentration of cesium-137, which was produced during the nuclear weapons tests in the 1950s and 1960s, was declining with an environmental half-life of about 10 years (Macdonald *et al.* 1996). The study concluded that there was no evidence of man-made contamination in the caribou and that they remain an important nutritious food source.

FIGURE 5.2-2
LEAST-SQUARE MEAN CONCENTRATIONS OF THREE METALS IN CARIBOU LIVER AND KIDNEY FROM THE NWT AND NUNAVUT



Source: [Data are from MacDonald et al. (unpublished ms).]

5.2.3 Development

Another significant threat to the habitat of wildlife in the north is the cumulative impact of large development projects that make a number of small changes to the terrestrial system. These small changes combine to produce stress on the biological community. Several issues are considered in this category, including the loss of habitat and the effects of development activities such as noise, dust, and the construction of buildings. Development has been an integral part of the northern environment for several decades; however, individual projects have been relatively small and widely dispersed. Mines may have affected local environments by building roads and other infrastructure and releasing contaminants to air, soil and water but the footprint of the mines were small in nature compared to currently proposed projects. Proposals for extensive oil and gas development, pipelines, permanent roads, hydro projects and several mines will make considerable changes to the landscape. A summary of the number of developments occurring within the range of the Bathurst and Porcupine caribou herds (Table 5.2-2) has been prepared by Kofinas and Gunn (2000)[1]. Some of the projects have been developed and expanded since the list was written in 2000.

The extent and significance of changes to northern wildlife caused by large development projects are still unclear and difficult to predict. One of the most heavily researched areas in this regard is the development of oil and gas fields on the Alaskan North Slope where oil exploration has been conducted in some form since the 1950s. It is possible to make a direct comparison of the Alaskan experience with the NWT because of the similarity in terrain and wildlife. Since the 1950s, the TransAlaska Pipeline has been built from the Alaskan northern coast to Valdez on the south coast, and the Prudhoe Bay oil field has been heavily developed. Extensive seismic activity has also been conducted since the 1950s. Originally, the seismic testing was conducted using very destructive land-based methods (Forbes 1992, 1995, 1997); however newer techniques and equipment have reduced the amount of damage caused in this phase of exploration. Other development includes roads, airstrips, gravel pads, drill rigs and other infrastructure needed for oil extraction. The development of oil reserves in this environment provides a very good comparison to the type of development that is beginning to occur in the NWT.

[1] http://www.taiga.net/sustain/lib/sustain2/cum_effects.html

TABLE 5.2-2
LIST OF ONGOING OR PROPOSED PROJECTS WITHIN THE RANGE OF THE PORCUPINE AND BATHURST CARIBOU HERDS

Activity Class	Activity
Bathurst herd	
Non-renewable resource explorations and development	• Izok Lake projects (base metals). Proposed; winter range. • Jericho Project (diamonds) Proposed winter range. • Ekati Mine (diamonds), Active on preferred migratory route. • Diavik Project (diamonds), Active; winter range. • Boston Windy Project (gold), Proposed; northern of calving grounds • Snap Lake Mine. Proposed (wintering grounds) • Kennedy Lake Mine. Proposed. (Winter range).
Non-renewable resource exploration and development	• No pipelines in area. • Extraction activities currently by road or air. • South Bathurst Inlet Sea Port Facility. Proposed. Suggested that various levels of shipping activities may affect migration across the inlet. (Animals swim or cross ice)
Year-round, service, and winter roads	• Yellowknife Road (year round). Active; winter range. • Three winter roads to support resource extraction and other development activities. All active. • Other service roads likely to be constructed if additional mine proposals are approved. • The proposed Bathurst Inlet Port and Road project would see an all-weather road constructed from Bathurst Inlet southwest to Contwoyto Lake.
Other activities	• Air traffic. Likely to increase with hydrocarbon and tourism development. • Increased access by hunters as a result of changes in hunting technology (i.e. faster snow machines). • Future changes in number of local and non-hunters; increased take. • Bush camps. Increase in number may follow if there is an improved economy and larger human population in villages.
Porcupine herd	
Non-renewable resource exploration and development	• On-shore gas pipeline routes -- from Mackenzie Delta and Prudhoe Bay south. Several alternatively currently proposals; winter range. • Coastal sea port(s) to support off-shore gas pipeline. Proposed; calving and post calving habitat.

TABLE 5.2-2 (Cont'd)
LIST OF ONGOING OR PROPOSED PROJECTS WITHIN THE RANGE OF THE PORCUPINE AND BATHURST CARIBOU

Activity Class	Activity
Year-round, service, and winter roads	• Dempster Highway - a year-round road completed in 1979. Active; transects winter range and across migratory routes. Increase in traffic is likely with oil and gas development and tourism in the region. Recent gas exploration activity in the Mackenzie Delta Region is projected to bring dramatic increase in large truck traffic on the Dempster. • Winter road to Old Crow, an ice road constructed in 1999. May be reconstructed in the future, depending on need and economy. • Year-round roads to and between communities. Possible roads in the areas of Aklavik, Arctic Village and Venetie, and Old Crow are today part of the local and regional development discussions. • Additional service roads (winter and year-round) are likely to accompany oil and gas development
Other activities	• Air traffic. Likely to increase with hydrocarbon and tourism development. • Increased access by hunters as a result of changes in hunting technology (i.e. faster snow machines). • Future changes in number of local and non-hunters; increased take. • Bush camps. Increase in number may follow if there is an improved economy and larger human population in villages.

Source: (Kofinas and Gunn 2000)[1]

[1] http://www.taiga.net/sustain/lib/sustain2/cum_effects.html[1]

Debate on the effects of oil development to wildlife on the Alaskan North Slope, including caribou, continues (Maki 1992, Cronin *et al.* 1998b, Ballard *et al.* 2000, Murphy and Lawhead 2000, Cameron *et al.* 2005). Three of the four barren-ground caribou herds that calve in areas adjacent to the oil development on the Alaskan North Slope have increased in size since the 1970s when oil production began to increase (Cronin *et al.* 1998b, Ballard *et al.* 2000). The Porcupine herd, which has not been exposed to oil development in a significant way, has declined during the same time, and there are plans by the U.S. to begin development in the Porcupine herd calving ground. Caribou use the open areas, such as roads and gravel pads, in the oil fields to avoid insects during the summer (Cronin *et al.* 1998a, Noel *et al.* 1998), but there is increasing evidence that females and calves avoid these structures during calving. Parturient females may move to suboptimal habitats to avoid oil activity during times of the year that are critical to calf health and nutrition (Nellemann and Cameron 1996, 1998, Cameron *et al.* 2005).

New developments in Alaska may also have other significant effects on the distribution of wildlife species. Buildings associated with oil development on the Alaskan North Slope has provided new habitat to the raven and the Arctic fox that have become "subsidized" predators because the developments provide food at the landfill and new structures for nesting or denning. For the raven, which doesn't naturally nest on the North Slope, the oil field structures provides unique nesting habitat. The influence of these predatory species on local bird and mammal populations is unknown.

Other structures have an impact on the local landscape far exceeding their physical footprint. Roads affect the local landscape by modifying permafrost, the drainage of surface water and by the transport of dust (Walker and Everett 1987, Walker *et al*. 1987). Recolonisation of abandoned gravel pads occurs very slowly. Walker and Walker (1991) suggest that although the local impacts from the oil industry are small in scale (less than 1 m^2 to 1 km^2), the cumulative impact from all the development affects the region on a mesoscale of 1 km^2 to 10,000 km^2. By comparison, climate change is predicted to affect the tundra regions at a larger scale of 10,000 to 1,000,000 km^2.

Based on the Alaskan experience, it is not unreasonable to expect that a similar level of development in the NWT will result in significant changes to the terrestrial environment, but the impact to major wildlife species that are valued ecosystem components is still unclear. Considering the potential changes in mammal and bird populations, and traditional hunting patterns, that may be caused by the cumulative effects of development, it is important that research and monitoring continue on all major species to ensure the long-term viability of the resource.

5.2.4 Harvesting

The terrestrial ecosystem is highly valued by the people of the North as the primary source of food (e.g., caribou, moose, small mammals, landbirds and waterfowl) as well as for the making of clothing items (from animal hides) and medicinal products (from various plants). Fur bearing animals are also trapped for sale of hides as a source on income. These harvesting activities can affect the populations of certain species.

Harvest statistics provide a record of the numbers and types of wildlife species collected annually in each community. Statistics have been compiled in the Sahtu Settlement Area (SSA), Gwich'in Settlements Areas (GSA) and the Inuvialuit Settlement Region (ISR), as required under the respective land claims agreements. The objectives of the harvest statistics are to establish the minimum wildlife harvest required to support the beneficiaries of the lands claims. The intent is to provide co-management boards with data to allow harvest levels sufficient to support traditional uses if a wildlife population declines to the point that restrictions must be placed on hunting and harvest levels. Currently, summary harvest survey reports cover eight years (1995-2002) for the GSA (GRRB, pers. comm.), ten years (1988-1997) for the ISR (Joint Secretariat 2003) and four years (1998-2001) for the SSA (SRRB 2002, 2003). A 5-year summary is in the process of being finalized for the SSA. These survey reports provide an excellent basis for the selection of Valued Ecosystem Components that are highly relevant to people in the communities. Unfortunately, similar surveys are not currently being undertaken for the unsettled land claim areas in the southern portion of the Northwest Territories.

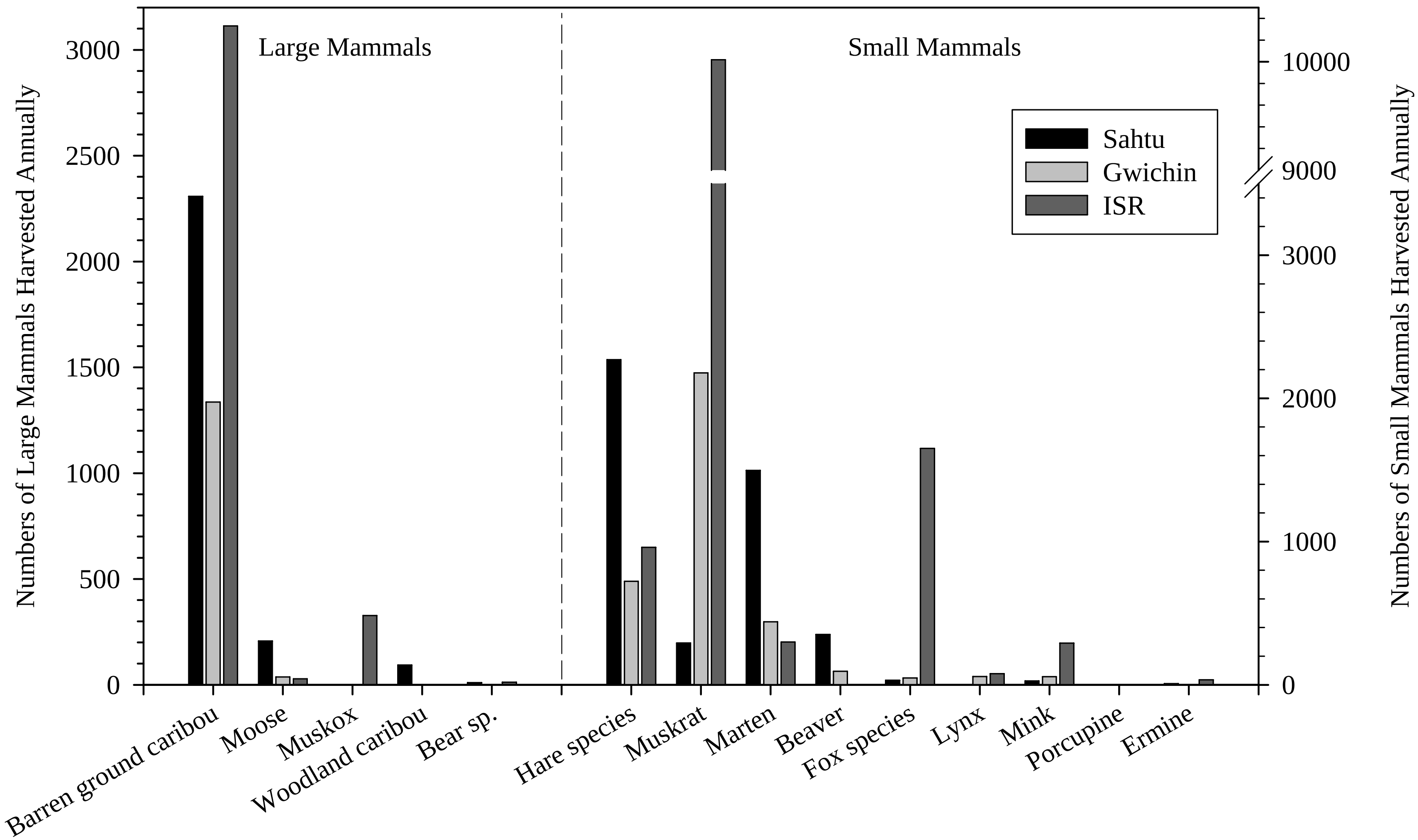
A summary of the major species harvested in the three regions noted above are shown in Figures 5.2-3 and 5.2-4 and Table 5.2-3. Similar wildlife species have been grouped under general categories for presentation purposes but also because the surveys include general categories when it is not known which species was collected (i.e. designated as hare species, fox species, duck species, etc.). Data for these miscellaneous categories and the individual species were pooled for this analysis. In addition, species for which relatively few individuals are taken, or may be harvested in only one region and not the others, are not included. Large changes in the number or condition of any of these species would be significant to harvesters, although the low numbers harvested for some species probably indicates opportunistic collections that may not occur in some years.

The data show major similarities between regions in the types and amounts of wildlife species harvested and the importance of barren-ground caribou, waterfowl and ptarmigan throughout the NWT. The same wildlife groups, although not necessarily the same species, are probably collected in the southern NWT as well (Kuhnlein *et al.* 1995, Morrison *et al.* 1995, Berti *et al.* 1998). There are clear regional differences in the individual species harvested, however the comparison shows the importance of these general wildlife groups to the communities in the settlement areas. For example, the Arctic hare is the dominant species harvested in the ISR while the snowshoe hare is the major hare species collected elsewhere. Comparison of the summarized data for the three regions show a broad diversity of wildlife mammal and bird species harvested.

TABLE 5.2-3
SUMMARY OF MAJOR WILDLIFE SPECIES HARVESTED IN THE GSA, SSA AND ISR THAT COULD BE USED AS ENVIRONMENTAL INDICATORS

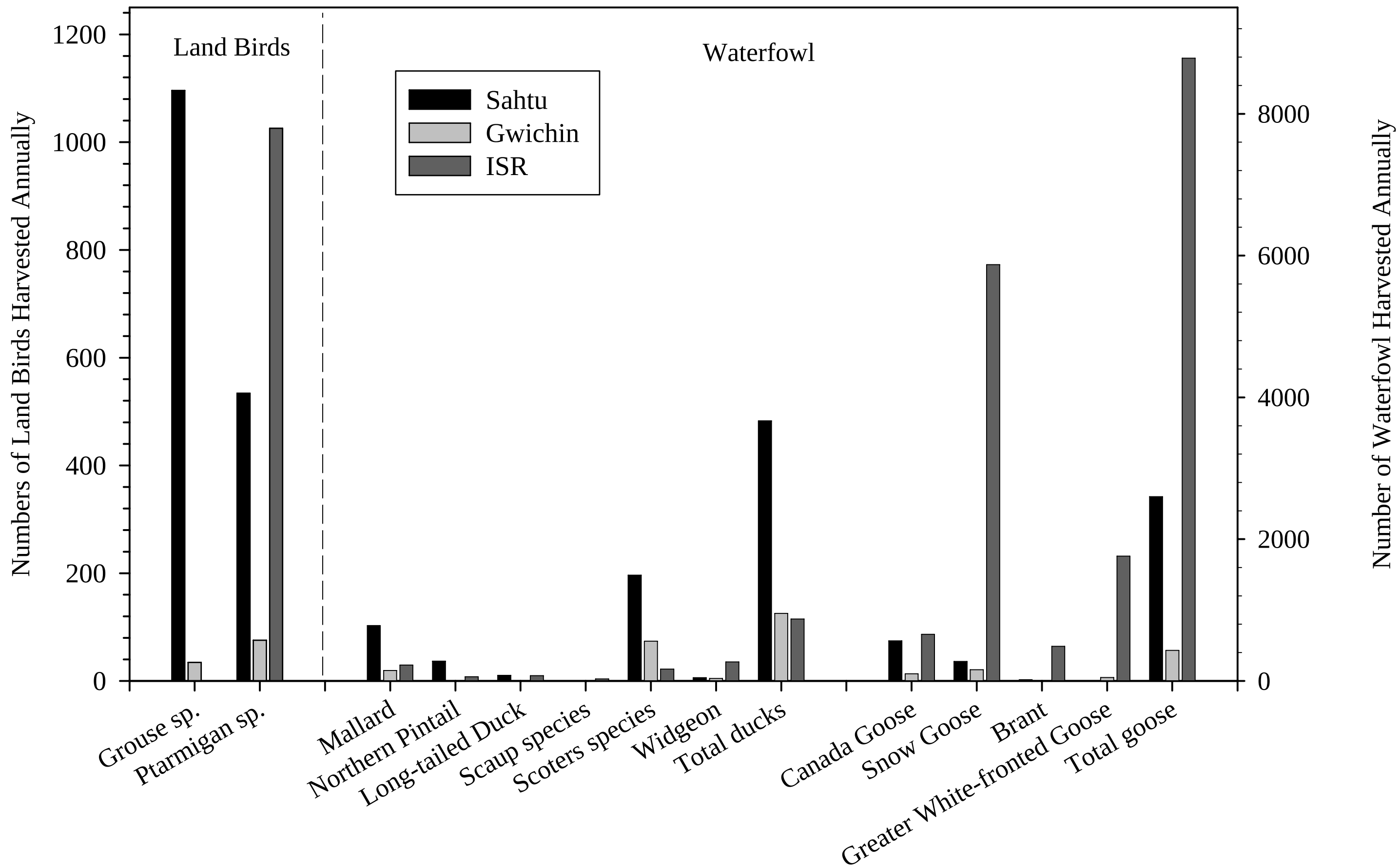
Common Name	Scientific Name	Common Name	Scientific Name
Mammals		***Landbirds***	
Barren-ground caribou	*Rangifer tarandus groenlandicus*	Ruffed grouse	*Bonasa umbellus*
Woodland caribou	*Rangifer tarandus*	Spruce grouse	*Dendragapus canadensis*
Moose	*Alces alces*	Sharp-tailed grouse	*Tympanuchus phasianellus*
Grizzly bear	*Ursus arctos*	Ptarmigan	*Lagopus sp.*
Black bear	*Ursus americanus*	***Waterfowl***	
Dall sheep	*Ovis dalli*	Canada goose	*Branta canadensis*
Small Mammals		Greater white-fronted goose	*Anser albifrons*
Arctic fox		Snow goose	*Anser caerulescens*
Red fox	*Vulpes vulpes*	Brant	*Branta bernicla*
Snowshoe hare	*Lepus americanus*	Mallard	*Anas platyrhynchos*
Arctic hare	*Lepus arcticus*	Northern pintail	*Anas acuta*
Lynx	*Lynx lynx*	Long-tailed duck	*Clangula hyemalis*
Marten	*Martes americana*	Merganser	*Mergus merganser*
Mink	*Mustela vison*	Scoter	*Melanitta sp.*
Muskrat	*Ondatra zibethicus*	Widgeon	*Anas americana*
Wolf	*Canis lupus*	Scaup	*Athya sp.*
Wolverine	*Gulo gulo*	Tundra swan	*Cygnus columbianus*
Ermine	*Mustela erminea*	Northern shoveler	*Anas clypeata*

FIGURE 5.2-3
SUMMARY OF ANNUAL HARVEST LEVELS OF MAJOR MAMMAL SPECIES IN THE GWICH'IN AND SAHTU SETTLEMENT AREAS AND THE INUVIALUIT SETTLEMENT REGION



Source: (Joint Secretariat 2003).

FIGURE 5.2-4
SUMMARY OF ANNUAL HARVEST LEVELS OF MAJOR LANDBIRD AND WATERFOWL SPECIES IN THE GWICH'IN AND SAHTU SETTLEMENT AREAS AND THE INUVIALUIT SETTLEMENT REGION



Source: (Joint Secretariat 2003)

5.3 TERRESTRIAL ENVIRONMENTAL QUALITY (TEQ) INDICATORS

Environmental monitoring programs use the concept of indicators to determine the state of the environment. These indicators undergo changes that reflect alterations in their environment and long-term trends in the status of the indicator are related to larger changes in the environment. Examples of useful indicators in the physical environment are air temperature, air quality, humidity and snow depth because they are easily measured and reflect the status of the physical environment.

Indicators of the status of the biological community are more difficult to select because of the large number of plant and animal species present, particularly over an area as large as the NWT, which includes sections of six ecozones. In addition, there are a large number of potential measurements that can be made on each indicator. Indicator species are chosen because of their ecological, societal or scientific value. Ecologically significant species tend to be keystone species that play a central role in the structure of the terrestrial food web. One example of a keystone species in the NWT is the barren-ground caribou, which covers large areas of tundra and is preyed upon by wolves, grizzly bear and golden eagles and harvested by virtually all communities. Large changes in herd size will have far-reaching implications. Similar arguments can be made for waterfowl because of their large numbers and influence on several other species. Several species that are representative of the wildlife harvested in the communities are evaluated in this assessment of the current status of the environment.

Based on these data, four indicator species were used for this assessment of the status of the terrestrial environment:

- Barren-ground caribou;
- Moose;
- Landbirds (grouse, ptarmigan); and,
- Waterfowl.

The indicator species were chosen primarily because of their importance to First Nations, the Inuit and Métis, but also because there was sufficient information available for each species to allow an assessment of their status. Advantages of using these species are that they are of great importance to northerners, there are extensive resources available to allow a scientific evaluation of their status and barren-ground caribou and waterfowl are considered keystone species. Two of the species are expected to be negatively affected by climate change (caribou, waterfowl) while the other two are boreal species and may benefit by warming conditions. The assessment was conducted by developing specific markers of the current condition of each of the indicator species.

In addition to the above, vegetation was considered as plant species distribution is expected to be impacted by large-scale environmental change. There is little high quality information available however, on the distribution of single species, so the best indicator of the distribution of species is on a landscape scale. Hence, vegetation was not included in this assessment although it is recognized that it should be considered in future assessments.

The species listed in Table 5.3-1 integrate the effects of environmental changes and are important to the traditional economy, have been studied in the region, and may provide a useful indicator of the state of the environment through time. Among the potentially useful indicators, only those with the most useful data records are discussed below.

TABLE 5.3-1
RATIONALE FOR SELECTION OF CANDIDATE TERRESTRIAL SPECIES AND INDICATORS OF ENVIRONMENTAL QUALITY AND TRENDS

Candidate Species for Valued Ecosystem Component	Indicators*	Rationale
Mammals		
Caribou (Barren-ground, Woodland, Mountain)	• **Population Size** • **Male:Female ratios** • **Cow:calf ratio** • **Body condition/Disease** • **Harvest Rate** • Contaminants	• Primary concern of communities • Keystone species of taiga and tundra biomes • Extensive database of monitoring and research
Moose	• **Population Size** • **Harvest Rates** • **Cow/calf Ratio** • **Male/Female Ratio** • Condition of habitat • Contaminants (esp. cadmium)	• Major concern of communities in western NWT. • Indicator of the health of the boreal system • Population distribution may affected by cumulative impacts by avoidance behaviour, increased hunting, etc.
Furbearers (marten, mink, lynx, fisher, wolverine)	• **Population size** • **Harvest/trapping rates** • Habitat condition	• Trapping continues to be a major source of income for some groups in communities • Small mammal populations can reflect changes from cumulative impacts
Birds		
Landbirds (incl. Grouse/Ptarmigan)	• **Population size and diversity** • Habitat condition	• Major food species in many communities • Population health an indicator of environmental quality
Waterfowl (geese, ducks) and Shorebirds	• **Population size** • **Long-term trends in population** • Nesting Habitat Condition • Contaminants	• Major food species in many communities. • Large database of population trends and health for several species.

*key indicators are in bold type.

5.3.1 TEQ Indicator - Barren-Ground Caribou

Several thousand barren-ground caribou are harvested annually through subsistence, resident and non-resident hunts in the NWT (Figure 5.2-3). The health and availability of barren-ground caribou is a continuing concern to residents of the NWT and the effect of any development on the ecology of the herds is significant. For this reason, maintaining the size and condition of the herds and understanding the reasons behind herd declines are of critical importance.

(i) What is being measured?

The major criterion used to monitor caribou herds is the total population size (Table 5.3-2). Generally, herd size is estimated using several techniques, including radio-collared female caribou and aerial surveys during calving when females congregate on the calving grounds, or post-calving in July. Additional measurements of herd condition include cow:calf ratio and male:female sex ratio that provide an estimate of the number of females available for reproduction and the ability of the herd to increase. Detailed estimates of calf survival in the first month after birth, rates of predation in young calves and the numbers of calves entering the breeding population in their second year provide critical information on the recruitment rate in the herd (Griffith *et al.* 2002). When used together, these indicators provide a good summary of herd dynamics and may provide the reasons behind a declining herd.

TABLE 5.3-2
SUMMARY OF INDICATORS FOR EVALUATION OF BARREN-GROUND CARIBOU STATUS

Indicator	Description
Population size	Total number of individuals indicates long-term trends in the herd. May be measured directly or estimated from number of breeding females on calving grounds.
Male:female sex ratio	Indicates the number of females available for reproduction in the current year relative to the number of males in the herd.
Cow:calf ratio	The number of calves relative to females. Other indicators indicate calf recruitment and calf net productivity.
Body condition	Several indicators of body condition (subcutaneous fat, kidney fat, intestinal fat, marrow condition) report the nutritional status of individual animals.
Habitat or range condition	Some investigators use estimates of range quality, or the date of green-up in spring, to predict herd condition.
Harvest rate	Generally should not exceed 5% of the known population, although some biologists recommend a level of 3%.
Disease	Proportion of the herd with active or positive signs of disease, or the incidence of disease level of (e.g., number of parasites, or bot/warble fly larvae).

Another series of indicators can be used to estimate the nutritional status of the herd. A workshop on monitoring body condition in caribou was held in 2000 (Kofinas *et al.* 2002) to determine the best set of indicators that could be used to estimate the health, or condition, of individual animals in a herd. The indicators would use a set of measurements from harvested animals (i.e. subcutaneous fat, kidney fat, intestinal fat, marrow condition) (Gerhart *et al.* 1996) with interviews and assessments from hunters. The body measurements were vital to the assessment because the body condition of females has been correlated with the body weight, survival of calves at birth and the ultimate success of the calves entering the reproducing population (Cameron *et al*. 1993, Cameron and ver Hoef 1994).

Several initiatives have been proposed to standardize the methods of monitoring the condition of caribou herds and to coordinate the programs in various jurisdictions (Kofinas *et al.* 2002). The most comprehensive system termed the Body Condition Study was developed for the Porcupine herd (Allaye Chan 1991, Allaye Chan-McLeod *et al.* 1999) and appears to be one of the most complete because of the amount of research used to develop the indicators. Several data sets on body condition are available for the various herds and the initiative to standardize and coordinate the programs is important. One of the protocols proposed for determining caribou condition at the 2000 Workshop is listed in Table 5.3-3.

TABLE 5.3-3
ONE PROPOSED SCHEME FOR DETERMINING CARIBOU CONDITION FROM HARVESTED ANIMALS

Level 1: Visual Appraisal	Level 2: Field Form	Level 3: Field Collection and Measurements
• Date	• Include everything from lower level	• Field measurements (include everything from lower levels)
• Location	• Lactating/pregnant	• Shoulder weight
• Age	• Abnormalities - liver, wounds, limping, joint condition, lesions in organs, etc.	• Level 3: Field Collection and
• Sex	• Body condition score	• Level 3: Field Collection and
• 3/5 classes of overall visual assessment (from "skinny" to "fat")	• Back fat depth	• Abnormal tissue samples
• Comments	• Bone marrow colour/consistency	• Contaminant tissue samples
	• Kidney fat	• Blood sample
	• Brisket fat	• Fecal sample
	• Opportunistic tissue samples	• DNA sample (skin) for herd identification

Source: (Kofinas et al. 2002).

An important initiative in the monitoring of caribou is the development of programs to use observations and measurements of hunters to monitor caribou condition. Hunter surveys could provide large numbers of samples (i.e. several thousand animals sampled per year for some herds) on a continuing basis. The range of observations that could be provided by hunters is listed in Table 5.3-4. Community-based input to the herd monitoring could be organized through the community hunts and provide the input of traditional knowledge throughout the process.

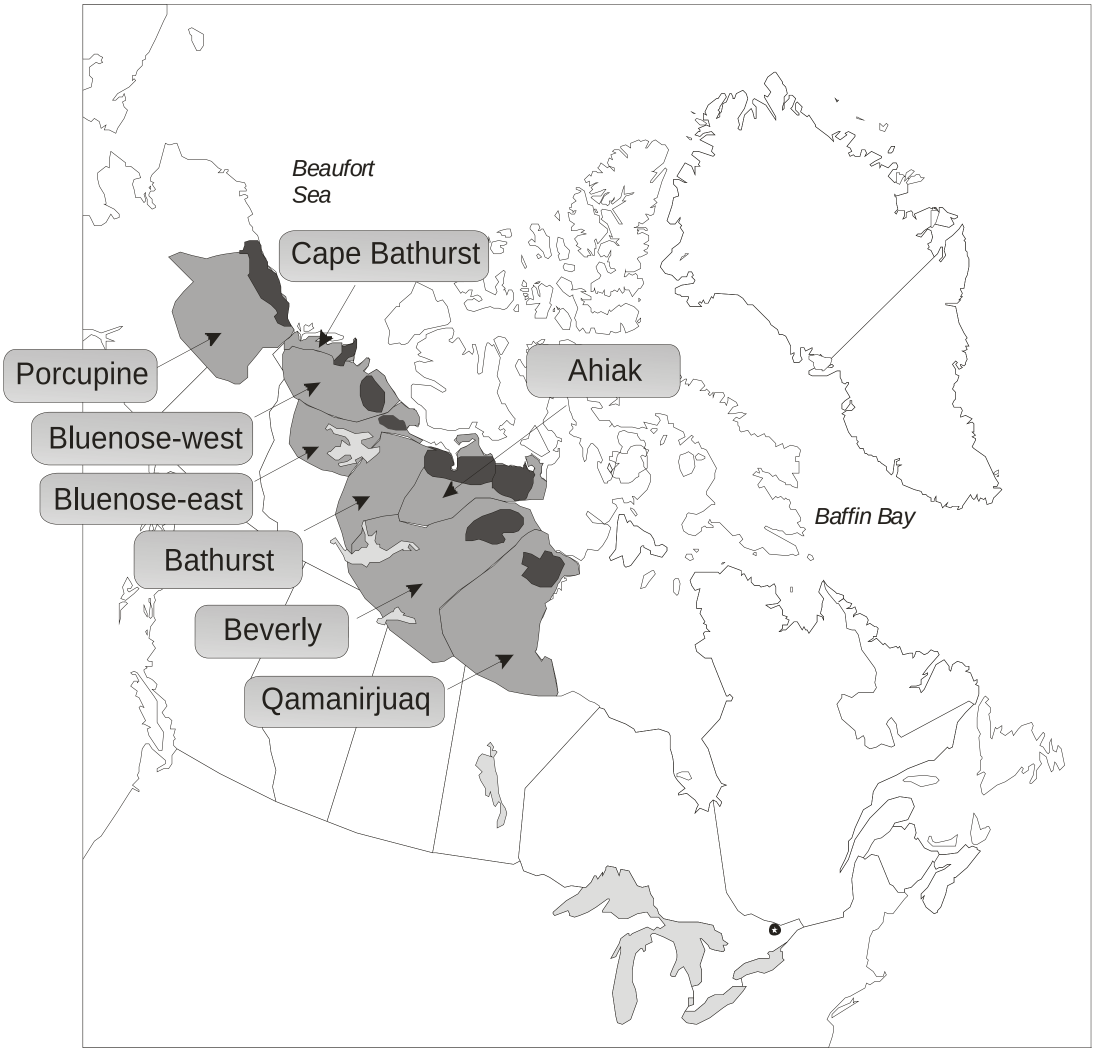
TABLE 5.3-4
SERIES OF MEASUREMENTS THAT COULD BE COLLECTED BY HUNTERS TO MONITOR THE CONDITIONS OF A CARIBOU HERD

Indicator	Measurement
Indicators hunters look for when selecting caribou	Size of rump
	Gait or waddle of walk
	Whiteness of mane
	Size of rack
	Symmetry & overall shape of rack
	Number of configurations or points on rack
	Size & shape of shovel
	Greyness of rack
	Social role of individual in group
	Posture of animals when moving
Post-mortem indicators of caribou health	Quantity of "backfat" (i.e. rump)
	Quantity of stomach fat
	Colour of marrow
	Tone & colour of lungs (lungs stuck to chest indicate poor health)
	Colour of kidneys and liver
	Absence of pus bags on kidneys
	Absence of "water" in muscles (water produced when animal is worked)
	Contents of stomach (grass-filled may indicate sick animal)
	Presence of parasitic larvae in kidneys

Source: Kofinas, G.P. 1998. The cost of power sharing: community involvement in Canadian Porcupine caribou co-management. Ph.D. dissertation. University of British Columbia, Vancouver.

There are eight major barren-ground caribou herds that occupy some area in the NWT during the year (Figure 5.3-1). A summary of the sizes and status of the individual herds is listed in Table 5.3-5, with the estimated harvest rate. Because of the different research and monitoring programs and management schemes, each herd will be assessed independently. Long-term trend data for five of the herds are summarised in Figure 5.3-1.

FIGURE 5.3-1
MAP OF CANADA SHOWING THE APPROXIMATE RANGE AND CALVING GROUNDS OF THE EIGHT MAJOR BARREN-GROUND CARIBOU HERDS IN THE NWT



Source: [Map is redrawn from Russell et al. 2002.]

TABLE 5.3-5
MOST RECENT CENSUS DATA ON NWT BARREN-GROUND CARIBOU HERDS AS REPORTED BY THE CIRCUMARCTIC RANGIFER MONITORING & ASSESSMENT NETWORK[1]

NWT Herd	Current Estimated Size	Status	Last Census Date	Next Proposed Date	Estimated Rate of Harvest
Bathurst	186,400	Declining	2003	Unknown	Estimate of ~14,000 in 1996.
Beverly	286,000	Unknown	1994	2000	14,000[1]
Qaminirjuaq	496,000	Unknown	1994	2000	-
Ahiak	200,000	-	1996	Unknown	unknown
Bluenose East	66,600	Declining	2005	-	5,000[2]
Bluenose West	20,800	Declining	2005	-	5,000[2]
Cape Bathurst	2,400	Declining	2005	-	-
Porcupine	123,000	Declining	2001	-	3,000

[1] – estimate is probably for both the Beverly and Qamanirjuaq herds.
2 – total estimated harvest of Bluenose East, Bluenose West and Cape Bathurst herds.

ii) Bathurst Herd

The Bathurst herd is one of the largest of the NWT herds and is more accessible to people than any other NWT herd (Case *et al.* 1996). Approximately 10 aboriginal communities, and the city of Yellowknife, lie within the range of the herd, which covers about 250,000 km^2. The herd over winters in the region of the NWT to the north and east of Yellowknife, migrates north in the spring, and calves to the south of Bathurst Inlet in Nunavut (Figure 5.3-1). Several abandoned mines and two diamond mines are currently present within the territory covered by the herd.

The background information on the herd is extensive, with many papers in peer-reviewed journals, traditional knowledge of the herd (Dogrib Treaty 11 Council 2001, 2002) and many published and unpublished reports relating to aspects of the biology and ecology of the herd. Knowledge of the herd is based on several scientific studies on herd numbers, movements (Dogrib Treaty 11 Council 2001) and body condition. A summary of research relating to the Bathurst herd was prepared by Gartner Lee Limited for the North Slave Métis Alliance (Gartner Lee Limited 2002), although the review is very selective in the references it includes. Many studies from the Government of the Northwest Territories, science journals and traditional knowledge studies were not included.

[1] http://www.rangifer.net/carma/about.html

A large step in the management of the Bathurst herd was taken when a management plan for the herd was finalized in November 2004 by the Bathurst Caribou Management Planning Committee[1]. The management committee is a partnership of 11 parties from the NWT and Nunavut, including DIAND, GNWT, Nunavut's Department of Sustainable Development, the Dogrib Treaty 11 Council, The Lutsel K'e First Nation, the Yellowknives Dene First Nation and the North Slave Métis Alliance from the NWT. The Department of Environment and Natural Resources is seeking comment on the Plan until April 15, 2005.

The management plan outlines a detailed strategy for monitoring and management of the herd, protection of the caribou habitat and the management of the harvest. Additional actions are recommended when the herd size is declining or lower than historic levels. Several objectives for maintaining herd size and condition are outlined, with specific monitoring actions. The actions include monitoring several indicators of the fitness of the herd, harvest rates and the influence of predators. Community input on the status of the herd and the harvest rate are a major portion of the plan. It is important that the commitments by all parties be followed in the level of priority listed in the Plan, given the reduction in the size of the herd during the 1990s.

Population estimates for the Bathurst herd extend back to the early 1950s (Banfield 1954), however estimates using standardized census methods began in the 1970's, when the herd was estimated at about 150,000 animals (Figure 5.3-2). The most recent survey of the Bathurst herd by the Department of Environment and Natural Resources shows that the number of pre- and post-parturient cows in the Bathurst herd declined significantly to approximately 80,756 from levels of about 150,000 in 1990 and 1996 and 204,000 in 1986 (Gunn *et al.* 2004). The survey was conducted in June 2003 using standard visual and photographic aerial survey methods and the error estimates around the population estimate are much smaller than both the 1990 and 1996 surveys and are close to those observed in 1986. The smaller error measurements provide more confidence in the population estimate and may provide a better indicator of long-term trend than by using the 1990 and 1996 data. Using male:female sex ratios and pregnancy rates from earlier studies, the total herd size was estimated to be 186,000 individuals in 2003, down substantially from 320,000 in 1996. Although the total population in 2003 is substantially lower than surveys in the 1980s and 1990s, current estimates place the size of the herd similar to those during the 1970s (Case *et al.* 1996). The study concludes that the herd has declined significantly since 1986 survey, at a rate of roughly 5% per year.

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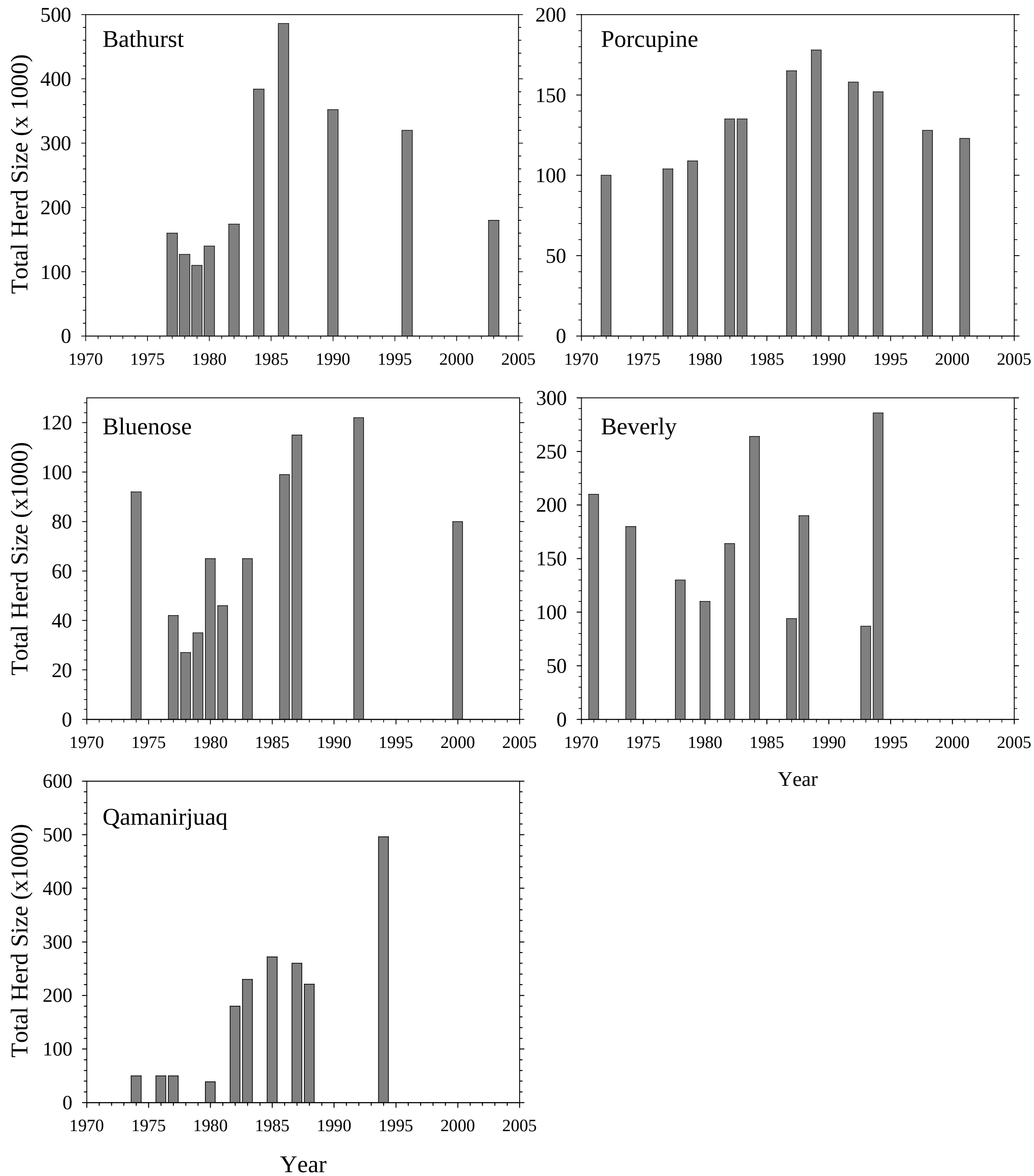
1 http://www.nwtwildlife.rwed.gov.nt.ca/NWTWildlife/caribou/Bathurst%20Caribou%20Management%20Plan%20Nov%2008%20RC.pdf

FIGURE 5.3-2
LONG-TERM TRENDS OF POPULATION ESTIMATES FOR THE MAJOR BARREN-GROUND CARIBOU HERDS IN THE NWT



Source: CARMA 2005[1]

[1] http://www.rangifer.net/carma/

The census of the number of females in the Bathurst herd was conducted using the most modern techniques and have been improved with discussions from other biologists (Gunn *et al.* 2004). It is not clear if more recent sex ratio and cow:calf ratios data are available for the Bathurst herd which makes it difficult to determine the reasons behind the observed decline. This leaves open the question of whether the decline is due to poor body condition of the females, losses of adults due to high harvesting rates, loss of calves due to high predation or weather during or post-calving or emigration from the herd to surrounding herds. If these data are not currently available, it is important that a program be conducted as indicated under the Bathurst Herd Management Plan to collect demographic data on the herd.

The Management Plan is a major step in collecting information on the herd in an organized and detailed fashion. It will formalize the collection of harvest rates, and place commitments on the territorial government to collect information relating to herd health. ENR has reported on its website[1] that the total number of Bathurst caribou hunted by resident and non-resident hunters was about 2000 to 2500 animals/year between 1996 and 2002. The total harvest, which includes the aboriginal and commercial harvest, was estimated to range from 14,500 to 18,500 in 1996, with a management objective at the time of 16,000 annually (Case *et al.* 1996). This was based on a total population estimate of about 350,000 for the herd, with a herd size of 300,000 to 600,000 needed to support the objective. These general objectives for the harvest rates are about 10 years old, and will need to be re-examined with the new census data, as it is unlikely that these rates could be maintained in the current declining population.

It is clear that there will be increasing pressure to increase development in the range of the Bathurst herd even though the effects of the development are largely unknown. Research in both Europe and Alaska has shown that roads, pipelines, airstrips, etc., can have a major impact on the movement and distribution of caribou and reindeer at some times during the annual cycles (Nellemann and Cameron 1996, 1998, Vistnes *et al.* 2001, Cameron *et al.* 2005). The most significant changes appear to occur in females during the calving period, who tend to avoid the infrastructure associated with development and may move to suboptimal habitat to calve if the level of development becomes too great. The clearest example of this may be occurring in Alaska with the Central Arctic herd (Cameron *et al.* 2005). Similar displacement could occur in the Bathurst herd, particularly if a permanent road is built to Bathurst Inlet and the number of mines continues to increase. Indicators should be developed and monitored in the herd to provide early warning signs of effects due to development.

[1] http://www.nwtwildlife.rwed.gov.nt.ca/NWTWildlife/caribou/bathurstharvest.htm

iii) Porcupine Herd

The Porcupine herd has been the subject of intensive study in the last 15 to 20 years because of its international distribution and the location of its calving ground in the Arctic National Wildlife Refuge (ANWR) on the Alaskan North Slope. The range of the herd covers about 250,000 km^2 in northeastern Alaska, and the Yukon and Northwest Territories. The herd calves on the Alaskan North Slope, but disperses to over winter in the northern NWT, Yukon and northeastern Alaska. Research on the herd has been conducted by both Canadian (Russell *et al.* 1993) and Alaskan (Griffith *et al.* 2002) research groups, often in collaboration with each other (Fancy *et al.* 1994). The herd has drawn considerable interest because the herd size has continued to decline since 1989, and is the only major herd on the North Slope to show a decline in numbers since oil and gas development in the 1970s began in earnest.

The Porcupine herd is managed by the Porcupine Caribou Management Board (PCMA) through the Porcupine Caribou Management Agreement. There is currently an International Conservation Agreement (1987) and an international plan with the United States for the conservation of the herd. The Plan outlines specific duties for the governments of the two countries in the interest of conserving the Porcupine herd, such as sharing harvest data and protecting the habitat. The Porcupine Caribou Management Agreement was signed in 1985 and is an agreement between the federal and territorial governments, the Council for Yukon Indians, the Inuvialuit Game Council, the Dene Nation and Métis Association of the Northwest Territories. The active role of the Arctic Borderlands Ecological Knowledge Society (ABEKS) is also important in sustaining the discussions between communities and First Nations about changes in the herd and the environment, and in helping to determine harvest rates.

The latest population census for the Porcupine herd was taken in 2001 and places the total herd at 123,000, or about the 8th largest in North America (Porcupine Caribou Management Board 2004). This level has continued to decline since the herd reached a maximum of almost 180,000 individuals in 1989. Griffith *et al.* (2002) report that the herd size appears to go through 30-40 year cycles but, if the current decline continues, the herd will reach the lowest levels ever recorded in 2005-2010. The herd appears to have a slower inherent growth rate than other herds on the North Slope, possibly due to higher rates of mortality in adults. The decline in herd size has occurred despite high rates of calf survival and productivity (Russell and McNeil 2002). Two recent bad years where calves were born during the migration caused lower than average rates of survival during the first month of life (Russell and McNeil 2002). The PCM Board reports that the total harvest is about 2,000 to 3,000 animals annually, or about 2-3% of herd size, with wolves taking an additional 3-5%. Detailed current information on the calving rate, calf survival, parturition rate are available to help determine the reasons behind the observed decline (Griffith *et al.* 2002).

The major concern with the Porcupine herd has to be the effect of expanding development in and around the calving grounds in ANWR. Displacement of calving females from optimal habitat could result in lower growth rates and survival in calves, and an increase in predation from grizzly bears, wolves and golden eagles (Murphy and Lawhead 2000). The use of sub-optimal calving habitat may have serious implications for the long-term status of the herd. While studies have reported extensive use of oil field roads and gravel pads during summer to avoid harassment by insects (Noel *et al.* 1998), the benefits of these open areas probably don't balance the potential loss of large areas of the calving ground. Other developments (Table 5.2-2) in the area include mines and roads in the wintering grounds in the northern Yukon and NWT.

(iv) Cape Bathurst Herd

The barren-ground herd that was traditionally known as the Bluenose herd because of its calving ground near Bluenose Lake has been classified into three separate herds based on separate calving grounds and genetics (Nagy et al. in prep.). The three herds are now called the Cape Bathurst, Bluenose-West and Bluenose-East herds, based on the placements of the calving grounds (Figure 5.13). Total harvest from the original Bluenose herd exceeded 5,000, of which 90% is for subsistence use.

The Cape Bathurst herd covers the smallest range of the three herds, with calving grounds on the Cape Bathurst Peninsula and the summer and winter range extending to the west (Figure 5.12). The annual range extends through the Mackenzie Delta. Population estimates indicate the herd size at 14,500 in 1987 and about 10,000 in 2000 when the herd was surveyed as a separate entity. A 2005 survey shows the herd has declined significantly to 2400, a decline of about 80% since the last survey. Although the decrease is considered to be part of the natural fluctuation in herd size, there are few data on the demography of the herd available to support that conclusion.

(v) Bluenose-west

The calving grounds of the Bluenose-west herd are to the immediate east of the Cape Bathurst herd, with the summer and over-wintering ranges extending to the west and south. There is considerable overlap of this herd with the summering and over-wintering range of the Cape Bathurst herd. The Bluenose-west herd has varied from a low of 27,000 in 1978 to a maximum of 122,000 in 1992 (Figure 5.13) and 75,000 in 2000. The most recent population estimate of 20,800 in 2005 represents a significant decrease in herd size. The SRRB also reports a calf recruitment study of the herd to update data collected in 2000. At that time, calves comprised 19.3% of caribou, which indicates a healthy rate of recruitment and an expanding herd.

(vi) Bluenose-east

The calving grounds of the Bluenose-East herd are to the east of Bluenose Lake and range to the west of Kugluktuk in Nunavut (Figure 5.12). The herd range extends south to Great Bear Lake, where some members over winter to the south of the lake. The herd is the major source of caribou for the community of Déline during the winter.

The Bluenose-east herd was designated as a separate entity in 2000, when the herd was estimated to be 100,000 animals. A census of the herd during post-calving was conducted in 1999-2000 using radio-collaring and aerial photo-census (Patterson et al. 2004). Part of the justification for the census was the concern that 5,000 to 6,000 animals were being harvested from the population annually, a rate that was not sustainable if the herd was substantially smaller than expected. A total of 84,412 adult caribou were photographed during the census, and a total population of 104,000 was estimated using published models. A second model gave a much higher population estimate, however the 104,000 figure is more widely accepted as being the most accurate. The census was conducted during post-calving, which is considered by the authors to be superior to those taken during calving. The recent 2005 survey indicates a decline in the herd size to 66,000, which is less of a decline than in the Bluenose-west and Cape Bathurst herds. It is important that the demographics and body condition of these herds be monitored.

(vii) Beverly/Qamanirjuaq

The Beverly and Qamanirjuaq herds have been co-managed through the Beverly-Qamanirjuaq Caribou Management Board (BQCMB) [1] since 1982. The Board is made up of a diverse group of community members from Nunavut, Manitoba and Saskatchewan, and officials from ENR and Nunavut's Department of Environment. One Dene and one Métis member from the South Slave are also on the Board. This representation reflects the roughly 20 communities on or near the range of the herds that harvest from it. The population in these communities is expected to grow from 10,000 in 1999 to 14,000 by 2020 (BQCMB 1999). The Board administers the Beverly and Qamanirjuaq Caribou Management Plan, which first came into effect in 1987 and was revised in 1996. A major project of the Board has been the mapping of the range of the Beverly-Qamanirjuaq herds, including the calving grounds, from historic records.

One objective of the Board is to maintain both the Qamanirjuaq and Beverly herds at an optimum size of 300,000 and a crisis level of 150,000. If either herd drops below the crisis level then recommendations will be provided to governments to protect the herd. The last census of the Qamanirjuaq herd was in 1994, when the when the herd size was estimated to equal 496,000.

[1] http://www.arctic-caribou.com/

At that time the Beverly herd stood at 286,000; however, a recently completed survey places the size at 89,800.
The total (subsistence and commercial) harvest in 2001 was estimated at 18,500 caribou, for an estimated 850,000 kg of meat. It is not clear if this harvest is from one or both of the herds but the harvest represents about 3% of the total of the two herds at the 1994 level or approximately 4 to using the updated herd size estimate for the Beverly herd.

Mineral exploration and mines are some of the major developments that could affect the herds, including uranium mines in northern Saskatchewan, where the herd over winters. The largest proposed development was the Kiggavik uranium mine about 75 km west of Baker Lake however the mine did not proceed. Roads, pipelines, and power lines are all potential stresses on the herd. The Board has developed a rating system, based on the biology of the herd to identify the most sensitive times during its life cycle (Table 5.3-6). The rating system is useful for defining the times that the herd could be susceptible to development pressures and can also apply to other herds in the NWT.

TABLE 5.3-6
SENSITIVITY OF CARIBOU AND RANGE OF THE BEVERLY AND QAMINIRJUAQ HERDS TO DEVELOPMENT

Caribou Life Cycle Period	Caribou Sensitivity Rating[1]	Range Sensitivity Rating[1]	Caribou-range Sensitivity Rating[2]
Spring migration	Moderate (3)	Moderate (3)	Moderate (6)
Calving	Very high (5)	Very high (5)	Very high (10)
Post-calving	High (4)	High (4)	High (8)
Late summer	Low (2)	Low (2)	Low (4)
Fall migration/rut	Low (2)	Low (2)	Low (4)
Early winter	Very low (1)	Low (2)	Low (3)
Late winter	Low (2)	Low (2)	Low (4)

Notes:
1 Ratings range from 1 (very low) to 5 (very high).
2 Caribou-range sensitivity rating = (caribou sensitivity rating) + (range sensitivity rating). Ratings range from 3 (low) to 10 (very high).
Source: [Calving remains the most sensitive time of the caribou life cycle. (BQCMB 1999)]

In summary, measuring the condition and health of a caribou herd is complex because several factors must be accounted for. The total size of the herd is the most common indicator of herd status but it may not reflect the true health of the herd. Other indicators such as the body condition of individual animals, the number of pregnant females or the rate of survival of newborn calves provide a better indicator of the ability of the herd to maintain the current rate of productivity. Traditional and local knowledge, which relies on ongoing assessments from hunters, is also a very important aspect of herd assessment. Disease rates (e.g., brucellosis) and parasite loads in major herds have also been tested by Environment and Natural Resources.

(viii) What is happening?

Currently in the NWT, three major herds (Bathurst, Beverly and Porcupine) are in a declining phase. The recently completed survey of the three herds that make up the Bluenose herd, indicates a significant decline in the size of all three herd compared to prior survey findings appear to be stable or increasing.

(ix) Why is it happening?

The reasons behind the declines in the Bathurst, Beverly and Porcupine herd are not clear. Several indicators of reproduction in the Porcupine herd suggest that calf production is the same as when the herd was expanding in the 1990s and that the condition of the females is good. This rules out calf mortality as the major cause of the decline; however other factors need to be tested.

(x) What does it mean?

It is difficult to interpret what the declines in the the major herds mean. As in all species of wildlife, caribou undergo cycles that are caused by natural factors. For example, a herd that is too large will overgraze its range and begin to decline as the herd birth rate and the condition of the individual animals declines. Climate, insect harassment and a large number of density-dependent and density-independent factors may come into play. Because of the possible effects of large-scale stresses like climate change, UV-B radiation and large-scale development, it is vital that research be continued into herd ecology and demography to aid in determining the reasons behind the decline.

(xi) What is being done about it?

There are major collaborative international research projects being conducted on the Porcupine herd and research is continuing into its status. A census was conducted on the Cape Bathurst, Bluenose-east and Bluenose-west herds in 2005. In addition, collaborative programs, such as the CircumArctic Rangifer Monitoring and Assessment Network, which was established under the Conservation of Flora and Fauna (CAFF) of the Arctic Council, are very important initiatives to exchange information between scientists and to help coordinate and standardize methods of herd assessment.

(xii) What are the information gaps?

Major information gaps include the need for census data for the Qamanirjuaq herd and current measurements of population demography of the Bathurst herd, if they are not currently available. A standardized approach to collecting information on herd condition, such as that discussed by CARMA, should be considered to ensure uniformity in monitoring methods between herds.

5.3.2 TEQ Indicator - Moose *(Alces alces)*

Moose are the largest in the deer family of mammals and are among the least social, which makes surveying populations difficult as individual animals must be counted separately. Moose are distributed throughout the NWT although very few are hunted above the treeline in the ISR where densities can be very low because it is at the northern edge of its range. There is some evidence that the range of the moose has recently extended further above the treeline and individual moose have been reported near Kugluktuk. Environment and Natural Resources reports a total population of about 20,000 moose in the NWT[1] however a population of >10,000 is suggested in the profile of the moose in the NWT Species Monitoring Infobase[2]. Fires in the Sahtu and Gwich'in areas were expected to decrease the populations in those areas, although the populations were expected to recover quickly.

(i) What is being measured?

Considering the importance of moose to traditional Dene diets (Morrison *et al*. 1995), there is very little published in the scientific literature on the status of the moose herd in the NWT. Most of the information is in small reports from co-management boards and usually covers moose populations in very small areas. Virtually all studies have been regional in nature and there does not seem to be an overall assessment of the species status available. A recent intensive survey[3] of moose in the North Slave region reported an average density of about 3/100 km^2. Of the two subregions surveyed, one region had a reasonable calf:cow ratio of 0.64, while the other region had a considerably lower ratio of 0.16. It was not reported if the different values indicate different conditions of the herd, problems with the survey or whether one population is declining.

The Gwich'in Renewable Resource Board has conducted several aerial surveys of moose populations in the GSA and report sex ratios and cow:calf ratios that indicate a healthy,

[1] http://www.nwtwildlife.rwed.gov.nt.ca/NWTwildlife/moose/populationstatus.htm.
[2] http://www.nwtwildlife.rwed.gov.nt.ca/rwed_infobase/asp/full.asp?SpecID=5.
[3] http://www.nwtwildlife.rwed.gov.nt.ca/pdf/NSRmoosesurveyposter.pdf.

sustainable population (Benn 1999, 2001). Similarly, the Wildlife Advisory Council (North Slope)[1], in conjunction with the Aklavik Hunters and Trappers, reported that the population on the North Slope between the Mackenzie Delta and the Blow River had increased substantially during the 1990s and the healthy male:female ratio and high calf recruitment indicate an expanding population.

The Gwich'in Moose Management Plan (GRRB 2000) reviewed the state of knowledge for the GSA and lists several concerns that are probably typical of each of the Settlement Areas and the Deh Cho. These concerns include the fact that population estimates are not available for the entire GSA, the status of the moose population is unknown and that the effects of the harvest on the population are unknown. This information is vital to understanding the state of the population and the effects of changing environmental conditions and development in the area. The effect of hunting on the population is also uncertain, as hunters may select for specific ages and sex that influence the rate of productivity. Approximately 40 moose were harvested annually in the GSA during the 1990s, although the total population in the GSA is not clearly defined. Environment and Natural Resources reports that resident and non-resident hunters hunt about 200 moose per year[1] over the entire NWT. The ISR harvest study reports about 28 moose are taken annually in the harvest, while about 200 are taken in the Sahtu (SRRB 2002, 2003)

The size of the moose population in the regions, and the NWT as a whole, gives a reasonable estimate of herd health, although species indicators such as sex ratios, calving rates and body condition estimates are important. There are also several research papers in the literature relating to the levels of disease in moose because of the influence of parasites and disease on local populations.

(ii) What is happening?

Moose are a large, nutritional part of the Dene/Métis traditional diet, but its overall status within the NWT is largely unknown. Because moose harvesting remains relatively successful, the population is assumed to be healthy and robust. Management of the species is through management plans in the individual Settlement regions, but because of its solitary nature and low density, collecting census data is difficult. The effect of disease (e.g., winter tick, *Parastrongylus* sp.) is also a major concern for the health of the moose but is probably only a significant problem on a local or regional level.

[1] http://taiga.net/wmac/consandmanagementplan_volume3/moose.html.

(iii) Why is it happening?

Fires in the Sahtu probably affected local moose populations; however, the population will probably recover with the habitat. Other populations of moose are probably affected by hunting, predators, particularly wolves, and disease.

(iv) What does it mean?

Overall, the NWT moose population is robust and the current rates of harvest can probably be maintained; however, the lack of NWT-wide data make this conclusion conjectural. Population surveys are probably not precise enough to determine desirable harvest rates accurately. For this reason, habitat condition, animal condition, calf productivity and population size should be monitored more closely.

(v) What is being done about it?

Management boards, in conjunction with Environment and Natural Resources, are conducting surveys on local moose populations in smaller areas of the NWT. In addition, harvest statistics are reporting the numbers of moose taken near communities and information on the age and sex of the harvested animal. This information is important for providing some data on the local population. The prevalence of disease in moose populations is being studied by research projects.

(vi) What are the information gaps?

Several gaps in information need to be addressed to assess the condition of moose in the NWT. Most of these gaps are summarized in the Gwich'in Moose Management Plan (GRRB 2000) but probably apply to other regions that are managing local moose populations, and to the whole of the NWT as well. Accurate population estimates are not available for the NWT or the regions, the health of the population in the regions is generally not known and the effects of the current rate of harvest are not known. Also, the condition of the habitat and the size of the home range, seasonal movements of moose and habitat selection are not well known in the NWT. In addition, the rates of predation are largely unknown. Although the moose is one species that may benefit from a warming climate, there is need to collect and analyze data from across the NWT for this species.

[1] http://www.nwtwildlife.rwed.gov.nt.ca/NWTwildlife/moose/harvestlevels.htm

5.3.3 TEQ Indicator - Landbirds (Grouse and Ptarmigan)

Landbirds make up a significant portion of traditional diets in the north (Morrison *et al.* 1995, Berti *et al.* 1998). The dominant species are sharp-tailed grouse (*Tympanuchus phasianelus*), spruce grouse (*Dendragapus canadensis*) and ruffed grouse (*Bonasa umbellus*) (commonly called "chickens") and willow (*Lagopus lagopus)* and rock ptarmigan (*Lagopus mutus*). These five species are members of the galliform order of birds and have several adaptations that allow them to survive in the north. Harvest survey data from the three Settlement Areas indicate that over a thousand of either grouse or ptarmigan are harvested annually (Figure 5.2-4). Grouse and ptarmigan do not migrate and hence are considered resident birds, which remain in a small range throughout the year.

(i) What is being measured?

Several national and international programs have been developed to monitor the status of landbirds in North America. The objective of most of these programs is to provide a consistent methodology to record the presence and numbers of birds at a given time and habitat every year in order to determine long-term trends. Many of these programs have been incorporated into the Canadian Landbird Monitoring Strategy[1] that is coordinated by the National Wildlife Research Center of the Canadian Wildlife Service, and run cooperatively with the US Geological Survey's Patuxent Wildlife Research Centre. These programs are very successful in the southern Canada and the U.S. where there is a high density of surveys for both summer breeding bird and Christmas bird counts. Surveys sites are widely scattered in the NWT (Normal Wells and Yellowknife provide the best data sets within the NWT) and only provide useful information for some species. For this reason, the current status of grouse and ptarmigan can best be determined by extrapolating trends from the boreal taiga that extends to the south and from harvest statistics.

Unlike waterfowl that are managed through international conventions and are monitored with extensive survey programs (see below), the status of landbirds is conducted through *ad hoc* programs using volunteers and professional biologists. One of the most important records of the status of birds is the North American Breeding Bird Survey (BBS) that has been conducted in Canada since 1967 but has only been active in the NWT for 10-15 years. The survey provides abundance, distribution and population trends for more than 400 bird species including many landbirds (Downes and Collins 2003). Volunteers and biologists conduct surveys of bird activity at approximately the same time every year. Several dozen routes are run in each province while very few are conducted in the NWT.

The survey is useful for determining the long-term abundance of many species. For example, some species of warblers and finch have declined steadily over the past few decades, while some

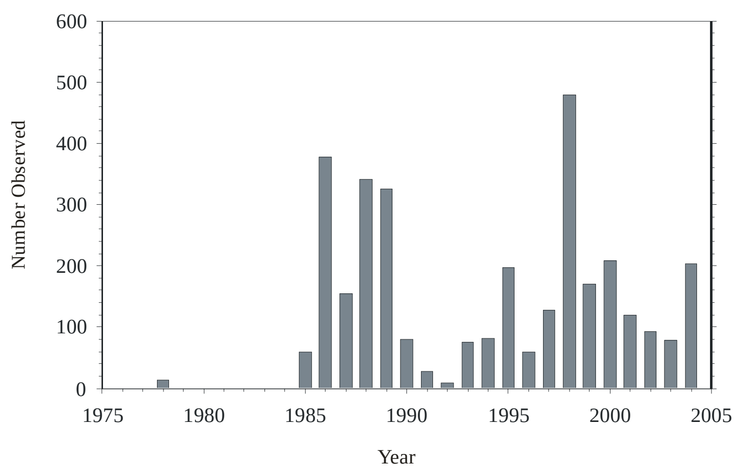
[1] http://www.cws-scf.ec.gc.ca/nwrc-cnrf/migb/01_1_3_e.cfm.

ducks, the crow and some warblers have been increasing in numbers at the same time. Within the ptarmigan and grouse species evaluated here, data are only available for the ruffed and sharp-tail grouse. Nationally, the ruffed grouse increased by 4.4% between 1991 and 2000, however in the boreal taiga plains[1], the species declined about 6% during the same time period. Nationally, the spruce grouse has declined marginally (5%) over the past ten years.

The Audubon Christmas Bird Count[2] (CBC) also provides some information on the abundance of species. The CBC takes places annually around Christmas and provides a yearly record of the birds present in a given area. Grouping together survey data within a region gives some indication of the long-term status of a species.

Although the Christmas Bird Count is very useful in determining long-term trends when several surveys are combined within small regions, very few data are available for grouse or ptarmigan species and no clear trends can be extracted from the information. There are approximately ten CBC sites designated within the NWT; however there are only about four sites for which long-term data are available. When all the data from 1970 to 2004 for the NWT are grouped, the number of ruffed grouse varied from zero to a maximum of five, with the latter value reported in 1994. Numbers of spruce grouse and sharp-tailed grouse were higher in some years than the ruffed grouse, reaching a maximum of 25 sharp-tailed grouse in one year, with the number of each species reported slightly higher in more recent years. Similarly, only eight rock ptarmigan have been reported between 1980 and 2004, all in 1994, for the entire NWT counts. The number of willow ptarmigan is extremely variable ranging from zero up to several hundred per year (Figure 5.3-3). These data do not provide suitable data to estimate population trends throughout the NWT.

FIGURE 5.3-3
NUMBER OF WILLOW PTARMIGAN OBSERVED IN ALL NWT CHRISTMAS BIRD COUNTS FROM 1978 TO 2004



1 http://www.cws-scf.ec.gc.ca/birds/Trends/species.cfm?lang=e&species_ID=3000.
2 http://www.audubon.org/bird/cbc/index.html.

Source: Audobon Christmas Bird Count

Hence, although the CBC has been widely accepted as an important survey tool for detecting long-term trend data of certain species, its usefulness is restricted in the NWT because of the few surveys conducted and the variability of the numbers reported. The numbers of observations are far too low to establish trends with any statistical confidence and the few surveys conducted over the NWT make this a poor method of detecting trends. It is more likely that harvest statistics within each community and region provide better indictors of population status and should be examined for evidence of long-term trends.

In summary, the populations of grouse and ptarmigan are being assessed by breeding Bird Counts, Christmas Bird Count and through harvest surveys. None of these methods provide enough comprehensive data to determine the status of these species across the NWT. There are no dedicated census programs for these species. The status of the species relies almost entirely on local knowledge and harvest data. Harvesters provide a record of local availability of these species but the information is restricted to local areas. It is important to note that there do not seem to be any landbird species that are being monitored with the precision and accuracy required to detect long-term trends.

(ii) What is happening?

It is difficult to assess the status of these species of landbirds and the variability of the long-term survey data is too inconsistent to speculate about trends in the population. It is assumed that the populations in the NWT are robust and can withstand the current harvest rates.

(iii) Why is it happening?

The poor base of data to evaluate population trends is a result of the biology and ecology of the landbirds and the difficulty in assessing the population density. The large land area of the NWT also makes it difficult to detect trends.

(iv) What does it mean?

It is not possible to conclude anything about population trends of these species because of the lack of data. Continuing harvest levels suggest a long-term stability of the populations but this could change with significant change in the climate.

(v) What is being done about it?

Harvest data are one of the better methods of tracking the presence of these birds near communities and should be continued. There is a good chance that these species benefit from warming climate if the plant species that provide their browse become more common.

(vi) What are the information gaps?

The information gaps have been discussed above. There are no dedicated censuses for these species so their general status is derived from the continuing harvest. There are also no surveys of their habitat. Both the Breeding Bird Survey and Christmas Bird Counts provide critical information on bird species and their presence should be expanded in the NWT.

5.3.4 TEQ Indicator - Waterfowl

Waterfowl are a major resource in the NWT and several waterfowl species are used in traditional diets in all regions of the territory (Figure 5.2-4). The term “waterfowl” refers collectively to species of ducks, geese and swans. Waterfowl are managed as an international resource more than any other group of wildlife considered here. Agencies in the U.S. and Canada, as well as in the NWT, are dedicated to understanding the status of waterfowl species. Hence, degradation of the over-wintering habitat in the south or high harvest rates during migration will directly influence the size and condition of the waterfowl populations in the NWT. Adaptive management strategies have also been implemented (Nichols *et al.* 1995, Johnson *et al.* 2002) to constantly assess the status of the populations, their habitats and the rate of harvest. Hence, although this report provides a single observation on the status of some waterfowl species, it is important that NWT continue to monitor the resource through these agencies. There are also several non-governmental organizations such as Ducks Unlimited, Bird Studies Canada, Bird Life International, the Nature Conservancy and the Canadian Nature federation that support research and initiatives such as the designations of Important Birding Areas (IBA)[1]. Currently there are 19 IBAs in the Northwest Territories.

(i) What is being measured?

In Canada, the Canadian Wildlife Service regulates the harvesting of waterfowl and produces three reports per year on the population status of migratory game birds (CWS 2004), proposals to amend the Canadian Migratory Bird Regulations for hunting regulations, and hunting regulations for the year. The major act of legislation in this area is the Migratory Birds Convention Act[2] (1994) which places responsibilities on the parties to monitor populations and establish harvest

[1] http://www.ibacanada.com/.
[2] http://www.cws-scf.ec.gc.ca/legislations/laws1_e.cfm.

rates of the resource. Regulations in the Act designate the times of the year and areas in which hunting can take place, the species and number of migratory game birds that can be hunted, the manner and equipment that can be used and the periods of the year in which a person may have game birds in their possession. The current Regulations in the Act do not regulate subsistence harvests.

Annual monitoring of the status of waterfowl populations is necessary because of the influence of environmental factors, such as long-term drought and climate change on waterfowl habitat and the intensive harvesting of the population in the south. For example, large changes in duck populations in the 1990s were directly related to the drought on the prairies. Similarly, a very late spring in the NWT in 2004 resulted in very low productivity in many waterfowl species (see below) which resulted in a decrease in early nesting species like the mallard and northern pintail. For this reason, continuous monitoring of nesting habitat in the NWT and elsewhere, the size of the breeding population, and the sex and age characteristics of the harvested birds is vital to predicting the long-term status of the individual species.

The methods used to conduct the census of waterfowl breeding populations are described in U.S. Fish and Wildlife (USFWS 2004). The 2004 survey is typical of the surveys conducted for several decades, giving consistency to the quality of the data obtained. In total, the surveys cover over four million square kilometres in western and northern Canada and the U.S.A. and are conducted by territorial, federal or provincial teams. The 2004 survey of the NWT waterfowl populations was conducted between May 20 and June 8, 2004. The surveys in the NWT cover several large tracts of the NWT, termed strata. Data reported by the U.S. Fish and Wildlife and Canadian Wildlife Service include two areas in northern Alberta (e.g., the Peace-Athabaska Delta) that are also assessed with the NWT data. The flyovers assess the indicated number of breeding pairs. There is no detailed habitat assessment in the NWT. The US waterfowl surveys regularly assess ponds in the south but this is not done in the north. However, the waterfowl habitat in the NWT was described as good in 2004 but it was noted that it was the latest spring in recent record with little open water in many of the parts of the NWT during the survey in June (U.S. FWS 2004).

A wide range of waterfowl species is hunted by residents and non-residents in the NWT and are important components of traditional diets. This assessment evaluated the status and harvest levels of two major species, total ducks and geese, all of which are harvested. Monitoring total duck species allows an assessment of general habitat conditions (total habitat area). The summary of population indicators is listed in Table 5.3-7. The species used as indicators were:

- Mallard (*Anas platyrhynchos*)
- Northern pintail (*Anas acuta*)
- All duck species

- Canada goose (*Branta canadensis)*

TABLE 5.3-7
INDICATORS OF THE STATUS OF WATERFOWL POPULATIONS IN THE NWT

Indicator	Description
Population	Number of individuals in the population; usually assessed as the number of breeding individuals
Harvest rate	Number of birds harvested locally, nationally and internationally on the same population
Juvenile:adult ratio in harvest	Number of young-of-the-year harvested relative to the number of adults harvested
Sex ratio in harvest	Number of males harvested to number of females
Habitat quality and area	The area of nesting habitat and the quality/suitability for nesting waterfowl.

Mallard

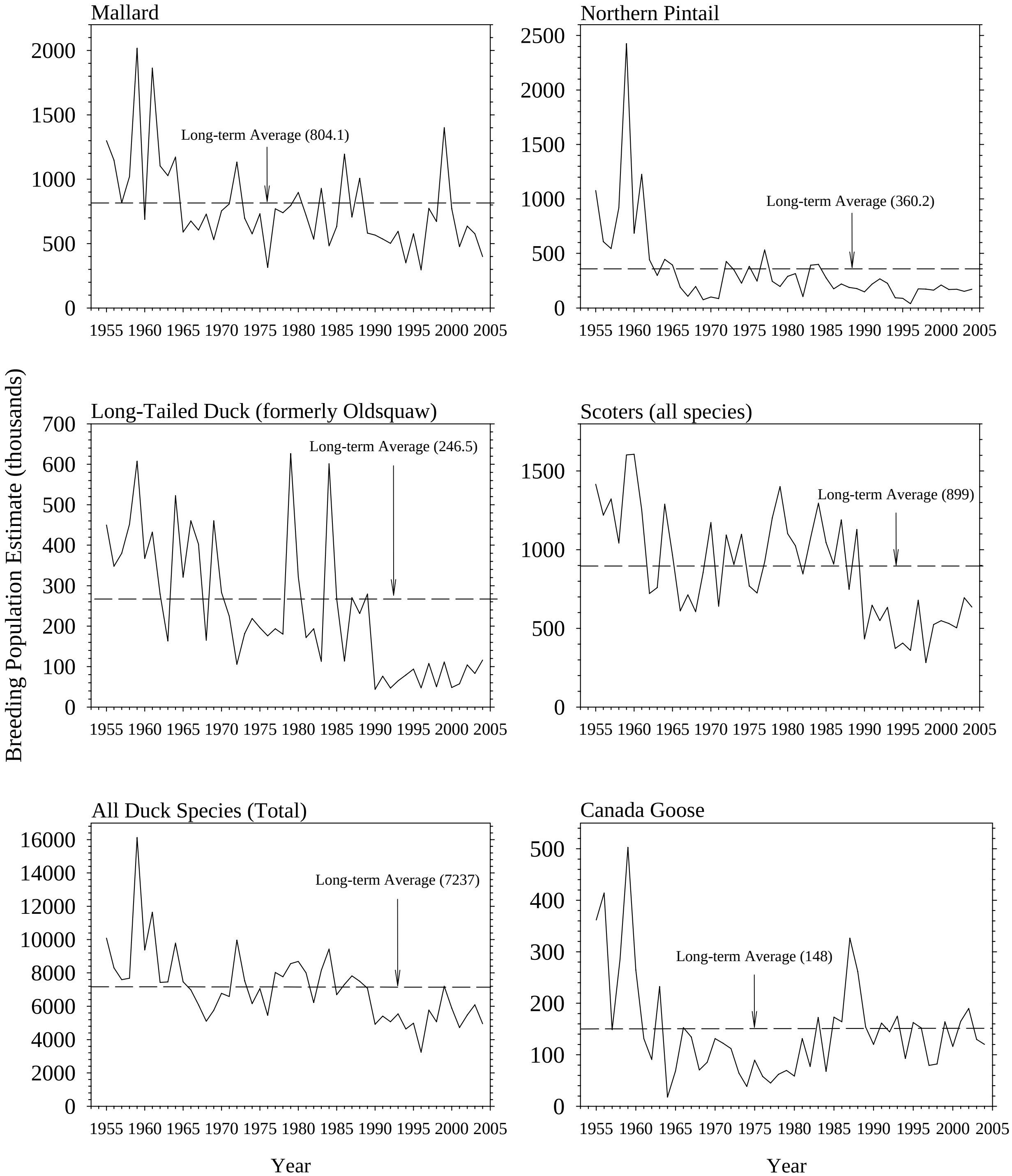
The mallard has been shown to undergo considerable changes in population size, largely because of the quality of nesting habitat and the weather during the nesting season. Nationally, the population of mallards dropped below the target level of 8 million birds designated by the North American Waterfowl Management Plan (NAWMP) in 2001 (CWS 2004). Much of this decline for the North American population is due to very low levels of production on the Canadian Prairies caused by drought conditions. There was a significant increase in the populations on the American prairies and in Alaska during the 1990s. It is expected that it may take several years of average rainfall in the prairies to recover many of the small lakes after several years of drought.

The NWT breeding population comprises about 10% of the mid-continent population of mallards in North America and follows the same general trends as the population on the Canadian Prairies. The breeding population has declined significantly since 2001, after reaching a major peak in 1999 (Figure 5.3-4). The 2004 population was estimated to be well below the 10-year and long-term mean (Table 5.3-8) although there appears to be no clear trend over the long-term from 1961 to 2004 (CWS 2004). Mallards are generally considered to be an early nesting species and hence may have been more affected by the exceptionally late spring in NWT in 2004 than other duck species. The high populations of mallards in both Alaska and the American prairies suggest that the NWT population will recover when the habitat and spring weather conditions are more favourable.

The NWT harvest surveys indicate that over 200 mallards are harvested annually in the ISR (Joint Secretariat 2003), about 700 annually in the Sahtu (primarily in the spring) (SRRB 2002), and about 150 in the Gwich'in Settlement Area (GRRB, pers comm.). Similar harvest rates in the

Deh Cho, Tli Cho and Akaitcho areas would put the total harvest level at about 2000 birds annually. Kruse (2004) reports total mallard harvests in the NWT between 1972 and 2003 at

FIGURE 5.3-4
LONG-TERM TRENDS IN BREEDING POPULATIONS OF MAJOR WATERFOWL SPECIES IN THE NWT AND NORTHERN ALBERTA



Source: (USFWS 2004)

TABLE 5.3-8
WATERFOWL POPULATION ESTIMATES FOR NORTHERN ALBERTA AND NORTHWEST TERRITORIES FOR 2002, 2003, 2004 AND THE 10-YEAR AND LONG-TERM AVERAGE POPULATION ESTIMATES

Species	Estimated Population (x 1000)					2004 Population Estimate as % Change From	
	2002	2003	2004	10-year mean	Long-term mean (1955-2004)	10-year mean	Long-term Mean (1955-2004)
Mallard	635.6	576.8	398.4	652.8	796.0	-39%	-50%
Northern Pintail	171.7	151.5	171.4	143.2	352.1	19.7%	-51.3%
Long-tailed duck	104.3	83.2	116.3	78.3	240.3	48.6%	-51.6%
Scoter (all species)	503.6	695.2	635.3	490.6	886.8	29.5%	-28.4%
Merganser	74.5	114.3	41.3	83.2	74.9	-50.3%	-44.8%
All dabbling ducks	2522.4	2770.7	2094.4	2398.8	2937.5	-12.7%	-28.7%
All diving ducks	2270.5	2432.6	2061.0	2257.1	3037.1	-8.7%	-32.1
All duck species	5475.3	6087.1	4948.3	5307.8	7177.2	-6.8%	-31.1%
Canada Goose	189.9	129.8	120.2	133.3	148.4	-9.8%	-19.0%

Notes:
Dabbling duck species included: mallard, American black duck, gadwall, American wigeon, American green-winged teal, blue-winged teal, northern shoveler, northern pintail.

Diving duck species included: redhead, canvasback, scaups, ring-necked duck, goldeneyes, bufflehead, ruddy duck.
Source: U.S. Fish and Wildlife Service (2003, 2004)

about 3,000 annually, although the numbers in later years are considerably lower than those in the 1970s when over 10,000 birds were harvested. In contrast, the total harvest of mallards across the continent is about 5 million birds in the U.S. and 500,000 in Canada. The total North American harvest in 2003 (5.53 million birds) was slightly higher than the 2002 level. The harvest levels in the NWT are clearly a very small fraction of the total number taken. U.S. FWS records report that the ratio of immature/adult mallards taken in the southern hunt is about 0.70, indicating that more adults than juveniles are taken. Most of this is due to the higher harvest rate of male adults (about four times higher than females), as an equal number of immature and adult female mallards are taken (Kruse 2004).

Northern Pintail

The Northern American northern pintail population underwent a significant decline during the 1980s, recovered during the 1990's and has begun to decline again since the 1990s (Figure 5.3-4) (CWS 2004). In 2004, the total population in North America fell to 2.18 million birds, far below the North American Waterfowl Management Plan 1998 target value of 5.6 million birds (NAWMP 1998). Much of this decline could be related to the fact that over 60% of the North American population of pintails is on the Canadian Prairies and drought and habitat loss affect the entire population. Unlike the mallard, which has shown declines in some populations and increases in others, the decline in the pintail appears to be occurring in all areas of North America. The harvest of the pintail has also followed the population trend, declining in the 1980s and increasing in the 1990s.

In the NWT, the northern pintail population has remained relatively stable over the last 30 years (Figure 5.3-4), however the numbers are much lower than the peak in the early 1960s. The breeding population estimate in 2004 was 171,400, about 50% lower than the long-term average, which includes the high levels in the 1960s (Table 5.3-7). The 2004 level was about 20% higher than that in 2003. In general, the number of pintails in the NWT reflects the same lower levels that are found throughout North America. The continental harvest of the pintail remains at about 389,000 birds, with about 48,000 of those in Canada. In contrast, about 60 birds (range of 10 to 268) are harvested annually in the ISR, 20-30 in the Gwich'in SA and 100 to 500 in the Sahtu (SRRB 2003).

Geese

Goose species are among the most heavily hunted waterfowl species in the NWT, numbering thousands of birds per year. Of these, the Canada and snow geese are hunted most heavily however other species, such as the greater white-fronted goose (*Anser albifrons*) or "yellowlegs", are also hunted in the ISR. Harvest surveys show that several thousand snow and greater white-fronted geese are hunted annually in the ISR, along with several hundred Canada geese (Figure 5.2-4). The same three species are harvested in the Gwich'in, although the numbers of each species harvested are considerably lower. With the several thousand geese harvested in the Sahtu (SRRB 2003), the total numbers of geese harvested in the NWT may approach 20,000, clearly a major source of nutrition and a major staple in the traditional diet.

Based on the various sizes, colouration and breeding habitats, the goose species known as the Canada goose has been divided into several subspecies of Canada goose (*Branta canadensis*) and cackling goose (*Branta hutchinsii*). The major species nesting in the NWT are the lesser Canada goose subspecies termed the short grass prairie Canada goose (*Branta canadensis parvipes*) and one form of cackling goose (*Branta hutchinsii hutchinsii*). The two species nest primarily in the ISR, on the mainland, Banks Island and Victoria Island. Surveys in the 1990s placed the number of geese at about 80,000 birds, however the 2004 spring waterfowl survey estimated 97,000 geese which was about 14% greater than in 2003 (U.S. FWS 2004). The estimates of this population have remained relatively stable over the last twenty years (Figure 5.3-4), although the 2004 estimate was about 20% below the long-term average (Table 5.3-7). The total level of harvest in the Central Flyway, which includes the NWT goose populations, remains at about 550,000 geese annually, with about four times more adults than immatures harvested (Kruse 2004).

The most commonly hunted goose species in the ISR is the lesser snow goose (*Chen caerulescens caerulescens*), which nests primarily on Banks Island. CWS (CWS 2004) estimates that more than 95% of the western Arctic population of lesser snow goose nest on Banks Island, with smaller breeding populations at the Anderson River and Kendall Island. The total population has increased from about 105,000 birds in 1960 to 165,000 in 1976 to over 479,000 in 1995 and well over 500,000 birds in 2002 (CWS 2004). Both the Anderson River population and another population on Wrangel Island, which migrates through western Canada, appear to be declining. The habitat on Banks Island may have reached the point where it cannot support the number of geese and the population may have to be stabilized. This overabundance of breeding birds in the nesting habitat is also seen in the greater snow goose nesting areas in the eastern Canadian Arctic, where the expanding population is destroying large areas of wetland. Several special measures are being undertaken in the provinces to increase the success rate of hunters and increasing the limits allowed per hunter. About 250,000 snow geese are harvested in the Central Flyway of the U.S. annually (Kruse 2004).

In summary, several indices are measured to determine the status of waterfowl populations. Surveys of breeding birds are conducted by federal, provincial and territorial agencies annually to determine the suitability of nesting habitat and the number of breeding birds. These methods have been used consistently for over forty years and provide a good long-term record for each species. Harvest records are also collected in some settlement areas in the NWT, nationally and in the U.S. Harvest records in the U.S. and Canada report the male:female and immature:mature ratios which are important for evaluating the effect of the harvest on breeding birds in the NWT.

(ii) What is happening?

Goose species are stable or are increasing significantly over historic levels. Several other waterfowl species are below their long-term averages; however this only seems to be a major factor for species such as the northern pintail and the scoters that are significantly below the long-term average for a long time.

(iii) Why is it happening?

The reason for the decline in some waterfowl species is unclear. Populations of some species that nest on the prairies declined with the onset of the drought; however, populations of the same species in other areas improved due to favourable local conditions. The northern pintail has declined significantly from its long-term trends. Other species are also below long-term trends and it is not clear whether the numbers will increase again in the future if current harvest rates continue

(iv) What does it mean?

The major impact of declining waterfowl populations is that some species would not be available for spring or fall harvest. However, because of the number of species present on lakes and in wetland areas, hunters can probably hunt other species opportunistically. Goose species are currently plentiful and are increasing.

(v) What is being done about it?

Several parties are acting together and independently to study the ongoing status of waterfowl species in the NWT. The Canadian Wildlife Service and the U.S. Fish and Wildlife Service maintain surveys of northern breeding areas and harvest levels in the south. There is a large amount of cooperation between the Canadian Wildlife Service and the U.S. Fish and Wildlife Service in collecting data, setting hunting limits and assessing the condition of individual species. Ducks Unlimited provides significant support for the program and some research projects.

(vi) What are the Information Gaps?

There are currently a large number of programs and resources dedicated to monitoring the status of the populations and habitats of these species. Information gaps include more research programs on the reasons for the declines in some species of waterfowl.

5.4 CONCLUSIONS AND RECOMMENDATIONS

The objective of this review was to evaluate the status of several terrestrial species in order to assess the general condition the NWT terrestrial environment. Indicators for the key species included measurements of the size, abundance and demography of the population; however the effort and resources used to monitor and conduct research on the species were also assessed. These are important considerations for determining whether it is possible to detect significant changes in a species in an environment undergoing stresses such as climate change and increasing development. Vegetation monitoring was not included in this assessment but should be an integral part of cumulative effects assessment because of the extensive changes to the arctic landscape expected with climate change.

This assessment concludes that the status of barren-ground caribou herds is mixed, with two of the major herds (Porcupine, Bathurst) declining significantly over the last decade for largely unknown reasons. Natural climatic, ecological and environmental factors probably contribute to the decline; however potential development in the calving grounds of the Porcupine herd may significantly alter the fundamental ecology of the herd. Increasing development in the form of mines, power lines and potential permanent roads in the range of the Bathurst herd may have similar effects. The three herds comprising the former Bluenose herd are stable at relatively large herd sizes and a census in 2005 will update the data available for the herds. The potential for oil and gas development near the Cape Bathurst and Bluenose West herds may place significant stress on the herds in the future. The status of the Beverly and Qamanirjuaq herds is difficult to assess because of the lack of recent census data although harvest rates continue at historic levels. Given the evidence of changing climate, it is recommended that a census be conducted on the major herds every five years and that research and monitoring programs on the stresses on the herds and their habitat be continued.

The status of waterfowl species is assessed annually by a team of Canadian and U.S. researchers, and the hunting levels set accordingly. Major duck species are lower than historic levels but the populations are abundant enough to support harvest rates in the NWT. Major goose species are continuing to expand and may have to be controlled to avoid the destruction of nesting habitat in the NWT and Nunavut. Landbird (grouse, ptarmigan) numbers are difficult to assess because of the small number of surveys in the Breeding Bird Survey and long-term data on the populations are not available. The best indicator of landbird species abundance is the harvest survey data which may provide some long-term record of species availability. However, changes in traditional lifestyle and variability in annual harvest rates make any population assessment difficult.

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ATTACHMENT 5A

NWT BIODIVERSITY ACTION PLAN

WILDLIFE-RELATED MONITORING PROGRAMS IN THE NORTHWEST TERRITORIES

APPENDIX 5A

NWT Biodiversity Action Plan

Wildlife-related Monitoring Programs in the Northwest Territories[1].

The NWT conducts a host of wildlife-related monitoring programs that help in determining changes in biodiversity and better understanding functional linkages in ecosystems.

A list of many of these monitoring programs can be found below.

The list includes monitoring conducted by federal and territorial governments, as well as non-governmental organizations and Aboriginal groups. This list does not include monitoring conducted by private industry.

In these programs, **Wildlife** includes any animal or plants.

Monitoring is defined as an activity undertaken at regular intervals and expected to continue on a long-term (e.g., 10+ years) or undetermined basis. The objective of monitoring is to detect changes -- sometimes still of an unknown nature, whereas the objective of research is to test hypotheses.

Research was defined as project that is expected to end when hypotheses were tested or when the objectives were completed. Research projects were not included in the monitoring list.

If tracking is done to investigate specific questions on, for example, movement or habitat use, then tracking is research. If tracking is expected to continue indefinitely so that it can be used as a tool to monitor movement, use, dispersion, population parameters etc. in a changing environmental context, then tracking may be considered Monitoring.

[1] http://www.nwtwildlife.rwed.gov.nt.ca/Biodiversity/news.htm

Detail list - Wildlife-related Monitoring Programs in the Northwest Territories.

Title	Schedule	Collaborators[1]
Ungulates and associated predators		
Moose Population Estimates and Population Composition (Fort Good Hope, Tulita, Norman Wells)	Every 5 years	RWED Sahtu Region
Census and Composition - **Dall's Sheep** (Katherine Creek and Palmer Lake study areas)	Annually	RWED Sahtu Region
Cumulative effects - **Northern Mountain Caribou** – (South Nahanni herd)	Annually	RWED Wildlife and Fisheries Parks Canada Yukon Renewable Resources
Population Trend – **Northern Mountain Caribou** (South Nahanni herd)	Every 5-6 years	RWED Deh Cho RWED Wildlife and Fisheries Parks Canada Yukon Renewable Resources
Population Survey - **Dall's Sheep** (Richardson Mountains NWT and Yukon)	Every 5-6 years	RWED, Inuvik Region DRR, Dawson GRRB VGFN
Calving Ground survey - **BG Caribou** (Beverly)	Every 5-6 years	Gov. of Nunavut RWED Wildlife and Fisheries
Calving Ground survey - **BG Caribou** (Bathurst)	Every 5-6 years	Gov. of Nunavut RWED Wildlife and Fisheries
Calving Ground survey - **BG Caribou** (B-Q)	Every 5-6 years	RWED Wildlife and Fisheries Gov. of Saskatchewan Gov. of Manitoba Gov. of Nunavut BQ Board
Photocensus - **BG Caribou** (Cape Bathurst and Bluenose-West)	Every 5-6 years	RWED, Inuvik Region RWED, Sahtu Region GRRB SRRB
Productivity - **BG Caribou** (Cape Bathurst and Bluenose-West)	Annually	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit
Recruitment - **BG Caribou** (Cape Bathurst and Bluenose-West, Bathurst herd)	Annually	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit GRRB SRRB

Title	Schedule	Collaborators[1]
		Department of Resources, Wildlife and Economic Development HQ
Cumulative effects – **BG Caribou** - (Bathurst herd)	Annually	RWED Wildlife and Fisheries WKSS
Site Use and Behaviour - **BG Caribou** surveys (Bathurst herd near Ekati)	Annually	BHP Billiton
Fall Composition - **BG Caribou** (Cape Bathurst and Bluenose-West) Bathurst herd	Every 5-6 years	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit Department of Resources, Wildlife and Economic Development HQ
Commercial Harvest Survey - **BG Caribou** (Inuvialuit Settlement Region and Gwich'in Settlement Area)	Annually	RWED, Inuvik Region
Contaminants - **BG Caribou** (Cape Bathurst and Bluenose-West)	Every 5 years	RWED, Inuvik Region RWED, Yellowknife
Outfitter Questionnaire - **Caribou** Health	Annually	RWED Wildlife and Fisheries
Environmental Contaminants in Caribou (Bathurst, Beverly & Cape Bathurst herds)	Every 5 years	RWED Wildlife & Fisheries RWED Inuvik Region RWED North Slave Region RWED South Slave Region
Population surveys **- Bison** (Mackenzie herd)	Every 2 years	RWED South Slave Region
Population surveys - **Bison** (Slave River Lowlands herds)	Every 2 years	RWED South Slave Region Parks Canada – Wood Buffalo National Park
Population surveys - **Bison** (Nahanni herd)	Every 5 years	RWED South Slave Region RWED Deh Cho Region
Composition (calf productivity & yearling recruitment) - **Bison** (Mackenzie, Slave River Lowlands, Hook Lake herds & Nahanni)	Annually	RWED South Slave Region RWED Deh Cho Region RWED Wildlife and Fisheries
Hunt monitoring **- Bison** (Mackenzie)	Annually	RWED South Slave Region Fort Providence Resource Management Board
Summer anthrax surveillance flights and monitoring of Brucellosis & Tuberculosis **-Bison** (Mackenzie bison)	Annually	RWED South Slave Region RWED Wildlife and Fisheries
Control Area surveys - **Bison**- - associated **Woodland Caribou, Moose & Wolf** (South Slave Control Area)	Annually	RWED South Slave Region Parks Canada – Wood Buffalo National Park
Population survey - **Peary Caribou, Muskoxen, and Arctic Wolves** (Banks Island)	Every 4-5 years	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit
Population survey - **Peary Caribou, Muskoxen, and Arctic Wolves** (NW Victoria Island)	Every 4-5 years	RWED, Inuvik Region

Title	Schedule	Collaborators[1]
Productivity and Recruitment - **Peary Caribou** and M**uskoxen** (Banks Island)	Annually	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit
Productivity and Recruitment - **Peary Caribou** (Melville Island)	Annually	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit
Late winter body condition and diet - snow urine study - **Peary Caribou and Muskoxen** (Banks Island)	Annually	RWED, Inuvik Region
Prevalence and Intensity of Infection of gastrointestinal parasites - **Peary Caribou and Muskoxen** (Banks Island)	Annually	RWED, Inuvik Region RWED, Wildlife & Fisheries, Yellowknife Western College of Veterinary Medicine
Harvest Survey - **Peary Caribou** (Banks Island)	Annually	RWED, Inuvik Region
Population Survey - **Muskoxen** (Mainland in Inuvialuit Settlement Region)	Every 5 years	RWED, Inuvik Region Parks Canada, Western Arctic Field Unit RWED Sahtu Region (usually)
Harvest Survey - **Muskoxen** (Inuvialuit Settlement Region -including commercial tags, subsistence harvest and sport hunts)	Annually	RWED, Inuvik Region
Fur-bearers, Carnivores and Small Mammals		
NWT **Small Mammal** Survey (across NWT)	Annually	RWED Wildlife and Fisheries Gov. of Nunavut, RWED Regions, RWED Forest Management University of Alberta, University Laval, University of British Columbia, Gwich'in Renewable Resource Board University of Alaska Museum
Lemming monitoring-**Collared and Brown Lemmings** (Aulavik National Park)	Annually	Parks Canada, Western Arctic Field Unit
Hare Survey (Forested NWT)	Annually	RWED Wildlife and Fisheries RWED Regions RWED Forest Management Gwich’in Renewable Resource Board
Beaver Lodge Densities (Willow Lake, Oscar Lake, Ramparts River)	Every 4 years	RWED Sahtu Region
Harvest/Hunting effort Questionnaire - Mountain **Grizzly Bears** (Mackenzie Mountains)	Annually	RWED (all regions) RWED Enforcement & Legislative services

Title	Schedule	Collaborators[1]
		RWED Wildlife and Fisheries
Harvest monitoring (problem bears killed, subsistence harvest, and sport hunts) - **Grizzly Bears** (Inuvialuit Settlement Region and Gwich'in Settlement Area)	Annually	RWED, Inuvik Region DRR, Dawson Gwich'in Renewable Resource Board
Problem bear monitoring - **Grizzly Bear, Polar Bear, and Black Bear**	Annually	RWED, Inuvik Region RWED, North Slave Region RWED, Deh Cho Region RWED, South Slave Region
Population surveys **- Grizzly Bear** (Inuvialuit Settlement Region and northern Gwich'in Settlement Areas)	Every 20-25 years	RWED, Inuvik Region GRRB DRR, Dawson
Site use and behaviour – **Grizzly, Wolf, Wolverine** surveys (near Ekati)	Annually	BHP Billiton
Population surveys - **Polar Bear** (South Beaufort, North Beaufort, and Viscount-Melville Sound)	Every 20-25 years	RWED, Inuvik Region DSD, Nunavut US Fish &Wildlife CWS
Harvest Monitoring **- Polar Bears** (Inuvialuit Settlement Region) problem bears killed, subsistence harvest, and sport hunts	Annually	RWED, Inuvik Region Wildlife Management Advisory Council (NWT)
Carcass Collection - **Marten** (Fort Good Hope area)	Annually	RWED Sahtu Region
Harvest Survey- **Arctic Wolves** (Banks Island and NW Victoria Island) (number, age, sex, and diet of wolves harvested)	Annually	RWED, Inuvik Region
Carcass Collection - **Lynx** (all regions)	Annually	RWED Wildlife and Fisheries RWED Sahtu Region RWED South Slave Region RWED North Slave Region RWED Inuvik Region
NWT-wide **Rabies** Monitoring	Annually	RWED Wildlife & Fisheries RWED Regions including RRO's GNWT Health & Social Services
Monitoring of **Cougar** sightings	Annually	RWED Wildlife and Fisheries RWED Sahtu Region RWED South Slave Region RWED North Slave Region RWED Inuvik Region

Title	Schedule	Collaborators[1]
Marine fishes, mammals and other species		
Beluga Harvest monitoring program	Annually	DFO Fisheries Joint Management Committee
Marine Mammal Stock assessments	Annually	DFO
Marine Fish harvest rates, abundance and health part of Tariuq (Ocean) Monitoring Program – sites including near Aklavik, Shingle Point, Tuktuyaktuk harbour, and Hendrickson Island.	Annually	Inuvialuit and Gwich'in communities and organizations DFO
Fish, Amphibians and Aquatic invertebrates		
Frog Watch NWT	Annually	Ecology North EMAN-North EMAN GNWT Private volunteers (Lead: Mike Fournier)
Contaminant monitoring in fish populations	Annually in different pops.	DFO
Rat River Char Monitoring – **Dolly Varden** stock (Rat River watershed)	Annually	Gwich'in Renewable Resource Board DFO
Birds		
Duck banding project (Willow Lake)	Annually	US Fish and Wildlife RWED Sahtu Region
Duck banding project (Mills Lake)	Annually	US Fish and Wildlife
Inventory of **Snow and Ross' Geese** - Vertical Aerial Photography	Every 5 years	CWS, Yellowknife
Snow Goose banding at Banks Island, Kendall Island and Anderson River colonies	Annually	CWS, Yellowknife
White-fronted Goose breeding surveys in the Mackenzie Delta/Tuktoyaktuk Peninsula areas	Every 3-5 years	CWS, Yellowknife
Thick-billed Murre Survey – part of Seabird monitoring strategy of the Canadian Arctic (Cape Parry) part of Canada's Conservation Plan for Seabirds and Colonial Waterbirds.	Every 5-10 years	CWS, Yellowknife
Trumpeter Swan Survey	Every 5 years	CWS, Yellowknife
Boreal **Ducks and Grebes** monitoring – productivity and habitat use (east of Yellowknife, North Arm of Great Slave Lake)	Annually	CWS, Yellowknife DU INAC Arctic Hydrometric Surveys Division, EC

Title	Schedule	Collaborators[1]
Boreal **Lesser Scaup** monitoring - Population Ecology (east of Yellowknife, North Arm of Great Slave Lake)	Annually	CWS, Yellowknife University of Saskatchewan Delta Waterfowl Foundation GNWT, DOT DU
Boreal **Songbird** monitoring – population and habitat use (Liard Valley)	Annually	CWS, Yellowknife GNWT INAC Acho Dene Koe First Nation Industry
Christmas **Bird** Count [3] (Norman Wells) part of North American Christmas Bird Count program.	Annually	RWED Sahtu Region Private volunteers
Christmas **Bird** Count [3] (Yellowknife) part of North American Christmas Bird Count program.	Annually	Ecology North Private volunteers
Christmas **Bird** Count [3] (Fort Smith) part of North American Christmas Bird Count program.	Annually	Private volunteers
Christmas **Bird** Count [3] (Fort Simpson) part of North American Christmas Bird Count program.	Annually	Parks Canada, Nahanni National Park Private volunteers
Peregrine Falcon Survey (Mackenzie River) part of 5-year North American Peregrine Falcon survey, and of Recovery Strategy.	Every 5 years	RWED Wildlife and Fisheries RWED Regions (Sahtu and Inuvik) RWED Forest Management Canadian Wildlife Service (part of North American-wide surveys)
Peregrine Falcon Survey (Aulavik and Tuktut Nogait National Parks) part of 5-year North American Peregrine Falcon survey.	Every 5 years	Parks Canada, Western Arctic Field Unit Canadian Wildlife Service RWED Inuvik Region (part of North American-wide surveys)
Raptor and breeding bird surveys (southern arctic near diamond mine sites)	Annually	BHP Billiton Diavik Diamond Mines RWED, Wildlife and Fisheries
White Pelican **Monitoring (Fort Smith and northern Alberta)**	Annually	Private volunteers (coordinator J. Van Pelt) Alberta Sustainable Resource Development – NE Region RWED, South Slave Region Wood Buffalo National Park
Breeding **Bird** Survey (Daring Lake)	Annually	RWED Wildlife and Fisheries Private volunteers (coordinator S Matthews)

Title	Schedule	Collaborators[1]
Whooping Crane Monitoring (in Wood Buffalo National Park and surroundings) part of Whooping Crane Recovery Strategy.	Annually	Wood Buffalo National Park CWS, Edmonton Whooping Crane Recovery Team USFWS University of Alberta
Bird monitoring - Spring Arrival Dates (Yellowknife)	Annually	RWED Wildlife and Fisheries Canadian Wildlife Service Private volunteers (coordinator R. Bromley)
Raptor Survey - Daring Lake	Annually	RWED Wildlife and Fisheries
Breeding **Bird** Survey (Norman Wells) part of North American Breeding Bird Survey	Annually	RWED Regions (Sahtu) Canadian Wildlife Service Private volunteers (coordinator A. Veitch)
Breeding **Bird** Survey (Yellowknife) part of North American Breeding Bird Survey	Annually	Cygnus Consulting Private volunteers (coordinator J Bastedo)
NWT-Nunavut **Bird** Checklist Survey-Incidental observations of birds are recorded for the NWT-Nunavut Bird Checklist Survey (NWT-wide)	Annually	Canadian Wildlife Service Parks Canada Private volunteers
Arctic **Shorebird** Monitoring Program (currently in test phase- anticipated start in next 2-3 years) part of Program for Regional and International Shorebird Monitoring (PRISM)	Annually, rotating among zones of BCR 3	Canadian Wildlife Service
Boreal and Taiga **Shorebird** Monitoring Program (currently in development phase- anticipated start of test phase in 1 year) part of Program for Regional and International Shorebird Monitoring (PRISM)	Annually, rotating among zones of BCRs 6 and 7	Canadian Wildlife Service
Terrestrial ecosystems – Forest and Tundra		
International Tundra Experiment - Canadian **Tundra and Taiga** Experiment on Phenology (Daring Lake)	Annually	RWED Wildlife and Fisheries EMAN-North Northern Ecosystem Initiative (Environment Canada) Gov. of Yukon
Tree **Phenology** study (Inuvik Region)	Annually	RWED Forest Management - Inuvik Region
Satellite monitoring of **plant productivity**	Annually	Parks Canada, Western Arctic Field Unit
Acid Rain National Early Warning System (ARNEWS), **Forest Health** Plot (4 plots in the NWT)	Annually first 5 years, every 5 years following	RWED Forest Management - Inuvik Region Gwich'in Renewable Resource Board Canadian Forest Service
Smithsonian Institute /Man and the Biosphere - **Forest**	Every 5 years	RWED Forest Management - Inuvik Region

Title	Schedule	Collaborators[1]
Plots (Inuvik Region)		Gwich'in Renewable Resource Board Aurora College Inuvik Campus
Forest - Permanent Sample Plots (Inuvik Region)	Every 10-15 years	RWED Forest Management - Inuvik Region
Forest - Regeneration plots (Inuvik Region)	Annually first 5 years, every 5 years following	RWED Forest Management - Inuvik Region
Vegetation Contamination Survey – as part of the Wildlife Effects Monitoring Program (Survey is related to gas and dust emissions, Ekati Mine sites and control sites)	Every 3 years	BHP Billiton
Post-fire Vegetation plots - (in various burns throughout Inuvik Region)	Annually	RWED Forest Management - Inuvik Region Gwich'in Renewable Resource Board
Tibbitt Lake **Post-Fire** Study (Vegetation transects - near Yellowknife and Gordon Lake - associated wildlife, micro-climate and hydrological monitoring).	Annually first 5 years, every 2-3 years following.	RWED Wildlife and Fisheries RWED Region - North Slave RWED Forest Management Indian and northern Affairs Department of Fisheries and Oceans Environment Canada High Schools
Ocean ecosystem		
Beaufort sea monitoring – biophysical oceanography (Temperatures, currents, depth, salinity)	Annually	DFO Institute of oceanographic Sciences (Sidney, NS) World Climate Research Programme World Weather Watch
Insects		
Beaufort Sea monitoring – biophysical oceanography (Temperatures, currents, depth, salinity)	Annually	DFO Institute of oceanographic Sciences (Sidney, NS) World Climate Research Programme World Weather Watch
Native Forest Insect Monitoring - **Spruce Budworm** (all forested regions)	Annually	RWED Forest Development - Hay River RWED Forest Management - Inuvik Region Canadian Forest Service
Native Forest Insect Monitoring **-Forest Tent Caterpillar**, **large Aspen Tortrix, Spruce Beetle** (some forested regions)	Annually	RWED Forest Development RWED Forest Management - Inuvik Region Canadian Forest Service

Title	Schedule	Collaborators[1]
Survey of Invasive Alien[2] Insects - **Larch Sawfly** (across forested regions in the NWT)	Annually	RWED Forest Development
Survey of Invasive Alien[2] Insects - **Birch Leaf Miner** (Yellowknife and Hay River)	Annually	RWED Forest Development City of Hay River City of Yellowknife RWED Wildlife and Fisheries Canadian Forest Service Canadian Wildlife Service (in YK only)
Multi-species - General		
General Status Ranks of Wild **Species** in the NWT– part of Accord for the Protection of Species At Risk in Canada (NWT-wide)	Every 5 years	RWED Wildlife and Fisheries Gov. of Nunavut RWED Regions Department of Fisheries and Oceans Canadian Wildlife Service Sahtu Renewable Resources Board Gwich'in Renewable Resource Board Wildlife Management Advisory Council (NWT) Fisheries Joint Management Committee Private volunteers
Community-based Ecological Monitoring – **multi-species** and bio-physical (Gwich'in Settlement Area)	Annually	Gwich'in Renewable Resource Board Arctic Borderlands Ecological Knowledge Society (Co-op) Private volunteers
Non-resident Hunter **Harvest** - Mackenzie Mountains	Annually	RWED Deh Cho Region
Outfitter **Harvest** – Mackenzie Mountains	Annually	Mackenzie Mountain Outfitters Association RWED Deh Cho Region
Resident Hunters **Harvest** Survey (NWT-wide) - associated fur-bearer and migratory birds information.	Annually	RWED Wildlife and Fisheries
Outfitter-Hunter **Wildlife** Observations – Mackenzie Mountain	Annually	Mackenzie Mountain Outfitters Association RWED Deh Cho Region
Pipeline **Wildlife** Monitoring - Enbridge Pipeline Right-of-Way (Norman Wells to Zama, AB)	Weekly	Enbridge RWED Sahtu Region RWED Deh Cho Region
Wildlife cards-Incidental observations of all species of wildlife are documented in and around Aulavik and Tuktut Nogait National Parks.	Annually	Parks Canada, Western Arctic Field Unit

Title	Schedule	Collaborators[1]
Deh Cho Territorial Parks **Wildlife** Observations (Territorial parks in Deh Cho Region)	Annually	RWED Deh Cho Region
Wildlife Disease Monitoring - Harvested Wildlife (NWT-wide)	Annually	RWED Wildlife & Fisheries RWED Regions incl. RRO's Canadian Cooperative Wildlife Health Centre
Winter Road - **Wildlife** Questionnaire (Yellowknife to Slave Geological Area)	Annually	RWED North Slave Region

Notes:
1 Shared budget or provided in-kind help.
2 Alien = Not native to North America.

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

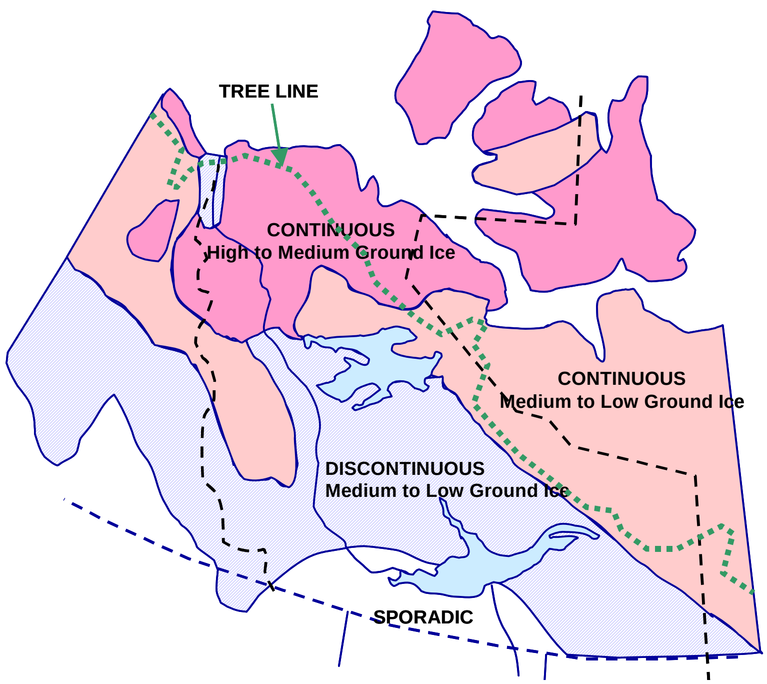
6.0 PERMAFROST, GROUND ICE AND SNOW COVER

6.1 INTRODUCTION

The Northwest Territories (NWT) has the third largest land area of the ten Provinces and three Territories in Canada; after Quebec and Nunavut. It has a total area of about 1,346,000 square kilometers; with about 13% of this area being fresh water. The uniqueness of NWT is that it is located within permafrost and is difficult to access most of its areas. A large part of NWT depends on winter roads and air transport for access and supplies. More than 50% of the permafrost is classified as sporadic and discontinuous that is readily disturbed by construction resulting in ground thawing and potential physical instability. Finally, NWT permafrost is warming 'rapidly' due to climate changes (Couture *et al* 2003).

Design and construction of projects in the NWT permafrost environment is considerably more difficult than in southern temperate parts of Canada. Challenges are created by the existence of frozen ground that may thaw due to construction disturbance and/or by warming due to climate change. Sensitive areas are located in high ground ice areas in both continuous and discontinuous permafrost and in all discontinuous and sporadic permafrost regions; these areas are highlighted in Figure 6.1-1.

FIGURE 6.1-1
SIMPLIFIED NRC CANADA PERMAFROST MAP MCR 4177



Source: (Heginbottom et al 1995).

Presence of permafrost and the magnitude of ground temperature that governs the properties and the sensitivity of permafrost to construction are dependent on many factors; some being: air temperature, vegetation, snow cover, orientation of the terrain and ice content. Since these factors vary across NWT, so does the condition of permafrost and its sensitivity to construction.

The impact of construction on frozen ground is different in discontinuous and continuous permafrost areas. In most southerly areas, permafrost has already thawed or is rapidly disappearing. A large part of NWT lies within discontinuous permafrost where ground warming may occur either due to removal of vegetation during construction or the slower process of air temperature rising. In continuous permafrost, the ground temperatures are colder and ground warming caused by vegetation disturbance is small. In these areas, ground warming is caused by climate change that alters the ground temperatures at a slower rate than is experienced by vegetation disturbance in discontinuous permafrost areas.

Warming that leads to thawing of the frozen ground may impact the physical stability of the natural terrain and structures built on permafrost. Thawing of the existing permafrost may result in: thaw settlement, ground instability, drainage course changes, high-suspended solid concentration in streams, and foundation settlement. Finally, the concept of encapsulation of wastes within permafrost may not work in the long-term period when climate warming is occurring.

Thawing of permafrost will impact areas in different years depending on present local permafrost ground temperatures and the rate of climate warming that varies with location. It is realistic to assume that significant warming will occur in about 30 to 100 years in NWT.

Physical development will increase with time and this will increase the footprint of human activity in NWT. An estimate of the present footprint of human activity in northern Canada is given ‘Estimate Physical Footprint of Human Activity’ study of the Slave Geological Province (Cizek 2003). Past human activities in the Slave Geological Province are summarized in Table 6.1-1.

TABLE 6.1-1
PHYSICAL FOOTPRINT OF HUMAN ACTIVITIES IN SLAVE GEOLOGICAL PROVINCE

Human Activity	Area, km^2	Percent of All Activities	
		Including Hydro	Without Hydro
Snare Hydro & Hydro Line Right of Way	135.5	46	
Past mine producers	39.2	13	24
Present mines; Ekati, Diavik & Snap Lake	32.0	11	20
Winter Roads, camps & borrow	8.6	3	5
Advanced exploration	73.5	25	46
Settlements	3.0	1	2
Others	4.4	1	3
Totals All Activities	**296.2**	**100**	**100**

Source: ***(Cizek 2003).***

The above estimate shows that, setting aside the Snare Hydro reservoirs, the largest human impact in the Slave Geological Province up to 2004 was produced by the mining industry. The past producing mines, largely abandoned orphaned mines, represent 24% of the total affected area, existing operating or under construction mines represent 20% and advanced exploration abut 46% of the human footprint. In comparison to the land area of the NWT, the disturbed areas cover less than 0.025% of the land mass.

NWT encompasses also a portion of the Slave Geological Province, Bear Province and the Interior Platform. The Slave Geological Province has more benign permafrost conditions then exist in the other two areas. The Interior Platform, which encompasses the Mackenzie River, has numerous settlements and the Norman Wells refinery with its associated pipeline. Also the areas adjacent to the Mackenzie River and its delta have seen large oil and gas explorations that may have disturbed the vegetation and thereby the permafrost equilibrium. Vegetation could have been disturbed by numerous seismic lines in areas below the tree-line and the construction of drill pads.

While the past producers encompass a slightly larger footprint than the present mine operations, they produced much smaller quantities of wastes (tailings and mine rock) than the present operations because they were mainly underground operations. Present mines, Ekati and Diavik, being open pit mines that employ large excavators and trucks, produce much greater quantities of mine wastes. Estimated total tonnage of mine rock and tailings reported during licensing of the mines is given in Table 6.1-2. Snap Lake mine waste tonnage will be considerably smaller because it will be an underground mine and will pump large volumes of the processed kimberlite into the mined-out underground workings.

TABLE 6.1-2
TONNAGE OF PROCESSED KIMBERLITE AND MINE ROCK OF NWT DIAMOND MINES (ESTIMATES BASED ON PRE-MINE LICENSE SUBMISSIONS)

Mine	**Volume (in million tones)**	
	Mine rock	**Processed Kimberlite (tailings)**
Diavik Diamond Mines	250	26
Ekati Diamond Mine	355	65
Snap Lake Diamond Project	1.4	12
Totals	606	103
Total mine rock and tailings		**709**

The Mackenzie Gas Project and the development of new mines from the advanced explorations will increase considerably the existing developed footprint. Mackenzie Gas Project's pipeline route is about 1220 km long and has three gas gathering areas, namely Niglintag, Taglu and Parsons Lake. It will likely develop additional gas gathering fields and extensive supporting infrastructures during its operation that will increase the footprint even more. Furthermore, the development of Beaufort Sea petroleum resources will require land based infrastructures.

6.2 ENVIRONMENTAL STRESSORS

6.2.1 Ground Temperature and Ground Ice

Permafrost is defined as a ground (soil or rock, including ice and organic material) that remains at or below 0ºC for at least two consecutive years (Everdingen 2002). This definition does not encompass vegetation cover, composition of the overburden (ice content) and the ground temperature. The latter two factors are important in assessing the effect of climate warming on permafrost conditions across the Canadian North. They indicate how the permafrost may react to construction and climate warming. High ice content within silt permafrost is illustrated in Figure 6.2-1. When this material thaws, its consolidation may disrupt the ground leading to erosion and sediment release.

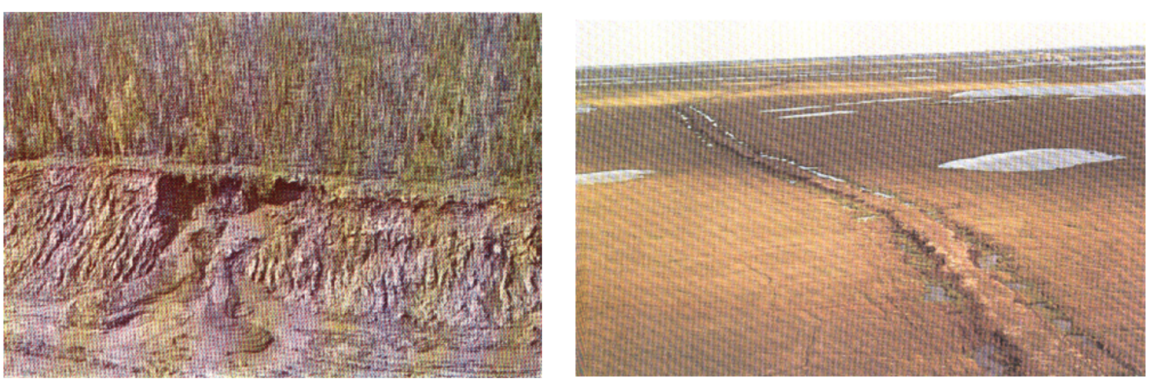
Areas with high ice content and in 'warm' ground temperature (range of 0 to minus 2ºC that is typical in discontinuous permafrost) are readily disturbed thermally by construction. This may lead to thaw settlement, slope instability and fine soil erosion.

Disturbance by construction is created by damaging the vegetation cover and excavating into frozen ground. In discontinuous permafrost areas, removal of vegetation cover (tree and bush cutting and removal of organic matting) generally leads to warming and thawing of the ground.

In continuous permafrost, the removal of vegetation cover causes the active layer to deepen and the new thawed zone may cause; settlement, ground instability and erosion. Damage to permafrost is illustrated in Figure 6.2-2.

FIGURE 6.2-1
HIGH GROUND ICE SHOWN BY ICE LENSES IN FINE-GRAINED SOIL

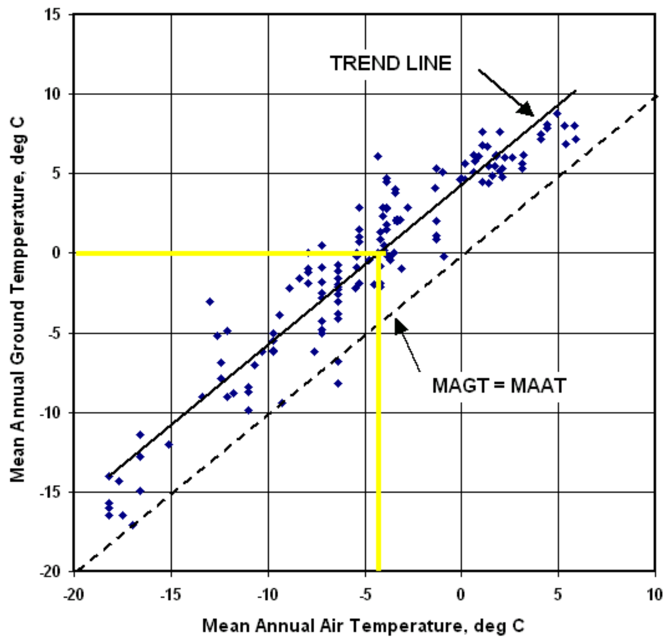
FIGURE 6.2-2
FLOW SLIDE ALONG DEMPSTER HIGHWAY CAUSED BY CUT INTO ICE RICH SOIL AND WATER ACCUMULATION AND SLUMPING ALONG A ROAD BUILT IN PRUDHOE BAY



Air temperature is a good indicator of the presence of permafrost and it provides a tool to estimate the ground temperature. It is not an exact indicator because other variables such as; vegetation, snow, and terrain have influencing roles. The permafrost group of the Geological

Survey of Canada (Smith & Burgess 2000) have developed a general relationship between the Mean Annual Air Temperature (MAAT) and Mean Annual Ground Temperature (MAGT) shown in Figure 6.2-3. The spread of points along the trend line show the influence of the other variables. For general estimation, it can be assumed that MAGT is about 4.5ºC warmer than the MAAT.

FIGURE 6.2-3
RELATIONSHIP BETWEEN AIR AND GROUND TEMPERATURES



Source: Smith & Burgess 2000.

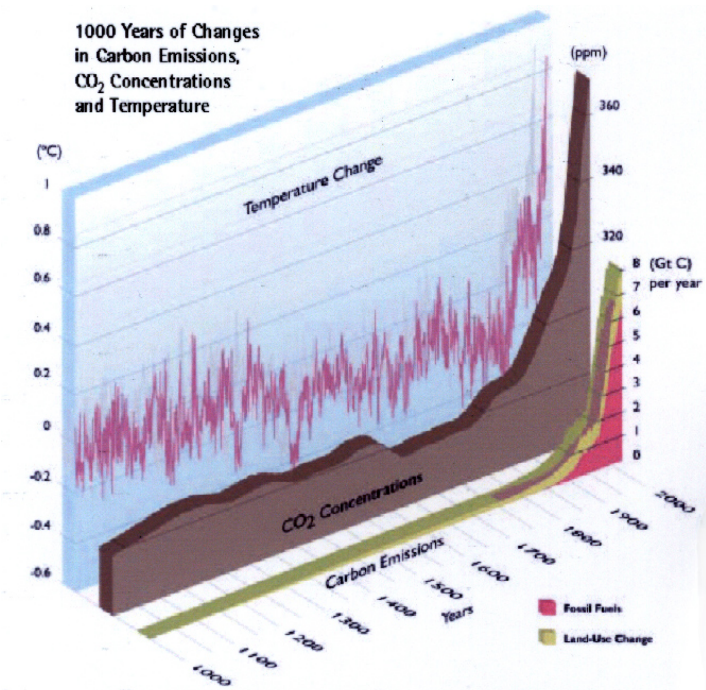
It needs to be noted that the temperature increment of 4.5ºC between MAAT and MAGT is an average. The increment at a specific location is dependent greatly on vegetation cover. At sites that are in trees and have a thick fibrous organic cover, permafrost may exist when MAAT is –1ºC. The incremental difference of 4.5ºC between MAAT and MAGT is representative of an area with no trees with thin organic mat or an area where the organic mat was either removed, compressed by construction equipment or fill as shown by the Lupin case history discussed below.

6.2.2 Climate Warming

During the last 10 years numerous studies have clearly demonstrated that climate warming is occurring and that the Arctic is warming at about twice the worldwide rate. The most recent authoritative study was commissioned by the Arctic Council, a high-level intergovernmental forum comprised of 5 northern nations and six Indigenous People; three of these being Canadian.

This study (Hassol 2004) concluded that human activities have increased the concentration of carbon dioxide, methane and other greenhouse gases that has led to climate warming. Furthermore, the Arctic is warming more rapidly than the world and much larger changes are projected. The rate of increase and the relationship between global carbon dioxide concentration and air temperature are shown in Figure 6.2-4.

FIGURE 6.2-4
RELATIONSHIP AND INCREASE OF CARBON DIOXIDE AND GLOBAL AIR TEMPERATURE



Source: Hassol 2004.

Highlights of the study are:

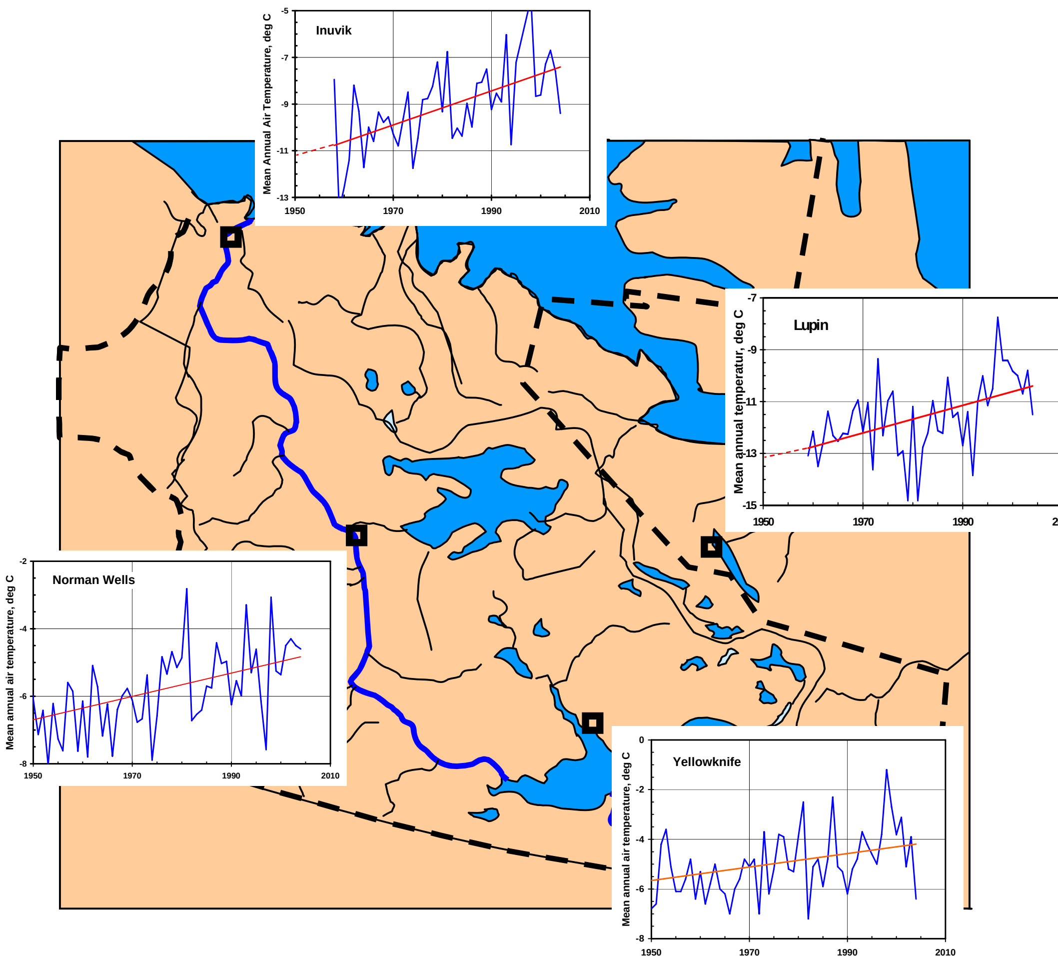
- Annual average Arctic temperatures have increased at twice the rate as that of the rest of the world over the past few decades.
- Increasing precipitation, shorter and warmer winters, and substantial decreases in snow cover and ice cover are among the projected changes that are very likely to persist for centuries.
- Projected temperature change from the 1990s to 2090s, based on the average change calculations by five ACIA climate models, indicate the mean annual air temperatures will be 3 to 5ºC warmer in the over land areas in the Arctic.
- Economic damage to infrastructure will result from permafrost thawing and coastal erosion and thawing will hinder land transport in winter.

Climate warming in northern permafrost areas has been reported in all countries in the northern hemisphere with major permafrost areas: in Alaska by Esch (1990) and Correl (2004); in Switzerland by Instanes (2003); and, in Canada by Etkin (1998), Byer (2004) and Burgess *et al.* (2004).

The rise of air temperatures across the NWT is evident from several Environment Canada meteorological stations that have records of about 50 years. These show that the air temperature has been rising in NWT for the last 50 years and the rate of rise has increased during the last 25 to 30 years. The increase is not evenly distributed across NWT.

MAAT at Yellowknife, Norman Wells, Inuvik and Lupin (in Nunavut but just northeast of the NWT-Nunavut border) are shown in Figure 6.2-5.

FIGURE 6.2-5
MEAN ANNUAL AIR TEMPERATURE RECORDS AT FOUR REPRESENTATIVE NWT LOCATIONS



Source: Environment Canada meteorological station records.

Data in Figure 6.2-5 show that the mean annual air temperature at any location fluctuates greatly on a yearly basis but there is a definite MAAT increase over the last 50 years. To show how the temperature increases across NWT and how this will impact the permafrost, the temperature data in Figure 6.2-5 was interpreted for the four locations as follows:

- rate of temperature increases were obtained from the linear trends;
- MAATs for 2000 were derived from the linear trends; and,
- number of years it will take for the ground temperature to reach 0ºC were estimated.

The results from this exercise are given in Table 6.2-1.

TABLE 6.2-1
MEAN ANNUAL AIR AND GROUND TEMPERATURES AT FOUR REPRESENTATIVE NWT LOCATIONS AND ESTIMATED NUMBER OF YEARS FOR GROUND TEMPERATURE TO REACH 0ºC

Locations	MAAT In 2000	MAGT In 2000	Avg. warming	Years to reach 0ºC
	ºC	ºC	ºC/100 yrs	MAGT
Yellowknife	**-4.3**	**0.2**	**3.4**	**0**
Normal Wells	**-4.9**	**-0.4**	**3.2**	**14**
Invuvik	**-7.7**	**-3.2**	**7.0**	**48**
Lupin	**-10.6**	**-6.1**	**8.4**	**78**

These results have the following implications:

- Permafrost along most of Mackenzie River valley may either disappear or be present in sporadic areas, found under thick vegetation covers, within about 50 years.
- Permafrost may disappear from within the continental part of NWT in less than 100 years.
- Project closure and reclamation design need to consider the disappearance of permafrost in less than 100 years.

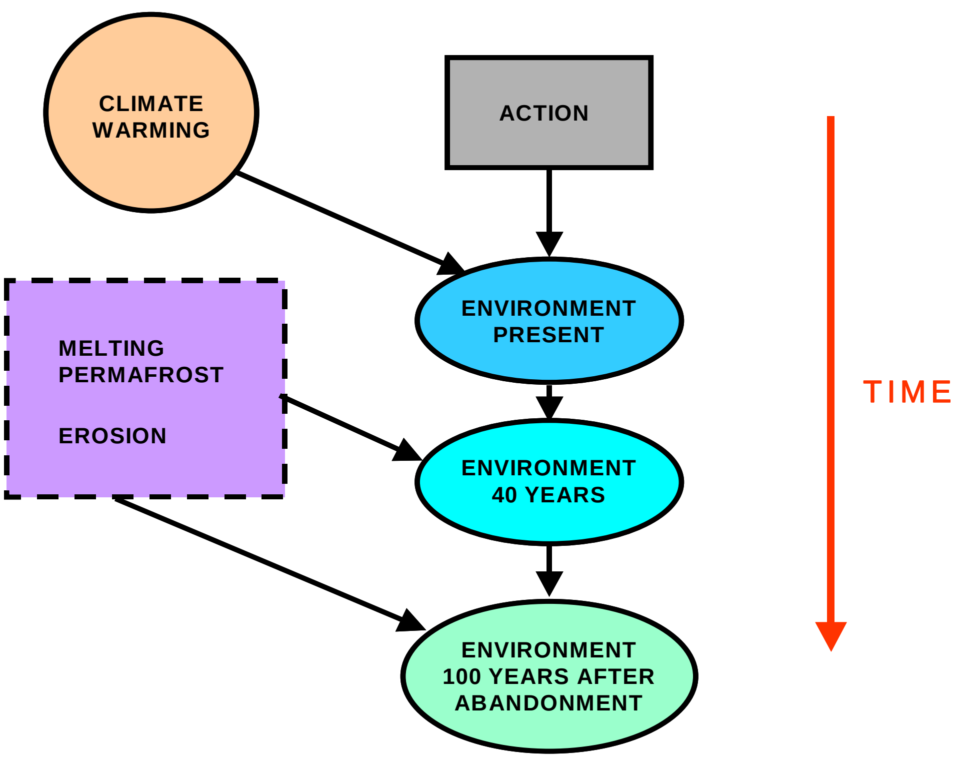
Potential environmental impacts of loss of permafrost include erosion of landforms along stream and riverbanks, lake and sea shorelines and slow sheet erosion of undulating land. Natural erosion will accelerate in permafrost regions as climate warms and thaws the permafrost. The thawing of the frozen ground that in turn will lead to ground softening, differential settlement and slope instabilities may create physical damage to terrain. These ground instabilities may occur even without any human alteration by projects or settlements. However, human activities, such as, construction of roads, pipelines, settlements, mine rock dumps or tailings storage facilities may increase even further the ground instabilities and environmental impacts. The hazards to infrastructure in Western Arctic and along the Mackenzie Valley due to climate warming was identified by Couture *et al* (2003).

At the present time serious physical damage due to climate warming is experienced in Switzerland's mountains where melting of glaciers and the underlying ground is producing numerous landslides (key note address at the 2003 Int'l permafrost conference in Switzerland). The importance of the climate change on permafrost and environmental impacts are demonstrated by the number of papers on these subjects (Chudinoa *et al* 2003, Dominnikova 2003, Gorshkov and Tishkova 2003, Hof *et al* 2003, Kershaw 2003, Khrustalev 2003, and Osterkamp 2003).

The NWT will experience some degradation of the terrain due to the thawing of permafrost caused by climate warming even without human activity contributions. However, alteration by Actions will further increase the instabilities of the ground as permafrost thaws and this in turn will lead to increased erosion and sediment loads.

Action is defined in the Cumulative Effects Assessment Practitioners Guide as any project or activity of human origin (CEAA 1999). The impacts by Actions that should be minimized are the ones caused by the construction of new projects. The impacts may occur several years after project abandonment. The relevance of climate and time to cumulative environmental impact monitoring is illustrated in Figure 6.2-6.

FIGURE 6.2-6
FACTORS RELEVANT TO CUMULATIVE ENVIRONMENTAL IMPACTS MONITORING



6.3 PERMAFROST, GROUND ICE AND SNOW INDICATORS

NWT differs from most of Canada, (as do Yukon, Nunavut and northern Quebec and Newfoundland and Labrador) in that much of the land mass is underlain by permafrost. The susceptibility of permafrost to change is dependent upon a number of factors including ground ice content, ground temperature, snow cover and vegetation cover. The deterioration of permafrost with time and the fact that different types of projects (e.g., roads, pipelines and mines (Actions)) produce different impacts, suggests that project type also needs to be considered in assessing the cumulative environmental impact of a project during construction, operation and for many years after project closure.

6.3.1 Permafrost Indicators

Permafrost by itself is not adequate to determine how it will behave under climate warming and human activities as determined by Actions. Two dominant parameters that determine the response of permafrost to an Action are the ground temperature and the volume of ground ice within the permafrost overburden. The ground temperature in turn is determined by several parameters that include: air temperature, vegetation cover, snow cover and ground slope. Air temperature is the most dominant parameter within this group of parameters. In summary, the key indicators of permafrost conditions are listed in Table 6.3-1.

TABLE 6.3-1
KEY INDICATORS OF PERMAFROST CONDITIONS

Valued Component (VC)	Indicators
Permafrost	Mean annual air temperature
	Mean annual ground temperature

6.3.1.1 Mean annual Air Temperature

The most important factor governing the presence of permafrost, its temperatures, properties and the ground temperature change due to climate warming is air temperature. Two air temperature measures that are used in the interpretation of permafrost are the cumulative daily and mean annual air temperatures. The cumulative daily air temperature controls the thawing and freezing of the active layer (layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost). However, the depth of the active layer is also strongly dependent on thickness of the organic layer, volume of water within the layer and snow cover being some of the other controlling parameters. This limits the value of the daily temperatures of assessing permafrost.

The mean annual air temperature (MAAT) is a more useful indicator for the general condition and stability of permafrost. As mentioned earlier, there is a good relation between the MAAT and the mean annual ground temperature (MAGT).

(i) What is being measured?

The benefit of using the MAAT as an indicator is the presence of a number of meteorological stations in the NWT managed by Environment Canada. Stations that have air temperature records of about 50 years are most indicative in the assessment of climate warming. Climate norms and averages can be obtained from htt://www.climate.weatheroffice.ec.gc.ca/.

Other meteorological stations, managed by DIAND and larger mine operators, have monitored the air temperature over shorter periods and can be used to augment the former information.

(ii) What is happening and what does it mean?

The mean annual air temperature is rising across the NWT but its rate of rise is not uniform across the NWT. The greatest rate of air temperature rise is occurring in areas with cold MAAT. This means the length of time to thaw the permafrost in the colder northern regions will nearly be the same as in the southern areas. The variability of the rise of the MAAT was illustrated previously in Figure 6.2-5 and Table 6.2-1.

(iii) What are the information gaps?

There are sufficient meteorological stations to monitor the MAAT and predict permafrost warming along the Mackenzie River. There is a limited long-term MAAT northeast of Yellowknife where many of the mines are located. The only long-term meteorological station in this area with MAAT data is the Lupin station that is located just north of the NWT/Nunavut border. This station may not continue to operate since the Lupin mine, where the station is located, has terminated its operation and is in the process of closure and thereby shutting down this meteorological station.

The MAAT gap can be filled with the meteorological stations operated by the new diamond mines, Ekati and Diavik, and the under construction at Snap Lake. These mines operate meteorological stations and report data annually to the licensing authority. These data could be incorporated into a NWT climate database.

6.3.1.2 Mean annual ground temperature

MAGT provides a direct measure of, and confirms how, climate warming is impacting regional permafrost. Scientific monitoring in Alaska (Osterkmap 2003), Russia (Romanovsky *et al* 2004) and Canada (Smith *et al* 2004) show a direct relationship between the MAAT and MAGT changes.

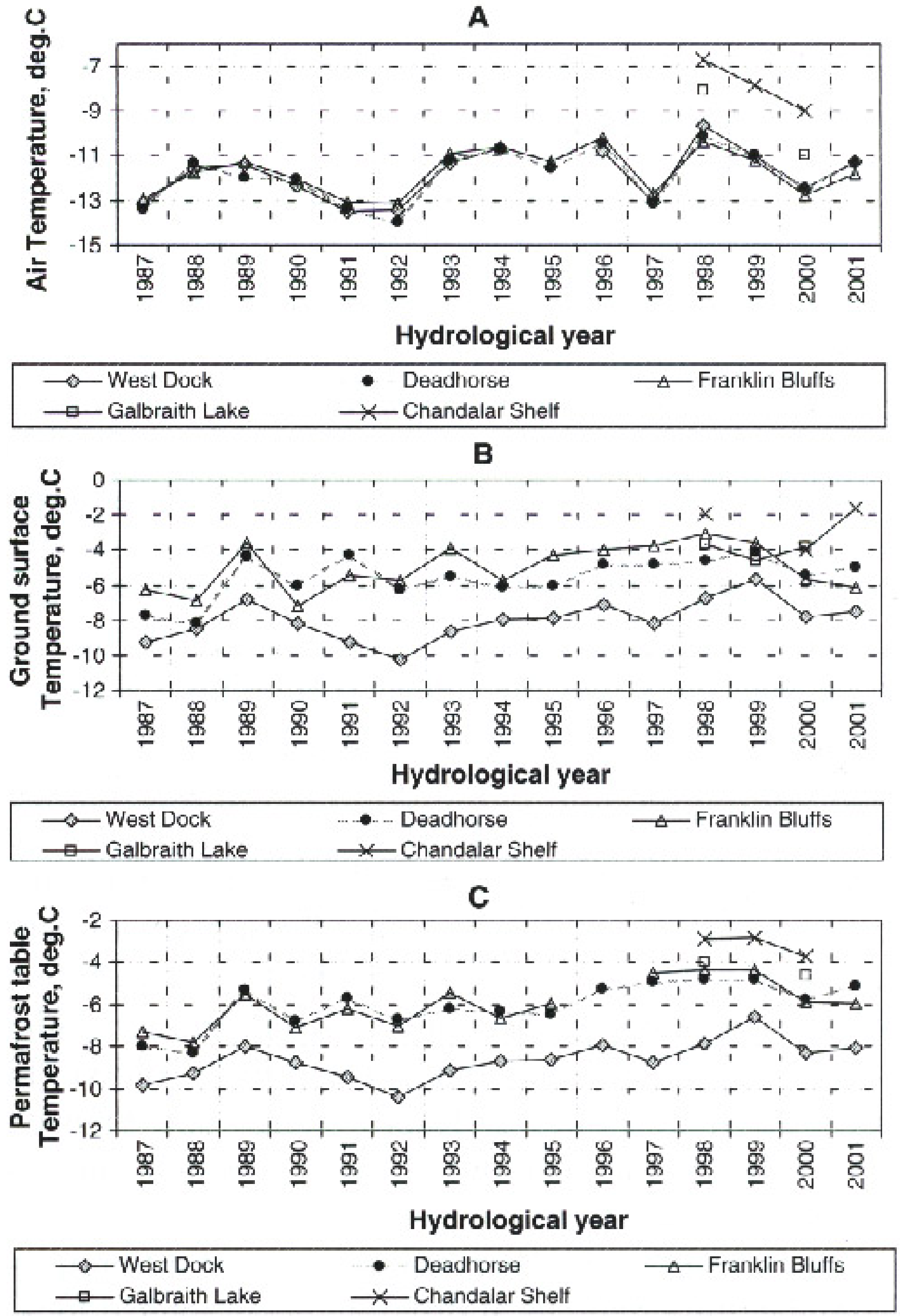
(i) What is being measured?

In Canada there is a lack of long-term MAGT monitoring. One site where such information is available for a period of 8 years is Lupin. The relationship between MAAT and MAGT obtained from this location can be seen in Figure 6.2-3 (presented previously).

(ii) What is happening?

Ground permafrost temperatures are rising across the whole northern hemisphere. This is illustrated by air and ground temperatures changes at 5 locations in Alaska shown on Figure 6.3-1 (Romanovsky *et al* 2004), measurements made near Norman Wells (Couture *et al* 2003) and most recently at Lupin (Holubec 2005).

FIGURE 6.3-1
AIR AND PERMAFROST GROUND TEMPERATURE CHANGES AT 5 ALASKA LOCATIONS

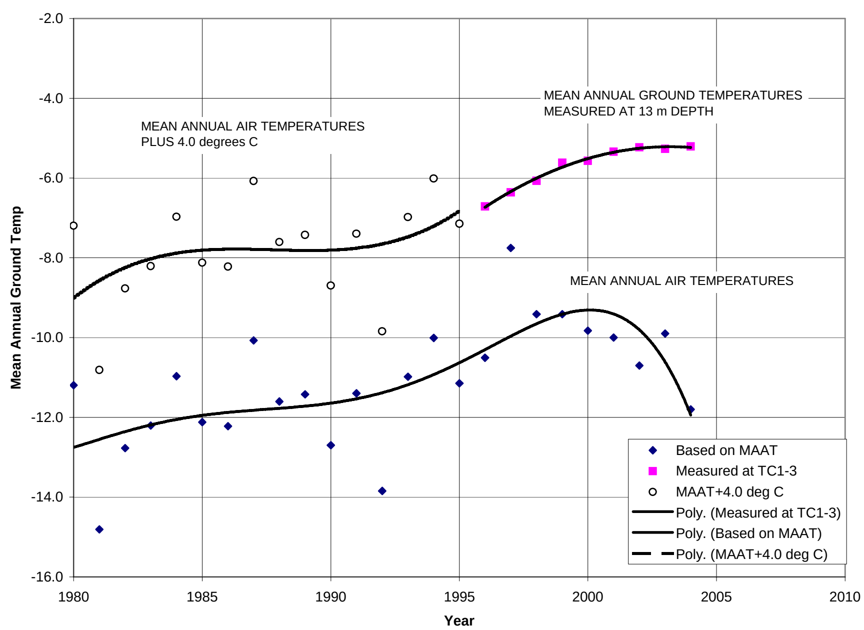


Source: Romanovsky et al 2003).

(iii) Why is it happening?

Figure 6.3-2 illustrates the ground warming and the relationship between MAAT and MAGT. This figure provides MAAT data from 1960 to 2004 and the measured MAGT from 1997 to 2004. To complete the MAGT information from 1960 to 1996 on Figure 6.3-2, the MAGT was derived from that year range using the 4ºC offset. This figure illustrates the warming of the permafrost is directly related to mean annual air temperature (MAAT).

FIGURE 6.3-2
MAAT AND MAGT MONITORED AT LUPIN



Source:Holubec 2005.

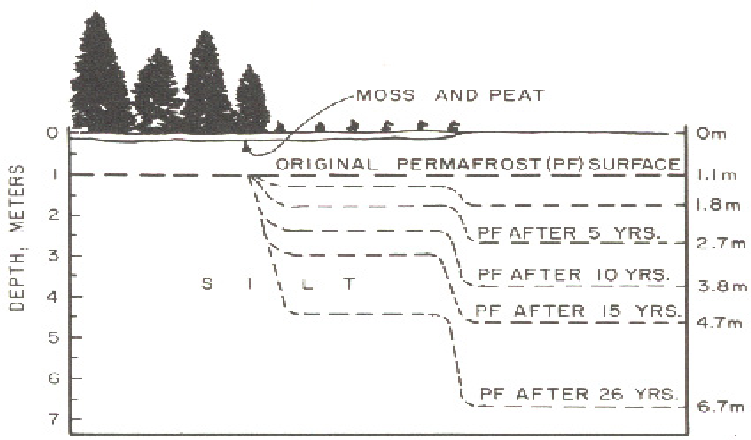
(iv) What does it mean?

International data that is confirmed by Canadian ground temperature monitoring in permafrost regions show that the permafrost ground temperature is rising in lock step with climate warming.

The rationale for monitoring the MAGT at selected sites is that permafrost warming may have a significant environmental impact in time on Actions that are founded on ice rich (high ground ice) permafrost and are not designed for climate warming. The rise in the ground temperature has different immediate impact below the tree-line, Area a), above the tree-line, Area b), and in the Arctic Islands, Area c), as stated below:

Area a) - has a MAGT in the range between 0 to –3ºC and therefore it is very sensitive to ground cover disturbance and permafrost thaw. Ground cover disturbance by clearing trees and removing the organic mat resulting in permafrost thawing is illustrated in Figure 6.3-3. Furthermore, even if the permafrost is preserved during construction, a large part of permafrost in this region will thaw within 10 to 50 years if the present climate warming continues at the present rate.

FIGURE 6.3-3
EFFECT OF VEGETATION REMOVAL ON PERMAFROST



Source: (Linner, 1973).

The warming of permafrost is, or will be, impacting both undisturbed areas and areas affected by Actions in the discontinuous permafrost regions that is represented by much of NWT. This was noted as early as 1990 by Etkin (1990) and more recently by Couture *et al* (2003) and Smith *et al* (2004).

Area b) - the MAGT in the area above the treeline ranges between –3 to –8ºC and is underlain by continuous permafrost. This area is not as readily affected by construction unless there is appreciable organic cover disturbance or major cuts are made in high ground ice conditions. However, permafrost may disappear in about 50 to 150 years. This would negate any dependence on permafrost for physical stability of dams, earth/rock embankments or the concept of permafrost encapsulation of waste materials.

Area c) - has colder MAGT than Area b) where prediction of the effect of climate warming on permafrost is more difficult. It is likely that even here the permafrost may disappear with time, but at a much later date, if the climate warming continues.

(v) What is being done about it?

General ground temperature information is provided in the Canadian Permafrost Map NCR 4177F prepared by Heginbottom et al. (1995). This information needs to be considered as general information since the ground temperature measurements were measured in different years between about 1980 and 1995 and these temperatures were not adjusted to one common year.

Considerable ground temperature measurements have been obtained along the Mackenzie River by the Permafrost group of the GSC Terrain Sciences Division (Smith *et al* 2004). It is likely that the Mackenzie Gas Project has installed similar sensors in the same area.

The ground temperatures information in the northeastern part of NWT where past and most recent mines are located is limited. The best long-term information is available from the Lupin Mine (located just north of the NWT/Nunavut border, Holubec 2005). Ground temperature information is reported to the Mackenzie Valley Water Board by the Ekati and Diavik but this is for relatively short time frame and it is not been analyzed for climate warming.

(vi) What are the information gaps?

There is limited information in regard to the present ground temperature within northeastern NWT and how it is responding to climate warming.

(vii) Overall Assessment and Recommendations

Air temperature - is the most significant parameter in determining the ground temperature and therefore the presence and the state of permafrost. It is recommended that:

- Air temperature data gaps in northeastern NWT be filled with the data from existing operating mines.
- Air temperature data for the NWT be collected and maintained in one central database. This would include data from Environment Canada and DIAND meteorological stations and stations operated by the mines.

Ground temperature – can be used for predicting the time when permafrost may thaw. A consistent ground temperature program should be developed that will provide an overall picture of the permafrost temperature in NWT and how it is changing. To accomplish this it is recommended that:

- A representative ground monitoring program be instituted that will monitor the ground temperatures at about a dozen NWT locations.
- Suitable locations are the existing meteorological stations along the Mackenzie River region and additional meteorological stations and ground temperature locations should be installed in the northeast NWT region.
- Specifications for the temperature sensor should be developed so that there is a consistency in information. The installation should be such, that malfunctioning cables can be replaced in existing tubes without the need for new drilling.
- One group should be responsible for design specification, collecting and analyzing the data and its distribution.

6.3.2 Snow Cover Indicators

Snow cover affects ground temperature because of its insulating properties and reflection of radiation. Snow is one of several parameters that determine the depth of the active layer and the magnitude of the ground temperatures.

(i) What is being measured?

Snow information in the NWT is monitored, assessed and compiled by Environment Canada and DIAND. This information includes snow cover area, depth, properties and duration that are used by water resource groups for hydrological reasons. Snow information collected by the Meteorological Services is available through Canada National Snow Information System for Water (http://www.socc.ca/nsisw/).

(ii) What is happening?

There are numerous scientific discussions on the effects of snow on the permafrost ground temperatures (Holube/GSC 2005). While there is agreement that snow insulates permafrost thereby resulting in warmer ground temperatures, it is also been observed that warmer ground temperatures are associated with snow cover melting earlier in the year due to climate warming.

(iii) What does it mean?

Snow cover is one of the parameters that determine the presence and the temperature of permafrost. However, it is not a dominant parameter and there is a lack of agreement on how it could be used to interpret permafrost ground temperatures.

(iv) Overall Assessment and Recommendation

Measurement of snow cover depth has not been shown to be particularly useful indicator of permafrost conditions.

6.3.3 Ground Ice Indicators

Ice is commonly present in frozen unconsolidated deposits (Johnston 1981); including gravels and bedrock (Mackay and Black 1973). Its volume and distribution within overburden varies greatly.

Ice is an important engineering design parameter if its volume is greater than what is required to fill the voids within a soil matrix or is present in rock fractures. In ice rich soil the ice may affect creep strength that governs slope stability of frozen ground. If the ground ice melts, thawing may produce uneven ground settlement and ground instability in soil and major seepage through fractures in bedrock when located beneath dams.

(i) What is being measured?

Areas with excess ground ice are established by visual identifications and measurement of ice lenses and the determination of ice volumes by melting of fine grained soils.

(ii) What is happening?

Ground ice information has been compiled by the GSC and presented in Canada Permafrost Map, MCR 4177F (Heginbottom 1995). This provides a general picture where ground ice (ice rich soils) is common and should be anticipated. However, presence of excess ground ice at a particular structure location, such as a road, pipeline, building foundation or dam, has to be investigated on a site specific basis.

(iii) What does it mean?

There is sufficient general information to indicate where ground ice may be found. However, for the design and construction of projects, this parameter has to be determined on site specific basis that requires detailed field studies for each structure.

(iv) Overall Assessment and Recommendation

Ground ice is a technical parameter that needs to be determined on site specific basis.

6.3.4 Human Activity/Action Indicators

The impact of human activities on the environment depends largely on the types of activities/actions and their design. The impact may vary from destroying habitat for animals to increasing ground instability or introducing metals in water. Ground instability may lead to erosion that in turn may release large quantities of suspended solids into streams, rivers and lakes.

The Yukon State of the Environment Report (1999) discusses the impacts of actions under different types of human activities. A similar approach was taken in the Updated State of Knowledge Report of the West Kitikmeot and Slave Geological Province (2001) in which the activities are discussed under stress effects due to human activities. In the Deh Cho Cumulative Effects Study, Phase I: Management Indicators and Thresholds (2004), actions are associated with Land and Resource use indicators.

Actions may be classified by type, e.g.: settlements, airstrips, plants, roads & pipelines and mines. This was done by Cizek (2003) for the assessment of human activities of the proposed Bathurst inlet port and road and used by Couture *et al.* (2003) in their paper on the hazards to infrastructure in the North associated with thawing of permafrost. Potential environmental impacts identified by these actions are shown in Table 6.3-2.

TABLE 6.3-2
ACTIONS AND THEIR POTENTIAL IMPACTS ON THE ENVIRONMENT

Action	Impacts and Comments
Settlements, Airstrips & Plants	• Compact area • Settlements & airstrips – likely long life • Settlements & plants – air and water quality • Reclamation requires removal of all physical structures • Likely low impact due to climate warming
Roads & Pipelines	• Linear geometry • May impact watersheds drainage • Impacts during construction and operation • Pipelines; likely operating for 50 years in NWT • Can be reclaimed relatively readily • Climate warming during operation if located in discontinuous permafrost
Mines	• Early mines were mostly small and underground • Most new mines are open pit that produce large quantities of waster rock and tailings • Waste rock may have large visual and migration impact if not designed properly • Major environmental impacts may not start until tens of years after closure if the site is not properly remediated • Tailings may lead to long-term sediment impacts caused by tailings cover and containment structure erosion and physical stability due to permafrost thawing • Potential large long-term environment impact if rock/tailings are acid generating and climate warming and erosion take effect

Actions may have common and specific indicators; for instance, size of land area being impacted and the depletion of esker material may be used by all actions. Actions specific indicators would be applicable to:

a) Settlements and plants that may impact on water quality;
b) Roads and pipelines that have long corridors where vegetation is cleared and that frequently impact a large number of watersheds and streams/rivers, and
c) Waste deposits from mines that may impact terrain and water quality when sulphides are present in the mine wastes.

Sample indicators that may be appropriate for actions include: land area and geometry; ground cover disturbance by construction; granular borrow needs (esker material); drainage impact (roads & pipelines); watershed crossed by unit length of (km^2/km); permafrost and physical stability over life of project and after closure; and, presence and quantities of sulphides in tailings or mine rock and long-term stability of closed storage design.

(i) What is being measured?

Quantifying the impact of actions on the environment in the NWT is in the preliminary stages and has done by several jurisdictions. Two examples where impacts were quantified are: estimation of the physical footprint of human activities in the Bathurst Inlet Port and Road Study Area of the Slave Geological Province (Cizek 2003), and the assessments of potentially acid generating mine wastes provided by abandoned and operating mines that are submitted to the MVLWB by licensed mines (Ekati, Diavik and Snap Lake mines)

(ii) What is happening and what does it mean?

NWT is experiencing much larger development than it has ever experienced in its history. The new operating diamonds mines are creating much larger terrain changes and are producing more mine waste materials than all the 36 closed, and in most instances orphaned, mines combined. Some of the mine wastes have a potential for leaching metals and the resulting seepage from these deposits may impact the quality of adjacent water. Large mine rock and tailings deposits may affect animal habitat and their migration routes. Finally, the stability of these waste structures may deteriorate if permafrost thaws with time.

The development of gas and petroleum resources along the Mackenzie River and Delta and the infrastructures that will be needed for the development of Beaufort Sea may impact the environment as much as the mining industry. The proposed Mackenzie Gas project will have a 1,200 km pipeline route with associated infrastructures and three gas gathering facilities near the Mackenzie Delta. It is likely that new actions with equally large areas and mine waste deposits will follow these actions.

(iii) What are the information gaps?

There is limited cumulative information in one organization to quantify impact of the abandoned, operating and planned projects. The collection of following information would be an asset in assessing the present and long-term effects of actions:

- Footprints of actions within NWT.

- Inventory of esker materials and their exploitation.
- Inventory of potentially metal leaching deposits.
- Measure of development within intermediate watersheds.

(iv) Overall Assessment and Recommendations

Industrial and residential developments and other human activity can have an impact on the physical environment, including permafrost conditions. Accordingly, it is recommended that:

- Actions should be defined for cumulative environmental monitoring and existing and future actions be grouped by type.
- Actions may be grouped as used by regulations and guidelines.

6.4 OTHER CONSIDERATIONS

Time is an important consideration in NWT because of climate warming. Climate warming and the eventual thawing of permafrost may lead to increased erosion. It is likely that when this occurs, access to abandoned sites will be difficult or impossible by winter/ice roads and the airstrips may not be available.

The Canadian Environmental Assessment Agency Guide (1998) indicates that monitoring environmental cumulative impact should consider past, present and future conditions. Variations of permafrost ground temperatures across the NWT and climate warming will lead to thawing of the permafrost and therefore the design of facilities (e.g., roads, dams, etc.) should to be evaluated at different time stages.

For instance, the greatest potential environmental impacts in the short time frame may occur during the construction and operation phases of facilities in areas with low ground temperature; such as is the case of the Mackenzie Gas Project. Routing of the pipeline through vegetated areas underlain by ground susceptible to thaw settlement may lead to problems during the construction period. Additionally, problems could be experienced during the operation phase since large section of the pipeline route is in discontinuous permafrost that may thaw during the operation phase of some 40 years.

Construction and operation of projects in the NWT are governed by federal and territorial legislation and regulation and land agreements with applicable aboriginal and First Nation's people. Some of the regulatory regimes include the Territorial Lands Act, Northwest Territorial Waters Act, Arctic Water Pollutions Prevention Act, Mackenzie Valley Resource Management Act, Environmental Protection Act, Fisheries Act and Canada Mining Regulations.

Guidelines provide objectives, principles and design criteria for planning, operation and final remediation of projects. Most of the guidelines prepared for the NWT were prepared by DIAND between 1987 and 1994. Other contributors have been NWT Water Board, Government of NWT and technical associations. A list of Guidelines prepared for the NWT and the agencies that have prepared these guidelines are given in Table 6.4-1.

Guidelines are complimented by technical publications, such as texts, technical reports, conference proceedings and journal papers. Texts and technical reports describe the properties and behaviour of materials, analyses methods, suggest design procedures and provide selected case histories. Conference proceedings and journal papers concentrate more on recent research and case histories. These do not provide the information that guidelines should provide.

Two of the most relevant textbooks on dams (temperature, climate) and permafrost were written in 1963 and 1981. These books are based on extensive experience and deal with both design and construction. These have been complimented by Environmental Geochemistry of Minesite Drainage (Morin and Hutt 1997) and extensive coverage of acid mine drainage by the MEND program. The most up to date technical information is presented in engineering journals, symposia and conferences.

Guidelines were prepared when climate warming and the concern about cost of remediation of orphaned mines were not identified. Present NWT guidelines do not sufficiently address NWT permafrost conditions nor do they consider the impact of climate warming on Actions. Hence, DIAND has initiated the preparation of new Guidelines for Mine Reclamation for NWT and Nunavut to be completed in late 2005 or early 2006.

Projects contemplated for development in the NWT need to:

- Reflect the complexity of permafrost,
- Address effect of climate warming; and,
- Consider cumulative environmental impact in the longer time span.

Closure planning needs to consider the fact that it is costly to access and remediate problems at remote sites once the infrastructure has been removed.

TABLE 6.4-1
PARTIAL LIST OF GUIDELINES AND TECHNICAL PUBLICATIONS RELEVANT TO NWT
DETAILED REFERENCE INFORMATION ON ABOVE GIVEN IN SECTION 8.2 REFERENCES

Guidelines - DIAND		
Reclamation Guidelines for Northern Canada	1987	DIAND
Guidelines for Tailings Impoundment in the NWT	1987	DIAND
Environmental Operating Guidelines: Access Roads & Trails	1990	DIAND
Guidelines for Acid Rock Drainage Prediction in the North	1992	DIAND
Mine Reclamation in Northwest Territories and Yukon	1992	DIAND
Land Use Guidelines: Access Roads and Trails	1984	DIAND
Environmental Operating Guidelines: Hydrocarbon Well-Sites in Northern Canada	1986	DIAND
Environmental Operating Guidelines: Access Roads & Trails	1990	DIAND
Guidelines for ARD Prediction in the North	1992	DIAND
Mine Reclamation in Northwest Territories and Yukon	1992	DIAND
Land Use Guidelines: Mineral Exploration, DRAFT	2000	DIAND
Mine Site Reclamation Policy for the Northwest Territories	2002	DIAND
Guidelines NWT		
Guidelines for Tailings Impoundments in the Northwest Territories	1992	NWT Water Board
Guidelines for Abandonment and Restoration Planning for Mines in NWT	1990	NWT Water Board
Env. Guidelines for Construction, Maintenance & Closure of Winter Roads in NWT	1993	GNWT
Guidelines - Others		
Canadian Water Quality Guidelines. Freshwater Aquatic Life.	1991	Environment Canada
Pipeline Abandonment; A Discussion Paper on Technical and Environmental Issues	1996	Pipeline Abandonment Steering Committee
A Guide to the Management of Tailings Facilities	1998	Mining Association of Canada
Watercourse Crossings	1999	Cdn Pipeline Environmental Committee
Dam Safety Guidelines	1999	Canadian Dam Association
Classical Textbooks and MEND Reports		
Water Crossing Handbook	1999	Cdn Pipeline Water Crossing Committee
Earth-Rock Dams, Engineering Problems of Design and Construction	1963	Sherard *et al.*
Permafrost, Engineering Design and Construction	1981	Edited by G.H. Johnston.
Environmental Geochemistry of Minesite Drainage	1997	K.A. Morin and N.M. Hutt
MEND Manual, Vol. 1 - Summary	2002	MEND Rpt 5.4.2 SENES Consultants Limited
MEND Manual Vol. 6 - Monitoring	2000	MEND Rpt 5.4.2f SENES Consultants Limited
Covers for Reactive Tailings Located in Permafrost Regions Review	2004	MEND Rpt; 1.61.4. I. Holubec

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Adam, K.K. 1978. *Building and Operating Winter Roads in Canada and Alaska.* Templeton Engineering Company for Environ Division, DIAND 221.

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DIAND, 2000. *Draft: Toward a Mine Site Reclamation Policy for the Northwest Territories.* Discussion paper. p 18.

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Fothergill, P., Anderson, J., Williams, R. and Antoniuk, T. 1999. Watercourse Crossing Handbook. Prepared by the Canadian Pipeline Water crossing Committee.

Hardy Associates (1978) Ltd. 1984. *Land Use Guidelines; Access Roads and Trails.* For Land Resources, Northern Affairs Program, DIAND p 49.

Hardy BBT Limited 1987. *Reclamation Guidelines for Northern Canada.* For Land Resources, Northern Affairs Program, DIAND. P 40.

Hardy BBT Limited 1990. *Environmental Operating Guidelines: Access Roads and Trails.* For Land Resources, Northern Affairs Program, DIAND. P 49.

Holubec, I. 2004. *Covers for Reactive Tailings Located in Permafrost Regions, Review*. MEND Report 1.61.4. October 2004. Pp 116.

Johnston, G.H. 1981. *Permafrost, Engineering Design and Construction.* National Research Council of Canada, John Wiley & Sons, 1981. 483 p.

Kent, R & Technical Advisory Committee 1990. *Guidelines for Abandonment and Restoration Planning for Mines in the Northwest Territories.* NWT Water Board. P 12.

Mining Association of Canada team 1998. *A Guide to the Management of Tailings Facilities.* Prepared as part of Environmental Management Framework. p 48.

Morin, K.A. and Hutt, N.M. 1997. *Environmental Geochemistry of Mine-Site Drainage: Practical Theory and Case Studies.* MDAG Publishing, Vancouver, BC. P 333.

National Energy Board 1996. *Pipeline Abandonment: A Discussion Paper on Technical and Environmental Issues*. For Pipeline Abandonment Steering Committee. P 41.

SENES Consultants Limited (SENES) 2002. *MEND Manual, Volume 1- Summary. MEND 5.4.2a.* Tremblay G.A. and Hogan, C.M. editors. P 109

SENES Consultants Limited (SENES) 2000. *MEND Manual, Vol 6- Monitoring, MEND 5.4.2f. MEND Program.* Tremblay G.A. and Hogan, C.M. editors. P 113,

Spencer Environmental Mgt Services Ltd. *Environmental Operating Guidelines: Hydrocarbon Well-Sites in Northern Canada.* For Land Resources, Northern Affairs Program, DIAND. P 38.

Steffen, Robertson and Kirsten (BC) Inc, 1992. *Guidelines for ARD prediction in the North*. For Department of Indian Affairs and Northern Development, p 122.

Steffen, Robertson and Kirsten (BC) Inc. 1992. *Mine reclamation in Northwest Territories and Yukon, Northern Water Resources Studies,* DIAND,

Stephenson, L.P. & Technical Advisory Committee 1987. *Guidelines for Tailings Impoundments in the Northwest Territories.* For NWT Water Board. P 39.

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7.0 HUMAN HEALTH

7.1 INTRODUCTION

Human health exists as a continuum from fully integrated physical, emotional, spiritual and social functioning to complete dysfunction and death. Measures of human health vary with respect to how the measure will be used in order to improve a particular aspect of health status. Each measurement is conceptualized with respect to how it will be implemented into programming to improve health.

In this component of the NWT SOE report, the focus is on measures of human health and its relationship to environmental quality. The World Health Organization (WHO) reflects on this relationship in its definition of environmental health and human health:

*"**Environmental health comprises those aspects of human health, including quality of life, that are determined by physical, chemical, biological, social, and psychosocial factors in the environment. It also refers to the theory and practice of assessing, correcting, controlling, and preventing those factors in the environment that can potentially affect adversely the health of present and future generations."***

In keeping with the WHO definition and the objectives of the NWT CIMP and Audit, the areas of human health which have been chosen for the human health valued components are those measures collected on the population through various data collection mechanisms (Statistics Canada and the NWT Bureau of Statistics). These measures of health are generally accepted as signals of disease occurrence and of risk factors affecting disease occurrence which potentially point toward assessing, correcting, controlling, and preventing adverse outcomes. In order to quantify these measures and to follow them in temporal sequence statistical samples representative of the population must be collected on a regular and systematic basis. Collection of data on vital events (births and deaths), demographics (age and sex), and residence (geographic distribution) of the reported events, allows rates to be calculated and compared to referent population when appropriate. Data collection also involves the acquisition of information on acute and chronic diseases occurring throughout life stages, as well as on the important determinants of health (income, education, employment, health care events and access) which have a significant impact on the expression of specific health states in the population.

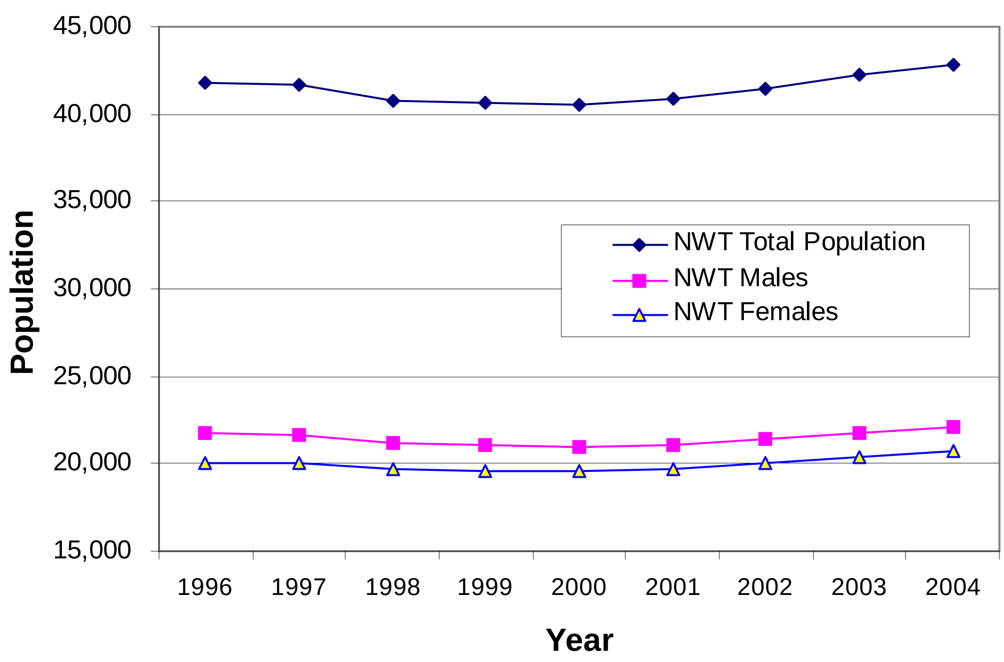
The focus of this component of the SOE is measures of health as denoted above, and not on the collective wellness of the community which requires the analysis of different kinds of data specific to the society's social and ethnical values.

7.2 HUMAN HEALTH INDICATORS

The provision of health services in the NWT is the responsibility of the Government of the Northwest Territories. Approximately 42,000 people live in the Northwest Territories with 45% of the population living in Yellowknife (i.e., 19,056 based on the 2004 NWT Community Population Estimates produced by the NWT Bureau of Statistics). The remainder of the population is spread amongst twenty eight other communities, several of which are only accessible by air. A summary of 2004 population estimates by community and ethnicity is provided in Table 7A.1-1 (Attachment 7A).

As demonstrated on Figure 7.2-1, there are approximately 2,000 more males than females in NWT. The relative proportions have remained fairly consistent since 1996 but the total population has shown an increasing trend since 2000 as seen from Figure 7.2-1. The proportion of First Nations and non-First Nations peoples is approximately the same as indicated on Table 7.2-1.

FIGURE 7.2-1
POPULATION OF NORTHWEST TERRITORIES BY SEX, 1996-2004



Source: Northwest Territories Bureau of Statistics

TABLE 7.2-1
POPULATION ESTIMATES BY ETHNICITY, 2000-2004

Year	Total	Aboriginal	Non-Aboriginal
2004	42,810	21,414	21,396
2003	42,206	21,306	20,900
2001	41,489	21,110	20,379
2000	40,822	20,893	19,929

Source: NWT Bureau of Statistics

In order to formulate a list of potential indicators (measures) of the human health valued component (VC), a literature search was carried out to seek information existing on the health of the NWT population and interviews were carried out with key informants (health specialists) knowledgeable about the data collection and reports on the NWT.

A web-based search using key terms (Canadian Aboriginal Health, NWT Health Status, and NWT statistics) identified a number of data sources, policy papers (e.g., Stout and Kipling 1999) and reports (e.g., Health Canada 2003) which assisted in focusing on potentially important health measures that could be of concern and be followed prospectively to measure progress in specific areas. A search on PubMed generated many recent publications on research being carried out among Aboriginals (First Nations and Inuit) in the NWT and throughout Canada which identify current health challenges. A large amount of population-based data is collected as well as information from special surveys. Much of these data are disseminated by the Northwest Territories Health and Social Services Department and the Northwest Territories Bureau of Statistics. There were areas of data collection distinctly missing. While data for sexually transmitted infections (STIs), suicides, and teen pregnancies are available by community for the NWT, Stout and Kipling (1999) point noted examples of missing data; disability and injury prevention, early pregnancies, mental health status, and attitudes towards sexuality and reproduction.

Insights into approaches to gather relevant and useful information to assess aboriginal health have emerged from the partnerships forged by University of Manitoba and First Nations. Some of these can be applied to the NWT in giving direction to data gathering (Elias *et al.* 2004) in some important areas where data are scarce such as those identified by Stout and Kipling in 1999. Aboriginal leadership, governance, and participation, as well as cultural relevance of chosen health components in making policy for change in health status in their settlement areas have been identified as important by a number of publications (Smylie *et al*. 2004) and need to be considered in making recommendations for data gathering in areas where data are lacking.

Interviews with key health specialists comprised the second approach to select indicators in order to obtain information from their experience in following health status in the NWT. Interviewees who collect, collate, and analyze population data were in the best position to provide credible information on the integrity of the data and the usefulness of the data as a reflection of good indicators of progress in health status, in the evaluation of intervention programs, and the ability to track trends over time (longitudinal data) and thus track what progress has been made.

Telephone interviews were carried out with the Medical Officer of Health and with various policy and statistics officials within NWT departments[30]. Informed interviewees provided population data and sources of data on the web, all of which were readily accessible.

Health specialists also discussed the limits of the data, including issues of small population size of most communities, small number of outcomes measured in small communities, and subsequently the inability to obtain stable rates of certain health outcomes, and completeness of the data. They also provided information on risk factor surveys and prevalence surveys of specific important chronic diseases such as diabetes.

In addition to interviews, data readily available on the internet were also reviewed. All this information collectively provided a list of potential indicators. A summary of the potential indicators and the rationale for their selection is provided on Table 7.2-2. Some of the chosen indicators are illustrated as examples of how particular health outcomes can be followed over time to determine health status in the population, and by inference, the potential impact of the environment on the population. Among the potentially useful indicators, only those with the most useful data records are discussed in Section 7.2.2.

[30] (Personal Communications with) Dr. Andrew Langford, Mr. David Stewart, Ms Gay Kennedy, Mr. Vincent Tam

TABLE 7.2-2
RATIONALE FOR SELECTION OF CANDIDATE INDICATORS OF HUMAN HEALTH

Potential Measures of Human Health Component	Potential Indicators*	Rationale
Population Demographics	• Population data • Age/sex distribution • Migration (emigration and immigration) • Life expectancy • Potential years of life lost (PYLL)	• Essential for monitoring health of population change • Denominator data essential for deriving rates for comparison with other jurisdictions • Life expectancy reflects survival of population, improvement in life expectancy reflect improvements of determinants of health • PYLL is an index of premature mortality with more weight given to younger people
Perinatal Health	• Birth rates • Fertility rate • Birth weights • Birth Defects • Breast feeding rates • Infant mortality rate	• Birth/fertility rates are important indicators of the health of the population • Low birth weight reflects many complex factors, such as nutrition, prenatal care, age of mother, and others. • Infant mortality is an important measure of health of children • Breast feeding is associated with lower rates of enteric disease, allergies, and other illnesses in children later in life, so are a potentially a valued health component to follow.
Mortality	• Leading causes of death by age and sex • Death rates by age and sex • Causes of death by disease: - Cancer - Cardiovascular - Injuries/poison - Suicides/homicides - Others	• Rates and causes of mortality are important indicator of the heath status of the population • Cancer, cardiovascular diseases and injuries/poison are leading causes of death in the NWT

TABLE 7.2-2 (Cont'd)
RATIONALE FOR SELECTION OF CANDIDATE INDICATORS OF HUMAN HEALTH

Potential Measures of Human Health Component	Potential Indicators*	Rationale
Morbidity	• Leading causes of morbidity • Causes of death by disease: - Cancer - Cardiovascular - Injuries/poison - Asthma - Diabetes - Depression - Infectious diseases - Sexually transmitted diseases - Others	• Rates and causes of morbidity are important health status of the population • Changes in the rates may be due to environmental exposures (e.g., changes in asthma may be due to environmental tobacco smoke, air pollution, others.) • The prevalence of diabetes is high among First Nations people
Social Determinants	• Family size and composition • Percent of lone parent families • Dependency ratio • Employment rate • Percent of families with income less than $30K, more than $75K • Income • Education • Housing and community characteristics • Violent crime rate • Juvenile crime rate • NWT shelter admissions	• The notion that health is wealth does not consider important social determinants which contribute to health such as food security, social networks, social exclusion and discrimination, poor housing, etc. Some of these determinants are related to wellness and social integration. The ones considered in this section are enumerated population measures in data bases. • Socioeconomic status indicators (e.g., education/income etc) provides a proxy measure of health status • Dependency ratio provides an estimate of burden of care on the working-age population.[31]

[31] Dependency ratio is defined as the population of those under 15 divided by the population age 15 to 64, multiplied be 100.

TABLE 7.2-2 (Cont'd)
RATIONALE FOR SELECTION OF CANDIDATE INDICATORS OF HUMAN HEALTH

Potential Measures of Human Health Component	Potential Indicators*	Rationale
Personal Health Practices and Risk Factors	• Smoking rate • Youth smoking rate • Alcohol consumption • Substance abuse • Physical inactivity • Obesity	• Smoking is a major contributor to fatal diseases such as cancer, cardiovascular, and others. • Age of smoking initiation is an important predictor of future behaviour. High smoking rates among youth may be indicator of high smoking rates in adulthood. • Heavy alcohol consumption is related to liver diseases and others, and is also often linked to other socio-economic indicators such as violence and injuries. • Moderate level of physical activity is associated with good health. Conversely, physical inactivity is conducive to obesity which in turn is a risk factor for diabetes and other diseases.
Environmental Factors	• Drinking Water and Sewage disposal • Proportion of population with distributed potable water • Proportion of population with adequate sewage disposal	• Access to potable drinking water is related to waterborne disease. Availability of potable drinking water provides an appropriate level of prevention of the burden of waterborne disease morbidity and mortality. • Proper sewage disposal will prevent the contamination of the environment and particularly, of water sources used for drinking and bathing. Fecal transmissions of viral and bacterial infectious diseases are also prevented with proper waste disposal which is a measure of preventive practices in the community.

For general consistency with the presentation of material for the other valued components, the following questions are addressed for the key indicators of human health (population demographics, perinatal health and population mortality):

- What is being measured?
- What does it mean?
- What are the information gaps?

Whereas seven questions were addressed for other valued components, the list was reduced to three key questions for the key indicators of the human health valued component. As insufficient information is available to address other indicators in this manner, only a general discussion of the available information is presented.

7.2.1 HH Indicator – Population Demographics

Important trends in population demographics include total population and age distribution, life expectancy and birth rate.

i) What is being measured?

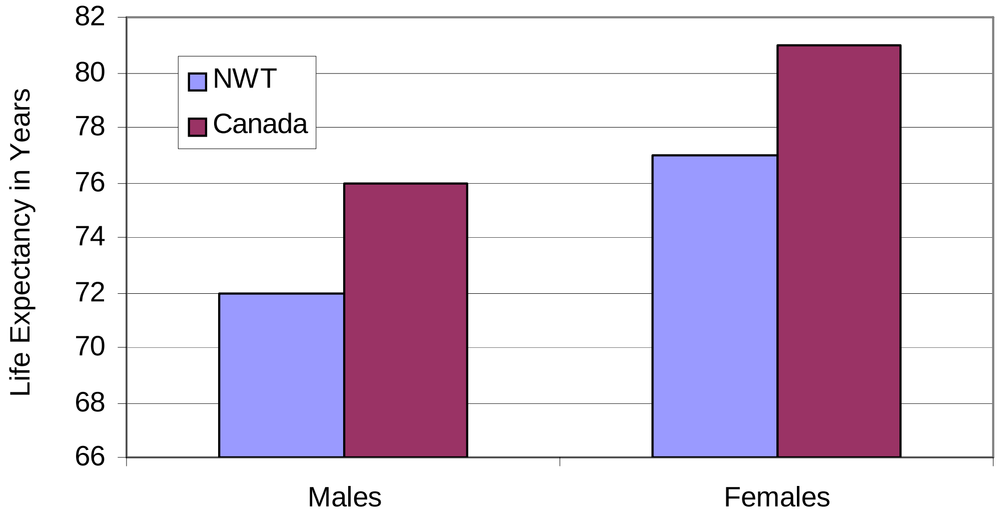
Data on population births, deaths including infant mortality, and life expectancy are available through Statistics Canada (Vital Statistics data base) and on-line for NWT via the Bureau of Statistics. These data are collected for the whole population and are considered of good quality. Although regional data is available, small numbers and high population mobility makes analysis at the regional level less meaningful. Infrequent events are reported as aggregated to the community being examined due to privacy issues. Data are also available by First Nations and non First Nations status.

ii) What does it mean?

Historically, birth rates in First Nations communities were higher than they are now, and infant mortality was higher and life expectancy was lower than non-First Nations people. Improvements in life expectancy reflect better infant survival, as well as improvements in determinants of health such as income, education, access to health care, and premature mortality due to accidents, better nutrition, etc. Improvements in infant mortality and premature death from accidents and suicide will impact on life expectancy considerably.

For the NWT, life expectancy at birth compared to the rest of Canada is about 4 years lower for both males and females (Figure 7.2-2).

FIGURE 7.2-2
LIFE EXPECTANCY AT BIRTH, NORTHWEST TERRITORIES AND CANADA, 1997



Source: Northwest Territories Bureau of Statistics.

Life expectancy at birth has improved among the First Nations population in Canada. In 2000, it rose to 68.9 years for males and 76.6 years for females, slightly lower than for the whole of the NWT population, an increase from 1980 of 13.1% and 12.6%, respectively (Health Canada 2003). Hence, measures of life expectancy and its major contributors over time would be good indicators of a valued health component for both the NWT population as a whole and for the Aboriginal population.

Birth rates and death rates both contribute to population growth rate. Although the value of the natural rate of increase in population is affected by both birth rate and death rate, the recent history of the human population has been affected more by declines in death rates than by increases in birth rates.[32] Better nutrition, greater access to medical care, improved sanitation and more widespread immunization contribute significantly to this population growth, while decreases in infant mortality affect life expectancy at birth. Improvements in all of these factors, and data to monitor the changes, contribute to the evaluation of valued health components.

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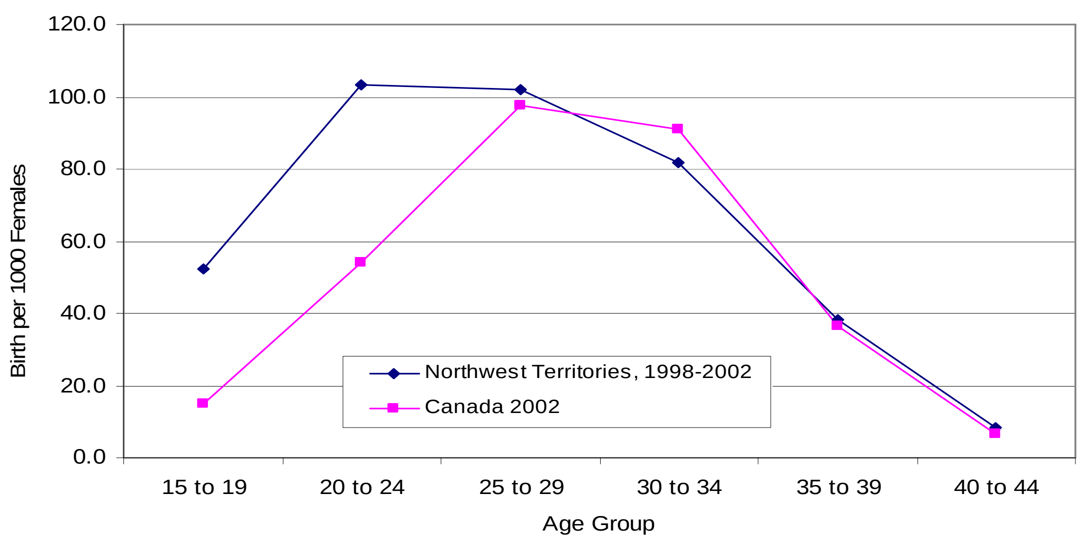
[32] Human Population Growth http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/Populations.html

The total fertility rate (TFR) can be used as an estimate of the fertility growth factor in a population, e.g., whether the childbearing population is replacing itself or not. A TFR of 2 or above indicates that, on the average, couples are producing at least two children to replace themselves. When the TFR exceeds 2 for an extended period, the next generation of childbearing age will probably be larger than the present population of that age if all other factors affecting the population, such as death rates and migration, remain constant. This means that the population will be growing steadily from within. In 2002 the fertility rate in women under 29 years of age in the NWT was nearly double in First Nations as the rest of Canada (Figure 7.2-3). In 1999, the First Nations birth rate was 23.0 births per 1,000 population, two times the comparable rate for Canada. Births to women under age 19 were high in the NWT including First Nations. Over half (58%) of First Nations women who gave birth in 1999 were under 25 years of age. This represents an area of importance to follow over time as improvements in education, employment and other determinants are associated with lower birth rates in this age group and may be considered as a positive attribute. However, these characteristics are generally associated with lower fertility, and lower rate of population replacement.

Lower fertility associated with older age with first child may indicate lack of population replacement which could be of concern, and therefore worth following as a valued health component. Figure 7.2-3 also points out that proportionally more births occur in NWT to women under 19 years of age than at older ages. This is a significant difference which may reflect many characteristics of the population including educational opportunities for women, control of fertility and reproduction, socio economic status, in general, and/or others factors. These factors need to be examined further.

FIGURE 7.2-3
AGE-SPECIFIC FERTILITY RATE



Source: NWT Bureau of Statistics

iii) What are the information gaps?

Information on population demographics was found to be relatively complete with no obvious gaps. However, there is the matter of confidential issues relating to small numbers.

7.2.2 HH Indicator - Perinatal Health

Birth/fertility rates are important indicators of the health of the population. Low birth weight reflects many complex factors, such as nutrition, prenatal care, age of mother, and others. Infant mortality is an important measure of health of children. Breast feeding is associated with lower rates of enteric disease, allergies, and other illnesses in children later in life, so are a potentially a valued health component to follow.

i) What is being measured?

The GNWT Department of Health and Social Services, through its Vital Statistics, routinely monitors birth outcomes and calculates rates (e.g., birth, fertility, infant mortality). Information is available by region and community. A breastfeeding survey was conducted in 1993.

iii) What does it mean?

The NWT experiences higher rates of infant mortality, nearly twice that of Canada as a whole (11 vs. 5.5 per 1000 live births). In 1999, the First Nations infant mortality rate was 8.0 deaths per 1,000 live births, or 1.5 times higher than the Canadian infant mortality rate of 5.5. However, infant mortality rate has been steadily declining in First Nations peoples (Health Canada 2003).

NWT experienced higher rates of high birth weight babies than the rest of Canada and slightly lower rates of low birth weight babies (Table 7.2-3). The First Nations and the Canadian populations had similar proportions of births with low birth weight in 1999; however, almost twice as many First Nations births were classified as high birth weight in the same year (Health Canada 2003).

TABLE 7.2-3
NUMBER PER 1000 BIRTHS OF LOW (<2500 GRAMS) AND HIGH (4000+ GRAMS) BIRTH WEIGHTS FOR NORTHWEST TERRITORIES AND CANADA

Year	Low Birth Weight per 1000 births		High Birth Weight per 1000 Births	
	NWT	Canada	NWT	Canada
2002	49.2	57.3	177.8	131.9
2001	32.6	55.4	207.2	136.2
2000	52.2	55.7	210.1	137.6
1999	59.2	56.3	168.4	133.3
1998	57.9	57.6	163.2	130.1
1997	36.1	57.8	169.2	123.4
1996	50.4	57.6	191.6	124.4
1995	44.2	58.4	170.9	120.0
1994	52.0	57.7	205.4	122.5
1993	48.9	56.8	135.7	124.4
1992	49.9	54.9	152.2	126.5
1991	43.5	55.4	165.0	121.8
1990	41.6	55.4	167.4	123.2
1989	50.4	55.5	142.7	121.6
1988	48.3	56.6	169.6	120.0
1987	52.6	55.3	145.8	119.0
1986	68.8	55.0	126.7	115.4
1985	43.8	55.7	181.3	112.6
1984	59.4	55.4	132.1	111.9
1983	53.5	56.0	134.2	110.1
1982	62.3	56.9	141.0	109.3
1981	47.0	58.9	104.4	104.0

iii) ***What are the information gaps?***

Birth defect reporting at birth is not mandatory but is being considered now as part of the birth defects monitoring system. Breast feeding rates are currently being measured and will be available in the future.

7.2.3 HH Indicator – Population Mortality

Population Mortality measures the crude mortality, age and sex specific mortality, and major disease specific mortality by age and sex – by region if numbers are large enough to permit analysis.

i) What is being measured?

The GNWT Department of Health and Social Services, through its Vital Statistics, routinely collects information regarding deaths and calculates death rates by cause.

ii) What does it mean?

The crude mortality rate for the NWT was approximately 4 deaths per 1,000 population for 2001 (Table 7.2-4). The four major causes of death for the NWT were cancer, circulatory disease, accidents (including suicides), and respiratory diseases.

TABLE 7.2-4
MORTALITY RATES PER 1,000 POPULATION IN NWT

2001	1996	1991	1986
4.0	3.6	3.6	4.2

Source: Northwest Territories Bureau of Statistics

The four leading causes of death for First Nations were injury and poisoning, circulatory diseases, cancer and respiratory diseases. For each of the causes of death, the rate has decreased when compared with the 1991 to 1993 period, from 22.4% for cancer to 40.9% for respiratory diseases, such as pneumonia and bronchitis (Health Canada 2003).

The crude mortality rate for First Nations males was 1.3 times higher than the rate for First Nations females in 1999. The rate difference is largely attributable to higher rates among males for injury and poisoning (147 deaths per 100,000 among males and 68 among females) and to circulatory disease (98 deaths per 100,000 among males and 72 among females) (Health Canada 2003).

Age-specific death rates in 1999 were higher in First Nations males than females for almost all age groups. The largest difference between the sexes occurs in the 5 to 9 and 20 to 24 age groups (Health Canada 2003).

Table 7.2-5 demonstrates that the mortality rate for infants (males and females) is much higher in the NWT than in the rest of Canada. Similarly, higher death rates occur in most age groups for males, and modest differences exist for females. Reasons for this need to be examined further, and more specific data needs to be collected to be able to implement preventive action to improve these rates.

TABLE 7.2-5
DEATHS PER 1000 POPULATION

Age (Years)	Males		Females	
	NWT Avg. (98-02)	Canada 2002	NWT Avg. (98-02)	Canada 2002
0	14.2	5.8	8.3	4.9
1 – 14	0.3	0.2	0.2	0.1
15 – 24	2.1	0.7	0.5	0.3
25 – 44	1.8	1.2	0.8	0.7
45 – 64	5.8	5.6	4.2	3.5
65+	57.1	51.4	43.1	42.5

Source: Northwest Territories Bureau of Statistics

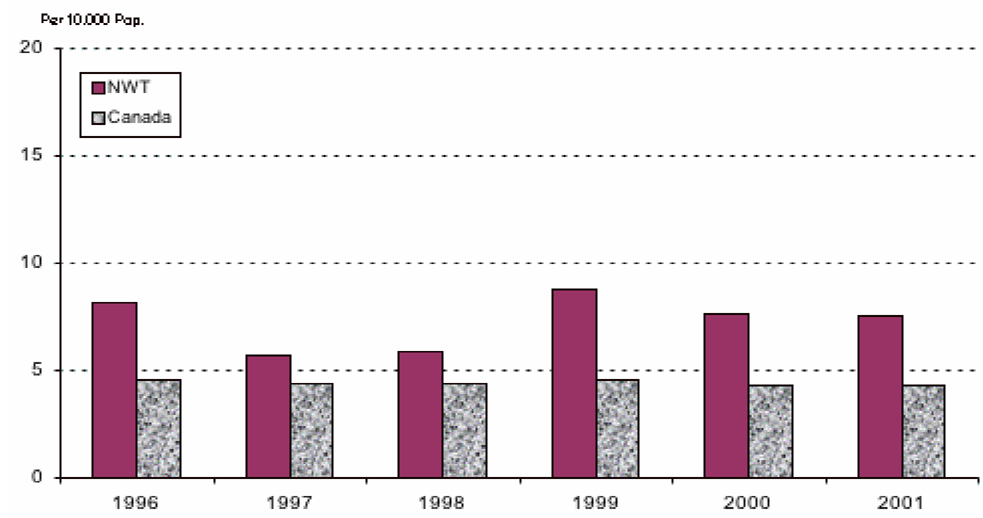
With respect to First Nations people, the most common cause of death for those aged 1 to 44 was injury and poisoning. Among children under 10, deaths were primarily unintentional (accidental). Suicide and self-injury were the leading causes of death for youth and adults up to age 44. For First Nations aged 45 and older, circulatory diseases were the most common causes of death. These trends parallel the Canadian population as a whole (FPT 1999). Motor vehicle collisions were a leading cause of death in all age groups (Health Canada 2003).

With respect to death from accidents, suicide, and homicide for the NWT and Canada, the NWT has shown higher rates from 1996 to 2001, as seen in Figure 7.2-4**.** First Nations age groups up to age 65 are at increased risk, compared with the Canadian population. First Nations males are at higher risk than females. The greatest disparity with the Canadian rates is for females aged 15 to 24 and aged 25 to 39 (approximately eight and five times the Canadian rates, respectively) (Health Canada 2003). Specific rates for small communities in NWT may not be shown due to privacy issues.

iii) What are the information gaps?

Information on population mortality was found to be relatively complete with no major gaps identified.

FIGURE 7.2-4
DEATH RATES FROM ACCIDENTS, SUICIDES AND HOMICIDES PER 10,000 POPULATIONS FOR CANADA AND NORTHWEST TERRITORIES



Source: Northwest Territories Bureau of Statistics

7.2.4 HH Indicator - Population Morbidity

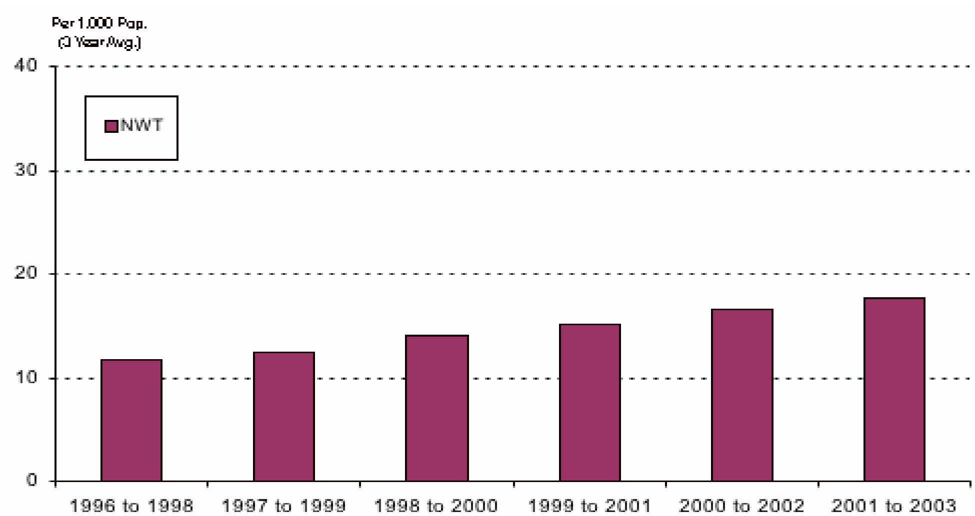
Morbidity refers to the relative incidence of disease. Rates and causes of morbidity are important measures of the health status of the population. Changes in the rates may be due to environmental exposures (e.g., changes in asthma may be due to environmental tobacco smoke, air pollution, others). In this section, health statistics on "Infectious Diseases" and for "Diabetes and Hypertension" are discussed separately.

7.2.4.1 Infectious Diseases (Sexually Transmitted Diseases, Tuberculosis)

At the time of preparation of this section, specific data on Infectious Diseases and especially vaccine preventable diseases were not found for the NWT; therefore, the Survey of Inuit and First Nations Health report was consulted. In 1999, First Nations people across Canada experienced a disproportionate burden of many infectious diseases compared to other Canadians as a whole. These include pertussis (3 times higher), Chlamydia (7 times higher), hepatitis A (5.3 times higher) and shigellosis (almost 20 times higher) (Health Canada 2003). The proportion of Canada's total AIDS cases contracted by Aboriginal people in Canada climbed from 1.0% in 1990 to 7.2% in 2001 (Health Canada 2002). Given that about half the population in the NWT is First Nations, these statistics indicate there is a need to focus on preventive and follow up actions in these health areas, which are considered good indicators of preventable population adverse health experiences. Over that same period, the tuberculosis rate among First Nations people remained 8 to 10 times than seen in the Canadian population as a whole (Health Canada 2003). This is not the case however, for the NWT population as a whole.

A specific breakdown of infectious diseases in the NWT by First Nations and non-First Nations peoples was not found. Reporting from regions of immunization status and communicable disease may be inconsistent. However, data on sexually transmitted diseases (STDs) in the NWT can be seen in Figure 7.2-5. The rise in STD may be attributed to better detection and reporting as well as a potential real increased rate from 1996 to 2003. Gaps exist where people do not seek hospitalization or health care as that is where reporting originates.

FIGURE 7.2-5
SEXUALLY TRANSMITTED INFECTION RATE PER 1,000 POPULATIONS (3-YEAR AVERAGE) FOR THE NORTHWEST TERRITORIES



Source: Northwest Territories Bureau of Statistics

7.2.4.2 Diabetes and Hypertension

Diabetes prevalence - Health Canada has used several approaches to determine the impact of diabetes on the Canadian population. National population health surveys carried out every two years, longitudinal surveys, diagnosis specific hospital discharge information, and the Aboriginal Peoples Health Survey (1991) provide an insight into diabetes morbidity and mortality. The surveys suffer from several shortcomings in that they constitute self reports, do not capture undiagnosed pre-diabetes, do not differentiate Type I or Type II diabetes, or may miss diabetes as an underlying cause of death.[33] Often, small numbers do not adequately represent the

[33] Public Health Agency of Canada. Diabetes in Canada. National Statistics and Opportunities for Improved Surveillance, Prevention, and Control. http://www.phac-aspc.gc.ca/publicat/dic-dac99/d14_e.html

communities of interest. The NWT participates in the National Diabetes Surveillance System and has good data on diabetes prevalence. The Canadian Community Health Survey, conducted regularly in the NWT by Statistics Canada, also asks respondents about diabetes and other chronic health conditions.

Hypertension prevalence - There is no central database available for hypertension, and no prevalence studies. As a major risk factor for cardiovascular mortality, this is an area that should be explored for NWT populations.

Dental Caries - Dental health measures are not collected systematically in the NWT. Dental decay rates for Aboriginal children in Ontario are two to five times higher than rates among non-Aboriginal children. They are far less likely to be decay-free (Health Canada 2003). Similar data could be developed for the NWT.

The incidence of asthma is enumerated by prevalence surveys.

7.2.5 HH Indicator - Personal Health Practices and Risk Factors

Factors that increase the risk of adverse health effects include smoking, alcohol and substance abuse, obesity and physical inactivity.

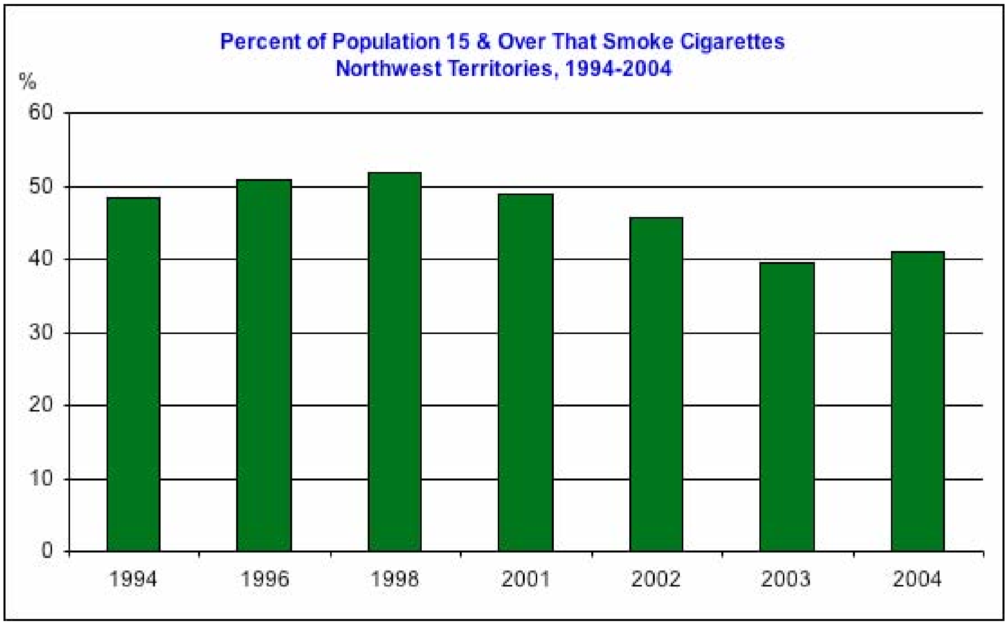
Smoking **-** Smoking rates for the Northwest Territories have been collected in a variety of household surveys for persons 15 years and over from 1994 to 2004. A summary of these data is provided in Figure 7.2-6.

A reduction in the smoking rate would be desirable for the NWT population as smoking is a risk factor for respiratory and cardiovascular disease as well as cancer. Periodic surveys can capture this information.

Alcohol and Substance Abuse **-** Figure 7.2-7 indicates the differences in the incidence of heavy alcohol use for Canada and the NWT with the NWT experiencing higher use of alcohol (incidence of heavy use being just one measure of alcohol use). Heavy use of alcohol is associated with adverse health outcomes, accidents as well as family and social adverse impacts. A detailed profile of alcohol consumption in the NWT is provided in Table 7.2-6.

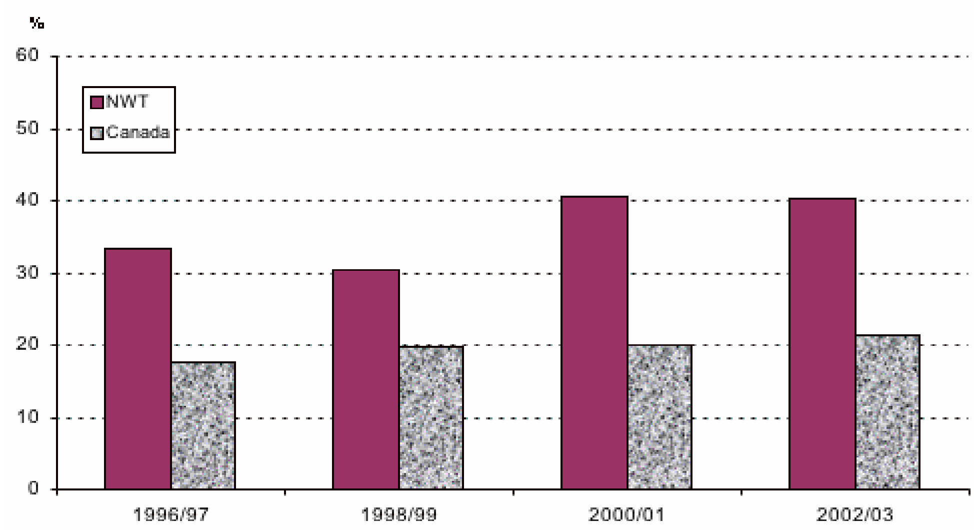
Obesity and Physical Inactivity **-** Obesity and physical inactivity are important risk factors for cardiovascular disease and premature mortality. This is an important health indicator whose data collection can be enhanced. There is some information in the health status report (National population health survey), but this is difficult to extract for NWT communities. A larger sample is needed to better identify the extent of this health problem in NWT and its communities.

FIGURE 7.2-6
PERCENT OF POPULATION 15 YEARS AND OVER THAT SMOKE CIGARETTES IN NORTHWEST TERRITORIES 1994-2004



Source: Northwest Territories Bureau of Statistics

FIGURE 7.2-7
INCIDENCE OF HEAVY ALCOHOL USE FOR CANADA AND NORTHWEST TERRITORIES



Source: Northwest Territories Bureau of Statistics

TABLE 7.2-6
PROFILE OF ALCOHOL CONSUMPTION IN THE NORTHWEST TERRITORIES

	Total	%	Current Drinker	%	Former Drinker	%	Never Drank	%
Persons 15 Yrs. & Over	30,431	100.0	23,748	78.0	5,247	17.2	1,295	4.3
Males	15,892	100.0	12,783	80.4	2,555	16.1	461	2.9
Females	14,539	100.0	10,965	75.4	2,692	18.5	834	5.7
15-24	6,413	100.0	5,383	83.9	477	7.4	454	7.1
25-39	11,466	100.0	9,639	84.1	1,588	13.8	223	1.9
40-59	9,602	100.0	7,102	74.0	2,186	22.8	314	3.3
60 Yrs. & Over	2,743	100.0	1,444	52.6	971	35.4	303	11.0
Employed	21,371	100.0	17,345	81.2	3,372	15.8	590	2.8
Not Employed	9,023	100.0	6,365	70.5	1,876	20.8	705	7.8
Less than Grade 9	3,542	100.0	2,101	59.3	1,117	31.5	324	9.1
Grade 9 - 11	7,843	100.0	6,133	78.2	1,288	16.4	370	4.7
High School Diploma	6,147	100.0	4,991	81.2	927	15.1	229	3.7
Trades Cert. Or Diploma	2,258	100.0	1,805	79.9	419	18.6	18	0.8
College Cert. Or Diploma	4,867	100.0	3,945	81.1	686	14.1	188	3.9
University Degree	5,455	100.0	4,599	84.3	690	12.6	166	3.0
Less than $20,000	11,054	100.0	7,881	71.3	2,287	20.7	834	7.5
$20,000 - $39,999	5,838	100.0	4,785	82.0	838	14.4	167	2.9
$40,000 - $59,999	5,257	100.0	4,325	82.3	757	14.4	159	3.0
$60,000 or more	6,594	100.0	5,437	82.5	1,084	16.4	73	1.1
Aboriginal	14,037	100.0	9,880	70.4	3,431	24.4	658	4.7
Males	7,013	100.0	5,122	73.0	1,557	22.2	266	3.8
Females	7,024	100.0	4,758	67.7	1,874	26.7	392	5.6
Non-Aboriginal	16,087	100.0	13,715	85.3	1,713	10.6	611	3.8
Males	8,698	100.0	7,558	86.9	945	10.9	195	2.2
Females	7,389	100.0	6,157	83.3	768	10.4	416	5.6
Yellowknife	13,355	100.0	11,438	85.6	1,406	10.5	495	3.7
Males	6,913	100.0	6,034	87.3	739	10.7	124	1.8
Females	6,442	100.0	5,404	83.9	667	10.4	371	5.8
Aboriginal	2,659	100.0	2,022	76.0	585	22.0	36	1.4
Non-Aboriginal	10,671	100.0	9,416	88.2	797	7.5	458	4.3
Regional Centers	7,335	100.0	5,426	74.0	1,503	20.5	358	4.9
Males	3,863	100.0	2,963	76.7	786	20.3	114	3.0
Females	3,472	100.0	2,463	70.9	717	20.7	244	7.0
Aboriginal	3,467	100.0	2,407	69.4	754	21.7	306	8.8
Non-Aboriginal	3,737	100.0	2,966	79.4	696	18.6	27	0.7
Rest of Communities	9,739	100.0	6,883	70.7	2,338	24.0	441	4.5
Males	5,115	100.0	3,786	74.0	1,030	20.1	222	4.3
Females	4,624	100.0	3,097	67.0	1,308	28.3	219	4.7
Aboriginal	7,912	100.0	5,451	68.9	2,093	26.5	316	4.0
Non-Aboriginal	1,677	100.0	1,332	79.4	220	13.1	125	7.5

Source: 2002 Northwest Territories Alcohol and Drug Survey

7.2.6 HH Indicator - Social Determinants

The notion that health is wealth does not consider important social determinants which contribute to health such as income distribution, food security, social networks, social exclusion and discrimination, poor housing, education, etc. Some of these determinants are related to wellness and social integration. The ones considered in this section are enumerated population measures in databases.

Some of the enumerated data include family size and composition, lone parent families, dependency ratio, employment rate, families with income less than $30,000 or more than $75,000, education, housing and community characteristics, violent crime, juvenile crime and shelter admissions.

A lower proportion of the population in the NWT than in the rest of Canada has not attained secondary school education (see Table 7.2-7 High School Graduation Rate). There has been some improvement in the past 10 years with some closing of the gap between NWT and the rest of Canada, a trend that needs to be followed as it is associated with better opportunities for employment, higher lifetime earnings, and better health status.

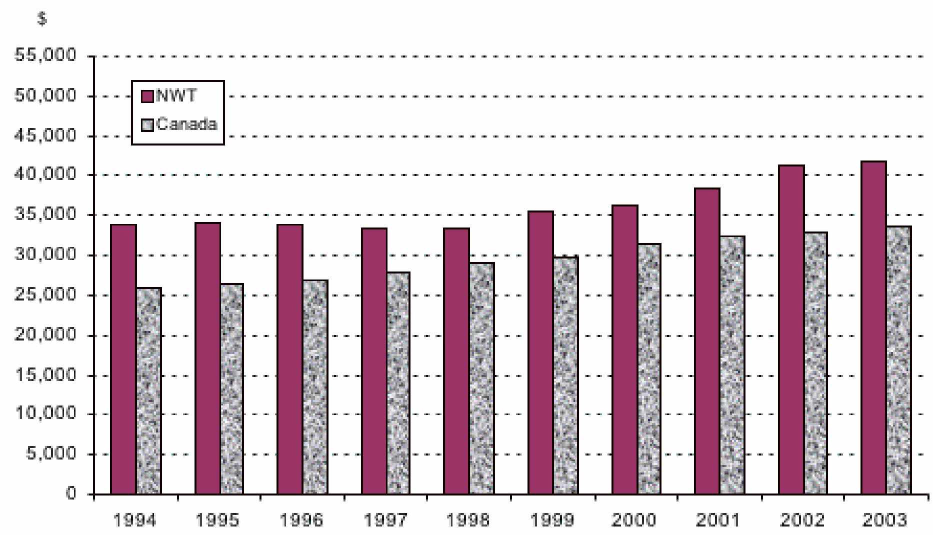
TABLE 7.2-7
HIGH SCHOOL GRADUATION RATE FOR THE NORTHWEST TERRITORIES AND CANADA, 1994-2001

Community	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01
Canada	77.4	76.6	75.9	75.2	76.1	76.6	75.9
NWT	37.5	33.6	37.0	38.8	42.2	38.8	44.6

Source: NWT data – NWT Education, Culture & Employment; Canadian data – Statistics Canada
Rates expressed as graduates per 100 eligible students.

Interestingly, high school graduation rate is lower in the NWT than in Canada but the average employment income is higher for the NWT than the rest of Canada (Figure 7.2-8). For specific communities, family income is also quite high. In 2002, the average family income in Yellowknife was over $100,000 (see Table 7.2-8). This statistic questions the adage that "wealth is health", a relationship seen in developed countries. However, discrepancies in this relationship in the NWT as compared to Canada merits investigation with respect to what factors actually contribute to the differences, and indicate areas of intervention to close that gap.

FIGURE 7.2-8
AVERAGE EMPLOYMENT INCOME FOR CANADA AND NWT, 1994-2003



Source: NWT Bureau of Statistics

TABLE 7.2-8
AVERAGE FAMILY INCOME BY COMMUNITY IN THE NWT, 1999-2002

Community	Year			
	2002	2001	2000	1999
Northwest Territories	$87,143	$80,225	$71,864	$70,463
Aklavik	51,141	51,606	44,781	42,625
Deline	49,757	50,564	39,523	43,492
Fort Good Hope	52,231	50,762	46,877	40,400
Fort Liard	58,773	55,273	52,671	48,800
Fort McPherson	57,248	49,352	43,274	40,740
Fort Providence	50,243	47,591	41,795	42,443
Fort Resolution	45,807	43,893	36,377	34,286
Fort Simpson	71,632	65,062	61,514	59,717
Fort Smith	77,935	72,156	64,977	66,429
Hay River	85,307	80,763	73,079	67,662
Holman	54,770	46,527	39,344	38,330
Inuvik	85,280	77,417	67,644	67,094
Lutselk'e	53,300	44,650	41,863	37,067
Norman Wells	104,895	97,953	94,994	93,747
Paulatuk	..	48,267	42,183	..
Rae Edzo	57,139	54,871	43,219	42,700
Rae Lakes	55,571	55,743	42,457	40,443
Tsiigehtchic	45,760	..	37,240	..
Tuktoyaktuk	58,733	53,604	38,736	41,519
Tulita	50,036	49,780	46,550	40,950
Wha Ti	53,464	45,427	44,109	43,480
Wrigley	..	..	53,200	..
Yellowknife	106,953	97,377	88,295	86,737

Source: Small Area Data Division, Statistics Canada

7.2.7 HH Indicator - Environmental Factors

Environmental factors that have been shown to most directly affect human health include the adequacy of potable water and sewage treatment systems. One of the potential consequences of inadequate water supplies is the contraction of waterborne gastrointestinal illness.

Drinking Water **-** All communities in the NWT have access to potable drinking water except for Colville Lake which is a small community of about 135 people in the Sahtu Region. Colville Lake does not have a formal/organized water supply and treatment system and is on a permanent boil water advisory. People get their water from the lake for daily uses. A small centrally located water tank does provide some chlorinated water (by batch chlorination) to some residents. However, because of the new turbidity guideline, Colville Lake will be getting a new water supply and treatment (filtration) system in a year or two. Other communities that do not currently have a filtration system but are using surface water as their raw water source will also be upgraded to include filtration in the near future.

The delivery system in most small communities (Hamlets and Bands) is by truck with the exception of Rae/Edzo (Tlicho Settlement Area) and Ft. McPherson (Gwich'in Settlement Area) which have both piped and trucked water delivery systems (Tam 2005).

Sewage Disposal **-** All communities in the NWT have a sewage collection/disposal/treatment system except for Colville Lake.

Most homes/buildings in small NWT communities have sewage holding tanks, which are pumped out regularly by sewage trucks. The waste water is then disposed of in lagoons for natural treatment. Some communities utilize wetland treatment instead of lagoons. Only one community (Ft. Simpson) has advanced treatment using mechanical/chemical/biological processes prior to river discharge.

Rae/Edzo and Ft. McPherson have both piped and trucked waste water disposal systems (Tam 2005).

7.3 CONCLUSION AND DISCUSSION

Population-based data from census and vital statistics are the most complete sources of data available for the NWT and are considered to be of good quality. These data can be separated by age, sex, and place of residence, and many by First Nations and Non-First Nations ethnic status. Birth outcome patterns can be examined by age of mother, birth weight, presence of birth defect, and place of residence as well as First Nations status. The systematic and continuous collection of these data allows for meaningful comparisons over time. Good data are also available for many social determinants (education, employment, income, family income) and life style risk factors (smoking, alcohol and substance abuse).

In addition to census and vital statistics data, the NWT Bureau of Statistics and Health and Social Services Departments reports results of surveys which monitor the health status of the residents of Northwest Territories. Examples of these include the Alcohol and Drug Survey and health status reports which review data on a periodic basis (5 years) when meaningful rates are more likely to result for smaller communities. The NWT also has a cancer registry established in the early 1990s. This person-oriented database will provide more continuous and systematic collection of cancer incidence and mortality in the Territory.

Most areas lack data related to chronic diseases, a problem also common to other areas of Canada. Data gaps include information on major chronic diseases such as musculoskeletal (mobility disorders), neurological and degenerative (dementias), hypertension and stroke, and diabetes. Birth defects are not well documented for the NWT. With some enhancements, it appears that most outcomes of value can be tracked in the NWT and in regions despite small populations in some communities. Reporting of communicable diseases and of immunization of children is not complete. Means of improving data collection on chronic diseases needs to be examined.

Despite the excellent efforts in gathering meaningful data in the NWT, there are intrinsic challenges in the collection, analysis, and dissemination of these data. Health outcomes in small communities can be measured, but reporting them may result in breach of confidentiality because of small numbers of cases which apply. Also, with few outcomes, rates on a year by year basis are unstable and one may not draw useful conclusions if following them over time.

Overall, most health characteristics considered worth tracking longitudinally are well documented. Longitudinal tracking can provide a good picture of where resources may be best put in order to make the most important interventions and contributions to the improvement of health status. One important indicator not specifically mentioned above is the routine tracking of health status by public health agencies and the documentation of changes in environmental factors such as drinking water supply and sewage management. This important activity, which serves to provide an objective measure of population health change over time, is scheduled to be reported to the public sometime in 2005 (Corriveau 2005).

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ATTACHMENT 7A

POPULATION DEMOGRAPHICS

TABLE 7A.1-1
COMPONENTS OF POPULATION CHANGE IN NWT BY TIME PERIOD (JANUARY 1, 2001 TO OCTOBER 1, 2004)

Year	Period	Beginning Population	Ending Population	Births	Deaths	Inter-provincial Migration			Net International	Error of Closure
						In	Out	Net		
2004	Jan-Sep	42,629	42,925	498	134	2,183	2,335	-152	84	-
	Jul-Sep	42,810	42,925	155	48	654	660	-6	14	-
	Apr-Jun	42,585	42,810	177	44	790	731	59	33	-
	Jan-Mar	42,629	42,585	166	42	739	944	-205	37	-
2003	Jan-Dec	41,791	42,629	637	172	2,664	2,439	225	148	-
	Oct-Dec	42,362	42,629	142	40	510	418	92	73	-
	Jul-Sep	42,206	42,362	151	48	907	884	23	30	-
	Apr-Jun	41,964	42,206	178	43	678	605	73	34	-
	Jan-Mar	41,791	41,964	166	41	569	532	37	11	-
2002	Jan-Dec	41,107	41,791	635	169	2,724	2,511	213	5	-
	Oct-Dec	41,674	41,791	142	39	491	465	26	-12	-
	Jul-Sep	41,489	41,674	151	47	924	818	106	-25	-
	Apr-Jun	41,239	41,489	177	42	640	533	107	8	-
	Jan-Mar	41,107	41,239	165	41	669	695	-26	34	-
2001	Jan-Dec	40,646	41,107	613	163	2,405	2,444	-39	90	-40
	Oct-Dec	41,144	41,107	147	37	389	525	-136	-11	-
	Jul-Sep	40,822	41,144	162	44	971	832	139	65	-
	Apr-Jun	40,638	40,822	160	34	595	541	54	20	-16
	Jan-Mar	40,646	40,638	144	48	450	546	-96	16	-24

Note: *Net International* represents the net total of all Immigrants, Emigrants, Returning Canadians, Non-Permanent Residents and Individuals Temporarily Abroad. *Error of Closure* represents the difference in population change as measured by the individual components of growth and that observed using 2001, 1996 and 1991 census based population estimates.

Source: *Statistics Canada, Demography Division.*

TABLE 7A.1-2
POTENTIAL YEARS OF LIFE LOST (<75 YEARS) IN NORTHWEST TERRITORIES (1999-2002)

Cause	Year			
	2002	2001	2000	1999
Total	2,861	2,587	2,570	3,328
Infectious & Parasitic Diseases	35	54	76	38
Neoplasms	717	426	463	582
Endocrine, Nutritional & Metabolic Diseases & Immunity Disorders		54	11	87
Diseases of Blood and Blood Forming Organs		-	70	-
Mental Disorders	25	104	123	49
Diseases of Nervous System & Sense Organs		59	7	26
Diseases of the Circulatory System	205	289	82	330
Diseases of the Respiratory System	81	86	57	34
Diseases of the Digestive System	81	112	108	15
Diseases of the Genito-Urinary System	57	-	5	32
Complications of Pregnancy, Childbirth & the Puerperium		-	-	-
Diseases of the Skin and Subcutaneous Tissue		-	-	-
Diseases of the Musculo-Skeletal System & Connective Tissue		13	-	-
Congenital Anomalies	497	-	-	75
Conditions Originating in the Perinatal Period	75	150	375	375
Symptoms, Signs & Ill-Defined Conditions	160	118	35	250
Accidents (Including Suicides)	928	1,122	1,158	1,435

Source: Prepared by NWT Bureau of Statistics, November 2004
Notes:
1. Potential Years of Life Lost is defined as the difference in years between an average life expectancy (75 years) and the age at which a person dies.
2. The small number of total deaths in the Northwest Territories may cause some variation in the data.
3. The data provided in this table use the ICD-9 classification of cause of death. As of 2000, Statistics Canada began using ICD-10, therefore, to display ICD-10 data in the ICD-9 categories, Diseases of the Nervous System, Diseases of the Eye and Diseases of the Ear were aggregated into Diseases of the Nervous System and Sense Organs. For other differences between ICD-9 and ICD-10, please contact the NWT Bureau of Statistics.

TABLE 7A.1-3
CENSUS POPULATIONS, FEMALES POPULATION AGED 15 TO 44, AVERAGE BIRTH AND FERTILITY RATES

Year	Population				Females (15 - 44)				Average Birth Rate				Average Fertility Rate			
	2001	**1996**	**1991**	**1986**	**2001**	**1996**	**1991**	**1986**	**2001**	**1996**	**1991**	**1986**	**2001**	**1996**	**1991**	**1986**
Total NWT	37,360	39,672	36,405	33,830	9,175	10,165	9,630	8,910	17.9	21.1	23.6	24.8	72.7	82.3	89.3	94.1
Inuvik Region	8,536	9,447	8,852	8,714	1,990	2,225	2,145	2,230	19.2	24.9	27.4	29.0	82.3	105.9	113.2	113.2
Aklavik	632	727	801	763	125	135	175	170	15.2	21.2	28.5	26.7	76.8	114.1	130.3	120.0
Colville Lake	102				15				27.5				186.7			
Deline	536	616	551	532	130	145	110	120	20.1	31.8	29.8	4.1	83.1	135.2	149.1	18.3
Fort Good Hope	549	644	602	562	120	135	120	110	18.9	24.8	33.6	33.5	86.7	118.5	168.3	170.9
Fort McPherson	761	878	759	760	160	180	160	180	16.8	23.9	25.6	24.2	80.0	116.7	121.3	102.2
Holman	398	423	361	303	105	120	100	85	16.1	34.5	27.7	26.4	61.0	121.7	100.0	94.1
Inuvik	2,894	3,296	3,206	3,389	730	880	865	990	21.4	25.4	25.1	27.9	84.7	95.2	92.9	95.6
Norman Wells	666	798	627	627	150	210	185	170	18.3	22.1	21.4	18.5	81.3	83.8	72.4	68.2
Paulatuk	286	277	255	193	60	50	50	45	14.7	24.5	40.0	32.1	70.0	136.0	204.0	137.8
Sachs Harbour	114	135	125	158	25	35	25	35	26.3	19.3	33.6	20.3	120.0	74.3	168.0	91.4
Tsiigehtchic	195	162	144	108	50	45	15	25	21.5	25.9	25.0	16.7	84.0	93.3	240.0	72.0
Tuktoyaktuk	930	943	918	929	215	200	220	215	19.6	21.6	29.8	40.0	84.7	102.0	124.5	173.0
Tulita	473	450	375	332	95	95	95	75	15.6	24.0	33.6	27.7	77.9	113.7	132.6	122.7
Fort Smith Region	28,824	30,225	27,553	25,116	7,185	7,940	7,480	6,680	17.5	19.7	22.2	23.2	70.0	75.0	81.7	87.3
Detah	182	190	150	131	45	45	30	20	11.0	11.6	12.0	7.6	44.4	48.9	60.0	50.0
Fort Liard	530	512	485	395	130	120	115	80	20.8	22.3	30.9	18.7	84.6	95.0	130.4	92.5
Fort Providence	753	748	645	588	165	175	145	130	18.1	23.3	27.6	20.4	82.4	99.4	122.8	92.3
Fort Resolution	525	536	515	447	110	100	120	100	16.8	19.4	29.1	7.2	80.0	104.0	125.0	32.0
Fort Simpson	1,163	1,257	1,142	987	270	325	290	260	15.6	21.6	21.2	28.6	67.4	83.7	83.4	108.5
Fort Smith	2,185	2,441	2,480	2,460	495	610	635	645	14.8	18.4	19.9	20.4	65.5	73.4	77.8	77.8
Hay River	3,510	3,611	3,253	3,006	825	880	840	780	18.2	20.2	23.1	25.3	77.6	82.7	89.3	97.4
Hay River Rsrv	269	253	216	180	50	60	45	45	0.9	0.8	1.9	1.1	5.0	3.3	8.9	4.4
Lutselk'e	248	304	286	273	55	60	70	45	40.3	21.7	32.9	26.4	181.8	110.0	134.3	160.0
Nahanni Butte	107				25				18.7				80.0			
Rae Lakes	274	256	252	183	45	45	55	40	22.6	28.9	22.2	16.4	137.8	164.4	101.8	75.0
Rae-Edzo	1,552	1,662	1,521	1,378	335	380	315	280	30.4	30.8	31.8	25.8	140.9	134.7	153.7	127.1
Wekweti	131	135	127	119	30	30	20	20	18.3	14.8	14.2	23.5	80.0	66.7	90.0	140.0
Wha Ti	453	418	392	345	90	90	65	75	22.5	22.5	31.1	27.8	113.3	104.4	187.7	128.0
Wrigley	165	167	174	161	25	35	40	30	19.4	26.3	21.8	21.1	128.0	125.7	95.0	113.3
Yellowknife	16,541	17,275	15,179	11,753	4,435	4,895	4,550	3,440	16.4	18.7	21.0	21.6	61.1	65.9	70.2	73.9

Notes: 1) Source: Statistics Canada, census data and vital statistics databases, prepared by NWT Bureau of Statistics.
2) Birth and Fertility rates represent the number of births per 1000 population and per 1000 females 15 to 44 respectively. For communities with small populations these rates should be used with caution.
3) Figures for unorganized areas and communities with populations less than 100 are not reported. These figures are included in Regional and Territorial totals.

TABLE 7A.1-4
INFANT MORTALITY PER 1000 LIVE BIRTHS IN NORTHWEST TERRITORIES AND CANADA (1981–2002)

Year	Northwest Territories	Canada
2002	11.0	5.4
2001	4.9	5.2
2000	8.9	5.3
1999	12.1	5.3
1998	17.7	5.3
1997	6.9	5.5
1996	4.9	5.6
1995	9.2	6.1
1994	12.2	6.3
1993	7.2	6.3
1992	10.6	6.1
1991	7.7	6.4
1990	3.4	6.8
1989	8.6	7.1
1988	8.2	7.2
1987	13.1	7.3
1986	12.1	7.9
1985	10.9	8.0
1984	19.2	8.1
1983	19.0	8.5
1982	13.7	9.1
1981	12.7	9.6

Source: Prepared by NWT Bureau of Statistics, November, 2004

TABLE 7A.1-5
LEADING CAUSES OF DEATH PER 10,000 POPULATIONS IN NORTHWEST TERRITORIES (1999-2001)

Cause of Death	**Canada Age-Sex Adjusted**	**NWT 5 Yr. Avg.**	**2001**	**2000**	**1999**
All Causes Total	31.70	37.17	39.54	38.19	39.54
Infectious & Parasitic Diseases	0.53	1.07	0.49	1.71	1.46
Neoplasms	9.62	9.47	8.97	10.53	10.50
Endocrine, Nutritional & Metabolic Diseases & Immunity Disorders	1.21	1.07	1.94	0.49	1.46
Diseases of Blood and Blood Forming Organs	0.12	0.10	-	0.24	-
Mental Disorders	0.75	0.97	1.21	1.47	0.73
Diseases of Nervous System & Sense Organs	1.29	0.97	1.21	0.98	0.49
Diseases of the Circulatory System	9.25	7.91	7.76	6.61	9.52
Diseases of the Respiratory System	2.14	3.50	3.88	3.92	2.44
Diseases of the Digestive System	1.19	1.56	2.91	1.71	0.73
Diseases of the Genito-Urinary System	0.51	0.44	0.49	0.49	0.73
Complications of Pregnancy, Childbirth & the Puerperium	0.01	-	-	-	-
Diseases of the Skin and Subcutaneous Tissue	0.04	-	-	-	-
Diseases of the Musculo-Skeletal System & Connective Tissue	0.19	0.10	0.24	0.24	-
Congenital Anomalies	0.34	0.44	-	-	0.24
Conditions Originating in the Perinatal Period	0.44	0.78	0.49	1.22	1.22
Symptoms, Signs & Ill-Defined Conditions	0.63	1.70	2.43	0.98	1.22
Accidents (Including Suicides)	3.45	7.10	7.52	7.59	8.79
Suicides	1.13	2.09	1.94	1.71	3.66

Notes:
1. For comparability, Canadian death rates by cause were applied to the NWT population on July 1, 2001 to calculate adjusted Canadian rates.
2. The data provided in this table use the ICD-9 classification of cause of death. As of 2000, Statistics Canada began using ICD-10; therefore, to display ICD-10 data in the ICD-9 categories, Diseases of the Nervous System, Diseases of the Eye and Diseases of the Ear were aggregated into Diseases of the Nervous System and Sense Organs. For other differences between ICD-9 and ICD-10, please contact the NWT Bureau of Statistics.

TABLE 7A.1-6
ALCOHOL CONSUMPTION IN THE NORTHWEST TERRITORIES (SOURCE: NWT ALCOHOL AND DRUG SURVEY, 2002)

	Total	%	Current Drinker	%	Former Drinker	%	Never Drank	%
Persons 15 Yrs. & Over	30,431	100.0	23,748	78.0	5,247	17.2	1,295	4.3
Males	15,892	100.0	12,783	80.4	2,555	16.1	461	2.9
Females	14,539	100.0	10,965	75.4	2,692	18.5	834	5.7
15-24	6,413	100.0	5,383	83.9	477	7.4	454	7.1
25-39	11,466	100.0	9,639	84.1	1,588	13.8	223	1.9
40-59	9,602	100.0	7,102	74.0	2,186	22.8	314	3.3
60 Yrs. & Over	2,743	100.0	1,444	52.6	971	35.4	303	11.0
Employed	21,371	100.0	17,345	81.2	3,372	15.8	590	2.8
Not Employed	9,023	100.0	6,365	70.5	1,876	20.8	705	7.8
Less than Grade 9	3,542	100.0	2,101	59.3	1,117	31.5	324	9.1
Grade 9 - 11	7,843	100.0	6,133	78.2	1,288	16.4	370	4.7
High School Diploma	6,147	100.0	4,991	81.2	927	15.1	229	3.7
Trades Cert. Or Diploma	2,258	100.0	1,805	79.9	419	18.6	18	0.8
College Cert. Or Diploma	4,867	100.0	3,945	81.1	686	14.1	188	3.9
University Degree	5,455	100.0	4,599	84.3	690	12.6	166	3.0
Less than $20,000	11,054	100.0	7,881	71.3	2,287	20.7	834	7.5
$20,000 - $39,999	5,838	100.0	4,785	82.0	838	14.4	167	2.9
$40,000 - $59,999	5,257	100.0	4,325	82.3	757	14.4	159	3.0
$60,000 or more	6,594	100.0	5,437	82.5	1,084	16.4	73	1.1
Aboriginal	14,037	100.0	9,880	70.4	3,431	24.4	658	4.7
Males	7,013	100.0	5,122	73.0	1,557	22.2	266	3.8
Females	7,024	100.0	4,758	67.7	1,874	26.7	392	5.6
Non-Aboriginal	16,087	100.0	13,715	85.3	1,713	10.6	611	3.8
Males	8,698	100.0	7,558	86.9	945	10.9	195	2.2
Females	7,389	100.0	6,157	83.3	768	10.4	416	5.6
Yellowknife	13,355	100.0	11,438	85.6	1,406	10.5	495	3.7
Males	6,913	100.0	6,034	87.3	739	10.7	124	1.8
Females	6,442	100.0	5,404	83.9	667	10.4	371	5.8
Aboriginal	2,659	100.0	2,022	76.0	585	22.0	36	1.4
Non-Aboriginal	10,671	100.0	9,416	88.2	797	7.5	458	4.3
Regional Centers	7,335	100.0	5,426	74.0	1,503	20.5	358	4.9
Males	3,863	100.0	2,963	76.7	786	20.3	114	3.0
Females	3,472	100.0	2,463	70.9	717	20.7	244	7.0
Aboriginal	3,467	100.0	2,407	69.4	754	21.7	306	8.8
Non-Aboriginal	3,737	100.0	2,966	79.4	696	18.6	27	0.7
Rest of Communities	9,739	100.0	6,883	70.7	2,338	24.0	441	4.5
Males	5,115	100.0	3,786	74.0	1,030	20.1	222	4.3
Females	4,624	100.0	3,097	67.0	1,308	28.3	219	4.7
Aboriginal	7,912	100.0	5,451	68.9	2,093	26.5	316	4.0
Non-Aboriginal	1,677	100.0	1,332	79.4	220	13.1	125	7.5

TABLE 7A.1-7
PROFILE OF CIGARETTE SMOKERS IN THE NORTHWEST TERRITORIES (SOURCE: NWT ALCOHOL AND DRUG SURVEY, 2002)

	Total	%	Current Smoker	%	Former Smoker	%	Never Smoked	%
Persons 15 Yrs. & Over	30,431	100.0	13,894	45.7	6,302	20.7	10,236	33.6
Males	15,892	100.0	7,342	46.2	3,377	21.2	5,174	32.6
Females	14,539	100.0	6,552	45.1	2,925	20.1	5,062	34.8
15-24	6,413	100.0	3,831	59.7	456	7.1	2,126	33.2
25-39	11,466	100.0	5,349	46.7	1,911	16.7	4,207	36.7
40-59	9,602	100.0	3,732	38.9	2,941	30.6	2,929	30.5
60 Yrs. & Over	2,743	100.0	903	32.9	943	34.4	897	32.7
Employed	21,371	100.0	8,811	41.2	4,767	22.3	7,792	36.5
Not Employed	9,023	100.0	5,069	56.2	1,535	17.0	2,419	26.8
Less than Grade 9	3,542	100.0	1,628	46.0	992	28.0	921	26.0
Grade 9 - 11	7,843	100.0	4,985	63.6	1,249	15.9	1,609	20.5
High School Diploma	6,147	100.0	2,803	45.6	1,137	18.5	2,207	35.9
Trades Cert. Or Diploma	2,258	100.0	1,177	52.1	545	24.1	535	23.7
College Cert. Or Diploma	4,867	100.0	1,929	39.6	946	19.4	1,993	40.9
University Degree	5,455	100.0	1,174	21.5	1,356	24.9	2,926	53.6
Less than $20,000	11,054	100.0	6,342	57.4	1,433	13.0	3,279	29.7
$20,000 - $39,999	5,838	100.0	2,761	47.3	1,304	22.3	1,772	30.4
$40,000 - $59,999	5,257	100.0	2,178	41.4	1,377	26.2	1,702	32.4
$60,000 or more	6,594	100.0	1,827	27.7	1,841	27.9	2,925	44.4
Aboriginal	14,037	100.0	8,504	60.6	2,549	18.2	2,985	21.3
Males	7,013	100.0	4,383	62.5	1,210	17.3	1,421	20.3
Females	7,024	100.0	4,121	58.7	1,339	19.1	1,564	22.3
Non-Aboriginal	16,087	100.0	5,213	32.4	3,674	22.8	7,199	44.8
Males	8,698	100.0	2,858	32.9	2,114	24.3	3,727	42.8
Females	7,389	100.0	2,355	31.9	1,560	21.1	3,472	47.0
Yellowknife	13,355	100.0	4,668	35.0	2,941	22.0	5,748	43.0
Males	6,913	100.0	2,442	35.3	1,447	20.9	3,025	43.8
Females	6,442	100.0	2,226	34.6	1,494	23.2	2,723	42.3
Aboriginal	2,659	100.0	1,356	51.0	576	21.7	728	27.4
Non-Aboriginal	10,671	100.0	3,310	31.0	2,340	21.9	5,020	47.0
Regional Centers	7,335	100.0	3,225	44.0	1,722	23.5	2,388	32.6
Males	3,863	100.0	1,547	40.0	1,128	29.2	1,188	30.8
Females	3,472	100.0	1,678	48.3	594	17.1	1,200	34.6
Aboriginal	3,467	100.0	2,003	57.8	618	17.8	847	24.4
Non-Aboriginal	3,737	100.0	1,197	32.0	1,051	28.1	1,489	39.8
Rest of Communities	9,739	100.0	6,001	61.6	1,639	16.8	2,100	21.6
Males	5,115	100.0	3,353	65.6	802	15.7	961	18.8
Females	4,624	100.0	2,648	57.3	837	18.1	1,139	24.6
Aboriginal	7,912	100.0	5,145	65.0	1,356	17.1	1,410	17.8
Non-Aboriginal	1,677	100.0	705	42.0	283	16.9	689	41.1

TABLE 7A.1-8
EDUCATIONAL ATTAINMENT IN THE NORTHWEST TERRITORIES

	Pop. 15 & Older	%	Males	%	Females	%
All Persons	29,506	100.0	15,541	100.0	13,965	100.0
Less than Grade 9	3,791	12.8	1,915	12.3	1,875	13.4
High School, No Diploma	5,639	19.1	2,942	18.9	2,697	19.3
High School Diploma	5,790	19.6	2,805	18.0	2,985	21.4
Other Certificate or Diploma	9,588	32.5	5,413	34.8	4,175	29.9
University Degree	4,129	14.0	2,127	13.7	2,001	14.3
Not Stated	570	1.9	338	2.2	232	1.7
All Aboriginal	13,507	100.0	6,866	100.0	6,641	100.0
Less than Grade 9	3,453	25.6	1,706	24.8	1,747	26.3
High School, No Diploma	3,919	29.0	2,005	29.2	1,914	28.8
High School Diploma	1,587	11.7	720	10.5	867	13.1
Other Certificate or Diploma	3,918	29.0	2,064	30.1	1,854	27.9
University Degree	237	1.8	128	1.9	109	1.6
Not Stated	392	2.9	242	3.5	150	2.0
All Non-Aboriginal	15,999	100.0	8,675	100.0	7,324	100.0
Less than Grade 9	338	2.1	209	2.4	129	1.8
High School, No Diploma	1,719	10.7	937	10.8	783	10.7
High School Diploma	4,202	26.3	2,085	24.0	2,118	28.9
Other Certificate or Diploma	5,670	35.4	3,349	38.6	2,322	31.7
University Degree	3,891	24.3	1,999	23.0	1,892	25.8
Not Stated	178	1.1	96	1.1	81	1.1

Prepared by NWT Bureau of Statistics, October 1999

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8.0 SOCIO-ECONOMIC AND COMMUNITY WELLNESS

8.1 INTRODUCTION

A "Human Health and Community Wellness" Value Component (VC) was identified in the 2002 and 2005 updated version of the Preliminary State of Knowledge of Valued Components for the NWT Cumulative Impact Monitoring Program (CIMP) Audit. This VC was the least developed of all the VCs, with no definition, no specific indicators and a lack of description as to the scope of the VC. Given the importance of this VC, the audit team separated out the VC into two distinct disciplines, specifically: (1) Human Health and (2) Socio-Economic and Community Wellness. A description and presentation of the former is presented Chapter 7.

Through both research[34] and consultation undertaken during the Audit, the long-term social and economic changes occurring in the NWT are of major concern to the people, particularly Aboriginal people in smaller communities.

While some socio-economic monitoring programs have been implemented as art of existing socio-economic agreements, the NWT CIMP document provides no definition of community well-being and no direction in terms of specific valued components or indicators to assess socio-economics and community well-being. Therefore, a set of VCs and indicators was proposed in the Audit Plan to guide the analysis contained herein. In general, the Socio-Economic and Community Wellness section focuses more on the assessment of what would be considered typical socio-economic measures. VCs were identified with corresponding indicators: economy and employment; population and government capacity; and, community well-being. The VCs and indicators are described in Table 8.1-1.[35]

A particular challenge associated with the Audit and in this area of socio-economics is the question of geographical scale. The aggregation of socio-economic indicator statistics at the NWT level masks the significance of trends at the community level and within the Aboriginal population, where the process of social change is the greatest and where the statistics reveal the highest incidence of social and economic problems. Therefore, the report presents data at the Territorial, region and community level in order to provide greater insight into the unique socio-economic context of the NWT.

[34] See for example, National Roundtable on the Economy and Environment. Aboriginal Communities and Non-Renewable Resource Development. Towards Sustainable Aboriginal Communities – A Vision for 2010-2025.

[35] Based on the work conducted in the Audit a revised set of VCs together with a corresponding set of indicators and a rationale for them is provided at the conclusion of this section.

TABLE 8.1-1
VALUED COMPONENTS AND INDICATORS CONSIDERED IN THE REPORT

Valued Component	Indicators	Rationale
Economy and Employment	• Changes in economic activity • Changes in economic sector composition. • Shift from traditional economy to modern economy • Labour force change • Seasonal versus full time employment • Local versus external employment • Sources of local labour • Migration and in-migration • Inter community migration • Changes in regional wages and salaries • Changes in income distribution • Changes in training programs • Opportunities for local businesses • Creation of local businesses	• It is essential to understand the NWT economy in the last two decades and the changes that have happened to the present time. These changes, particularly since the late 1990's have been profound in the workforce and have had significant effects on the communities and the populations in the last few years. The planning, exploration and development of the diamond mines have lead the way in creating the greatest change, however new mines (not only diamonds), the potential pipeline development and transmission line development are also contributors. These developments will have significant effects on all aspects of the economy and in turn the populace and community well being make these essential indicators to include in this "baseline" data. Sources include census data, monitoring reports undertaken in relation to the diamond mines and other NWT qualitative and quantitative data
Population and Government Capacity	• Population change by community • Changes to public and private sector housing • Housing affordability • Local and territorial government infrastructure capacity	• It is critical to understand the population change over time. Again, the development of the diamond mines has had a great effect on the population and the local capacity in the communities. Internal migration between the small communities has also caused substantial change. Some of this migration has gone from the smaller communities into Yellowknife, which has caused great changes for both the communities and the people themselves. Both housing and municipal services are critical to these communities and families as many have gone from publicly supported housing into privately supplied housing.
Community Well-being	• Existing social patterns - divorce, crime, safety • Current social movements / patterns • Characteristics of the existing and incoming residents • Capabilities of existing social organizations • Attitudes towards development • Major issues facing the population • Impact on women's lifestyles	• In terms of community well-being, all of the previous indicators are critical to the concept of community well being. These indicators demonstrate the effects of all the economic and environmental changes that are faced by the communities in the NWT.

8.2 SELECTION OF SOCIO-ECONOMIC AND COMMUNITY WELLNESS INDICATORS

8.2.1 Overview

Generally, this report incorporates and reports on the indicators used by the Government of the Northwest Territories (GNWT). These include a set of 20 social indicators as well as selected other indicators also tracked by the GNWT.

8.2.2 GNWT Social Indicators

The 20 social indicators were developed by a GNWT interdepartmental working group in response to a 2002 Social Agenda Working Group recommendation regarding the need to identify a set of social indicators that could be used to describe and monitor social conditions in NWT communities. The 20 social indicators were based on the general areas of population health, education, crime and safety, housing, families and children, income and employment and Aboriginal culture. Filters were applied to possible indicators in order to select key indicators. Table 8.2-1 provides an overview of the filters that were used.

TABLE 8.2-1
FILTERS USED TO SELECT SOCIAL INDICATORS

Filter	Description
Availability	Is it currently available or do the data need to be collected?
Frequency	How often is the indicator currently collected?
Time Series	Is there historical information to show change over time?
Geographic detail	Is it available at a territorial level or at a community level?
Responsiveness	Will the indicator change over time?
Variability	Is there extreme variation in the indicator from period to period that makes trend identification difficult?
Outcome Indicator	Outcome indicators are preferred over output, input or other indicators?
Relevance	Is the indicator relevant to social conditions?
Understandability	Is there a reasonable expectation of most being able to understand the indicator?
Reliability	Is the data source reliable, ongoing and free from bias
Comparability	Are there comparable data for other jurisdictions?

Source: NWT Social Indicators Consultation Report (Undated).

After identifying 20 indicators, the working group undertook a consultation process with non-governmental organizations and other levels of government. Following this process, the NWT Bureau of Statistics developed community reports highlighting data for each of the 20 indicators. Where available, the data are presented for 33 communities, the NWT as a whole, NWT smaller communities and Canada. Data sources include various GNWT departments and Statistics Canada. The 20 social indicators and the general area that they address are identified in Table 8.2-2.

TABLE 8.2-2
SOCIAL INDICATORS

Area of Focus	Indicator
Population Health	• Incidence of Heavy Alcohol Use
	• Death Rates From Accidents, Suicides and Homicides
	• Sexually Transmitted Infection Rate (three year average)
Education	• Percentage of Population 15 Years and Older with at Least High School
	• High School Graduation Rate
Crime and Safety	• Violent Crime Rate by Detachment
	• Rate of Juvenile Crime
	• Shelter Admissions
Housing	• Percentage of Households in Core Need
	• Percentage of Households with 6 or More Persons
Families and Children	• Percentage of Lone Parent Families
	• Children Living in Low Income
	• Child Protection Investigations
Income and Employment	• Population Dependency Ratios
	o Less then 15 Years of Age
	o 60 Years of Age and Over
	• Population Mobility
	• Average Employment Income
	• Income Disparity
	o Percentage of Families with Income Less Than $30,000 o Percentage of Families with Income Greater Than $75,000
	• Employment Rate
Aboriginal Culture	• Percentage of Aboriginal People 15 Years and Over Able to Speak an Aboriginal Language
	• Use of Harvested Meat and Fish

Source: NWT Bureau of Statistics http://www.stats.gov.nt.ca/Social/home.html).

The GNWT set of 20 social indicators was selected as the basis of this report for the following reasons:

- The GNWT will be maintaining and publishing data for these indicators, on an annual basis.

- The indicators were the product of a GNWT interdepartmental committee mandated to develop indicators that could be used to track social conditions. Selection of indicators was based on the filters outlined in Table 8.2-1.
- The indicators facilitate review and comparison of data across time and geography. For most of the indicators, data are available by NWT community, NWT district, NWT smaller communities, the entire NWT, and for Canada.

8.2.3 Population and Economic Indicators

In addition to the set of social indicators, specific GNWT population and economic indicators have been selected. These indicators were selected because there are good historical and current data as well as comparable data for Canada and/or other provincial or territorial jurisdictions. In some cases there are not community data but these indicators provide high level information about the NWT as a whole. The indicators selected are shown in Table 8.2-3.

TABLE 8.2-3
DEMOGRAPHIC AND ECONOMIC INDICATORS

Area of Focus	Indicator
Population	• Yearly population estimates
	• Components of population change
	• NWT population growth by age
Economic Indicators	• Gross domestic product
	• Consumer price index

8.3 DATA SOURCES AND PRESENTATION

The main source of data was the NWT Bureau of Statistics. The Bureau collected data for each of the 20 social indicators as well as the population and economic indicators. The Bureau's data for these indicators reflects Statistics Canada data, as well as the results from various surveys conducted by GNWT departments.

In many cases data are presented for the NWT as a whole, NWT regions, NWT smaller communities and by community. The NWT regions and NWT smaller communities are defined below. The definitions of the indicators are taken from the NWT Bureau of Statistics, NWT Social Indicators Consultation Report (undated) and from the NWT Bureau of Statistics website.

8.3.1 NWT Regions

When data are presented by region, the data include the following communities (see Table 8.3-1) unless otherwise specified.

TABLE 8.3-1
NWT REGIONS AND ASSOCIATED COMMUNITIES

Region	Communities	
Beaufort-Delta	• Aklavik • Fort McPherson • Holman • Inuvik	• Paulatuk • Sachs Harbour • Tsiigehtchic • Tuktoyaktuk
Sahtu	• Colville Lake • Fort Good Hope • Tulita	• Déline • Normal Wells
Deh Cho	• Fort Liard • Fort Simpson • Jean Marie River • Trout Lake	• Fort Providence • Hay River Reserve • Nahanni Butte • Wrigley
South Slave	• Enterprise • Fort Smith • Kakisa	• Fort Resolution • Hay River • Lutsel K’e
North Slave	• Dettah • Wekweti • Wha Ti	• Rae Lakes • Rae-Edzo
Yellowknife	• Yellowknife	

8.3.2 NWT Smaller Communities

Whenever data are presented for the NWT smaller communities, the data include the following:

- Aklavik
- Holman
- Paulatuk
- Sachs Harbour
- Tsiigehtchic
- Colville Lake
- Déline
- Fort Good Hope
- Tulita
- Fort Liard
- Hay River Reserve
- Jean Marie River
- Nahanni Butte
- Trout Lake
- Wrigley
- Enterprise
- Fort Resolution
- Kakisa
- Lutsel K'e
- Dettah
- Rae Lakes
- Wekweti
- Wha Ti

8.4 RESULTS – DATA FOR EACH INDICATOR

The following section presents and overviews the data for each indicator. This provides a scan of the NWT as a whole, and in many cases provides comparisons between:

- NWT and Canada
- NWT smaller communities and the NWT as a whole
- NWT communities

This section includes reports for both the 20 social indicators and the population/economic indicators.

8.4.1 Population

This indicator is based on Statistics Canada information. Comparable data are available for provinces and territories across Canada. The data include an adjustment for over and under coverage (i.e., under coverage is the number of people that were missed on the census counts). In the NWT under coverage is approximately 7-10% (Personal Communication, Angela Cocco).

Table 8.4-1 presents the population estimate for the NWT. Data are presented for the 1991 through 2004 period only since Statistics Canada did not produce population estimates for the NWT (separate from Nunavut) earlier than 1991.

TABLE 8.4-1
NWT YEARLY POPULATION ESTIMATES

Year	Persons
1991	38,746
1992	39,431
1993	39,829
1994	40,580
1995	41,427
1996	41,748
1997	41,635
1998	40,816
1999	40,654
2000	40,499
2001	40,822
2002	41,489
2003	42,206
2004	42,810

Source: Statistics Canada (based on data provided by NWT Bureau of Statistics - Personal Communication, Angelo Cocco)

The population of the NWT began to decline in 1997, a trend that continued until 2001. The 2004 population represented an increase of 1.4% compared to 2003.

According to the 2001 Census (see Table 8.4-2), slightly over half of the population is of Aboriginal identity.

TABLE 8.4-2
ABORIGINAL IDENTITY

NWT Total Population	**37,105**
Total Aboriginal Identity	**18,730**
Total Non-Aboriginal Identity	**18,370**

8.4.1.1 Components of Population Change

This indicator is based on the change in total population numbers according to births, deaths and net migration. These statistics are summarized on Table 8.4-3 for the 1992 through 2003 period.

TABLE 8.4-3
COMPARISONS OF BIRTHS, DEATHS AND NET MIGRATIONS

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Births	852	834	824	874	815	723	681	659	673	613	608	610
Deaths	144	143	143	131	152	138	146	162	157	163	171	175
Net Migration	-240	29	145	-370	-566	-793	-1022	-410	-415	38	99	256

Source: Statistics Canada (as recorded in the NWT Bureau of Statistics, 2004 Socio-Economic Scan, Statistical Supplement).

Positive migration occurred in 2001, 2002 and 2003, following several years of negative migration. Since the 2003 birth rate is lower than it was 10 years ago and the death rate is higher than 10 years ago, migration to the NWT is a key factor in population growth.

In the late 1990's there were a number of mine closures or layoffs that may have contributed to the population decline in the NWT. In 1997 Colomac Mine closed while Giant Mine and Miramar Con Mine laid off 40 and 120 workers respectively. As well the GNWT workforce declined in anticipation of creation of Nunavut Territory. By mid-1998 the Ekati mine was in operation with the Con Mine operations resuming in 1999 and the Lupin and Giant Mine operations beginning in 2000. As well, between 1997 and 2000 there were licenses issued for oil and gas explorations (Sahtu, Fort Liard and Beaufort Delta). Diavik mine construction commenced in December 2000 and the mine started production in February 2003 (GNWT, Communities and Diamonds 2003 Annual Report, August 2004).

8.4.1.2 Five Year Population Mobility

Five year population mobility is a measure of the number of people 5 years and older who did not live in the same community 5 years earlier. Of the total number (total migrants) there two sub-sets: internal migrants and external migrants. Internal migrants are those people who moved from somewhere in Canada and external migrants are from outside of Canada. Internal migrants can be further subdivided into: (i) intra-territorial migrants – those people who moved to a different community from within the NWT; and, (ii) inter-provincial migrants – people moved into the NWT from elsewhere in Canada. The statistics for NWT five year population mobility are presented in Table 8.4-4 for 2001. Data for Canada are not available.

TABLE 8.4-4
FIVE YEAR POPULATION MOBILITY

Area	Population Five Years & Older	Total Migrants	Internal Migrants	Intra-Territorial Migrants	Inter-Provincial Migrants	External Migrants
Entire NWT	33,970	8,475	7,950	2,210	5,740	520
NWT Smaller Communities	7,075	945	910	470	440	20
Beaufort Delta	5,620	1,310	1,260	530	735	50
Sahtu	2,120	520	510	195	320	10
North Slave	2,290	230	220	115	105	10
Deh Cho	2,715	450	450	155	280	10
South Slave	6,020	1,375	1,310	515	805	50
Yellowknife	15,205	4,590	4,200	700	3,495	390

Source: Census (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

Of the total migrants who relocated from somewhere in Canada (internal migrants) the vast majority moved to a larger centre or region with larger centres (54% to Yellowknife, 16% to the South Slave, 15% to the Beaufort Delta, and the remaining 14% divided among the Sahtu, Deh Cho, and North Slave). The larger centres in the South Slave and Beaufort Delta that experienced higher in-migration for 2001 are Hay River, Fort Smith, and Inuvik.

Comparing intra-territorial and inter-provincial migrants for the NWT as a whole, there were 2.6 times more people who moved from outside of the NWT than within. The difference is particularly noted for Yellowknife where, of the people who moved there between 1996 and 2001, 83% came from elsewhere in Canada (inter-provincial migrants). In NWT smaller communities as a group, the intra-territorial rate was only slightly greater than the inter-provincial rate.

The diamond industry is likely a factor in Yellowknife's high in-migration rate. In the fall of 1996, construction of the BHP Billiton Ekati Diamond Mine began while construction of the Diavik diamond mine began in December of 2000. Construction of De Beer's Snap Lake project commenced in 2005 (GNWT, Communities and Diamonds 2002 Annual Report, July 2003). Each of these companies has an office in Yellowknife. As well, a number of companies and services have developed to service the diamond industry. For example, in 2002 there were three diamond-cutting factories in Yellowknife.

As large-scale industrial projects continue to be proposed for the NWT in-migration rates will likely rise, and movement from smaller centres to larger ones may increase. Such trends could lead to negative impacts on demographics in the NWT in so far as the Aboriginal – non-Aboriginal balance is concerned. Additionally, increased intra-territorial movement into larger centres could be detrimental to the sustainability of smaller communities needs. Further research and analysis in these areas should be conducted.

8.4.1.3 Population Share by Community Type

This indicator helps assess the degree of urbanization in NWT, based on population comparisons between a) Yellowknife b) Inuvik, Hay River and Fort Smith and c) smaller communities. Population share for each community type is presented as a percentage of total NWT population in Table 8.4-5.

TABLE 8.4-5
PERCENTAGE OF NWT POPULATION – BY COMMUNITY TYPE

	1976	**1981**	**1986**	**1991**	**1996**	**2001**	**2003**
Yellowknife	26.6	31.4	34.7	41.7	43.5	44.3	44.6
Inuvik, Hay River, Fort Smith	30.1	27.5	26.1	24.4	23.6	23.0	22.8
Smaller communities	41.3	41.0	39.2	33.9	32.9	32.7	32.6

Source: Statistics Canada, 2003 NWT Bureau of Statistics Community Population Estimates
(as recorded in the NWT Bureau of Statistics, 2004 Socio-Economic Scan, Statistical Supplement)

Between 1976 and 2003 the population of Yellowknife increased from 26.6% to 44.6% of the total population of the NWT. In the same period, the other community types reported a declining percentage of the total population of the NWT.

As mentioned above, Yellowknife has a low unemployment rate, a high in-migration rate and a corresponding increase in the city's population. This likely reflects the economic opportunities in the city, many of which relate to the diamond industry. The urbanization trend in the NWT may also reflect the global social trend of urbanization.

8.4.2 Population Health

Statistics on incidence of heavy alcohol use, death from accidents, suicides and homicides and rates of sexually transmitted infections are reported in Chapter 9 and thus are not discussed in this chapter.

8.4.3 Education

8.4.3.1 Population 15 Years and Older with at Least High School

This indicator is measured as the percentage of population 15 years of age and over that have a high school diploma or more as their highest level of education. Since 2001, this information has been collected from Statistic Canada's labour force survey. Prior to 2001, the data were from the national census and the NWT Bureau of Statistics community labour force surveys. Comparable data are available for Canada (1991, 1996, 2002), provincial and territorial jurisdictions, and NWT communities. Data for ever third year over the 1989 through 2004 period are provided on Table 8.4-6.

TABLE 8.4-6
PERCENTAGE OF POPULATION 15 YEARS AND OLDER WITH AT LEAST HIGH SCHOOL

Area	1989	1991	1994	1996	1999	2001	2004
Canada		61.8		65.2		68.7	
NWT	59.8	59.9	63.2	63.5	66.1	64.8	67.5
NWT smaller communities	28.2	34.0	32.5	40.0	36.6	38.9	36.8
Beaufort-Delta	50.9	50.9	52.3	56.3	54.5	54.9	55.6
Sahtu	45.3	48.3	50.4	57.1	54.3	55.7	52.1
Deh Cho	37.4	40.7	39.7	47.3	45.3	45.0	46.6
South Slave	57.9	58.8	59.2	61.5	67.3	64.5	67.7
North Slave	20.3	26.6	35.0	29.5	31.0	30.3	35.3
Yellowknife	78.2	73.9	79.0	75.3	80.6	77.7	82.1

Source: 1989, 1994 and 1999 - NWT Labour Force Survey; 2004 - NWT Community Survey; 1991, 1996 and 2001 – Census (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

The percentage (of population 15 years and older with at least high school) for the NWT is quite similar to that for Canada but is almost double the rate of NWT smaller communities. Since 1989, the rate has increased in all regions of the NWT with the highest increases being recorded in the North Slave, South Slave and Deh Cho regions. In 2004, rates of 70% or higher were recorded in Fort Smith, Hay River, Inuit, Norman Wells and Yellowknife while rates of 35 or less were recorded in Colville Lake, Déline, Fort Liard, Holman, Kakisa, Nahanni Butte, Rae Lakes, Trout Lake, Wekweti and Wha Ti.

8.4.3.2 High School Graduation Rate

This indicator measures high school graduates as a percentage of persons 18 years of age. The data are collected from NWT Education, Culture and Employment and from current population estimates are summarized on Table 8.4-7. Data are not presented for communities as students in one community may attend school in another community. Statistics Canada collects comparable data for Canada, although Canadian data are not available for 2001-02 to 2003-04.

TABLE 8.4-7
HIGH SCHOOL GRADUATION RATE (EXPRESSED AS PERCENT)

Area	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
Canada	77.4	76.6	75.9	75.2	76.1	76.6	75.9	na	na	na
NWT	37.5	33.6	37.0	38.8	42.2	38.8	44.6	37.1	43.6	45.3

Source: NWT data – NWT Education, Culture & Employment; Canadian data – Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).
na – not available.

The NWT high school graduation rate was less than half the rate recorded for Canada in 1994-95 through 1996-97 but has been increasing over the years to a rate of 45.3% in 2003-04.

8.4.4 Crime and Safety

8.4.4.1 Violent Crime Rate

This indicator is measured as the number of violent crimes per 1000 persons. The data are available from the Canadian Centre for Justice Statistics and Statistics Canada (see Table 8.4-8). Violent crimes include homicides, attempted murders, assaults (sexual and other), other sexual offences, abductions, and robberies.

TABLE 8.4-8
VIOLENT CRIME RATE BY DETACHMENT (INCIDENCES PER 1000 PEOPLE)

Area	1996	1997	1998	1999	2000	2001	2002	2003
Canada	10.0	9.9	9.8	9.6	9.8	9.9	9.7	9.6
NWT	45.8	53.8	50.9	50.2	49.0	49.0	57.3	67.9
Beaufort-Delta	67.4	80.7	78.5	76.2	70.7	68.5	93.2	102.5
Sahtu	51.7	74.9	70.3	74.6	53.5	52.7	55.7	80.3
Deh Cho	71.7	90.7	101.4	83.1	94.5	75.5	95.2	117.2
South Slave	53.3	55.1	49.3	45.2	45.3	54.6	63.3	75.7
North Slave	47.9	63.2	58.2	50.5	51.6	56.8	76.9	57.9
Yellowknife	29.1	32.2	27.7	32.7	32.6	32.8	31.7	43.9

*Number of reported violent crimes per 1,000 population.
Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

Between 1996 and 2003, the NWT violent crime rate increased by over 20 points while the Canadian rate remained stable. The crime rate in the Beaufort Delta and Deh Cho regions is over 100, more than ten times the Canadian rate. Within each of these two regions, the data increased by 40 points between 1996 and 2003. The communities of Fort Good Hope, Fort Liard, Fort McPherson, Fort Providence, Fort Resolution, Fort Simpson, Paulatuk and Tuktoyaktuk all recorded rates of over 100 in 2003. Yellowknife recorded the lowest community violent crime rate at 43.9 in 2003, increasing from 29.1 in 1996. It is important to note that incidents in a particular detachment may include incidents from surrounding communities.

8.4.4.2 Rate of Juvenile Crime

This indicator is defined as the number of youth charged with a crime per 1000 persons between 12 and 17 years of age. These data are available from the Canadian Center for Justice Statistics at Statistics Canada. Data are available for NWT communities, Canada, and the provinces and territories. Tables 8.4-9 and 8.4-10 provide a summary of the data for males and females respectively. To compensate for data volatility, each year's data represent a three-year average of data (e.g., 2003 data are an average of 2001, 2002 and 2003 figures).

TABLE 8.4-9
RATE OF JUVENILE CRIME (MALES, THREE YEAR AVERAGE)

Community	1998	1999	2000	2001	2002	2003
Canada	76.0	71.5	69.7	68.8	68.3	64.3
NWT	183.1	189.8	181.9	198.3	197.3	211.9
Beaufort-Delta	263.5	317.0	347.3	371.1	348.2	328.1
Sahtu	533.5	498.7	478.6	527.7	463.8	473.0
Deh Cho	236.7	296.2	270.8	277.3	229.7	270.9
South Slave	180.8	138.1	142.7	183.1	221.7	261.1
North Slave	225.1	192.6	45.0	52.9	83.0	195.3
Yellowknife	86.7	98.3	101.4	101.4	101.1	94.8

*Number of male youths (between 12 and 17 years of age) charged with a crime per 1,000 male youth, three year average
Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

TABLE 8.4-10
RATE OF JUVENILE CRIME (FEMALES, THREE YEAR AVERAGE)

Area	1998	1999	2000	2001	2002	2003
Canada	22.7	21.7	21.4	21.5	22.0	20.6
NWT	70.8	68.6	67.6	73.0	79.7	90.7
Beaufort-Delta	137.9	128.8	121.9	144.5	146.2	161.4
Sahtu	82.4	95.6	83.9	127.3	158.6	180.9
Deh Cho	69.4	81.9	86.6	49.3	60.4	86.3
South Slave	102.3	86.1	82.1	89.7	114.2	122.2
North Slave	36.4	30.3	15.5	0.0	4.2	13.8
Yellowknife	31.7	32.5	38.6	40.6	39.0	46.9

*Number of female youths (between 12 and 17 years of age) charged with a crime per 1,000 female youth, three year average
Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

In 2003, the NWT male juvenile crime rate was more than three times the Canadian rate, while the female rate was more than four times comparable data for Canada. Between 1998 and 2003 the juvenile male crime rate in Canada decreased by almost 12 points while the NWT rate increased by 28 points. During the same time period the Canadian female rate decreased by two points while the NWT rate increased by 20 points. In 2003, the Beaufort-Delta and Sahtu regions experienced the highest rates for both juvenile male and female crimes. In the same year, the lowest juvenile male rates were recorded in the Yellowknife region while the lowest female rates were recorded in the North Slave region. In 2003, juvenile male crime rates of over 300 were noted in Fort Good Hope, Fort McPherson, Fort Providence, Fort Simpson, Inuvik, Norman Wells, Tuktoyaktuk, and Tulita. Only Fort Good Hope recorded a female rate of over 300 but the highest female rates occurred in the nearly all the same communities as noted for males.

8.4.4.3 Shelter Admissions

Shelter admissions include the number of women and children admitted to shelters in the NWT. The data are collected by the NWT Department of Health and Social Services and a summary of data is provided in Table 8.4-11. Similar data are not available at the community level, for Canada or other provinces and territories.

TABLE 8.4-11
ADMISSIONS OF WOMEN AND CHILDREN TO NWT SHELTERS

Area	Women				Children			
	1999-00	2000-01	2001-02	2002-03	1999-00	2000-01	2001-02	2002-03
NWT	296	257	295	342	334	364	321	350

*Number of Women and Children admitted to shelters.
Source: NWT Health & Social Services (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

The number of women and children being admitted to shelters in the NWT between 1999-00 and 2002-03 increased by 15.5% while the rate for children increased by 5%.

8.4.5 Housing

8.4.5.1 Percentage of Households in Core Need

This indicator is measured as the percentage of households in core housing need, where need is defined as a household that has a housing problem of suitability, adequacy or affordability and does not have the income necessary to correct the problem. The data are collected through the NWT Housing Needs Survey and the NWT Community Survey. Community data are available and are summarized on Table 8.4-12 on a regional basis. No comparable data are available for Canada or the provinces and other territories.

TABLE 8.4-12
PERCENTAGE OF HOUSEHOLDS IN CORE HOUSING NEED

Area	1996	2000	2004
NWT	19.7	20.3	16.3
NWT smaller communities	48.2	45.0	35.3
Beaufort-Delta	23.7	22.1	22.2
Sahtu	38.1	35.0	28.0
Deh Cho	50.1	35.1	24.9
South Slave	21.2	20.2	14.3
North Slave	61.4	52.6	34.9
Yellowknife	4.7	11.1	9.1

Source: 1996 and 2000 - NWT Housing Needs Survey; 2004 – NWT Community Survey (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

Between 1996 and 2004 there was a 17% decline in the percentage of households that were in core housing need. In 2004, the highest housing need was recorded in the North Slave region although the percentage in this region declined significantly since 1996. With the exception of

Yellowknife, all regions have a rate that is higher than the NWT rate and smaller communities have a higher percentage across all time periods. In 2004, the highest rate was recorded in Colville Lake where 75.8% of households were in core need, although this represented a 15-point decline from 1996. Other communities with percentages of 40 or over in 2004 included Déline, Lutsel K'e, Nahanni Butte and Wrigley. The lowest rates in 2004 were recorded in Norman Wells (8.5%), Yellowknife (9.1%), and Hay River (9.3%).

8.4.5.2 Percentage of Households with Six or More Persons

The data for this indicator are collected through the NWT Housing Needs Survey and the NWT Community Survey and are presented on Table 8.4-13. Crowding is considered to be an issue in NWT households with more than six people.

TABLE 8.4-13
PERCENTAGE OF HOUSEHOLDS WITH SIX OR MORE PERSONS

Area	1981	1986	1991	1996	2001	2004
Canada	5.5	3.9	3.2	3.3	3.1	na
NWT	13.9	11.5	9.8	8.6	7.2	7.0
Smaller NWT Communities	33.7	30.4	23.0	16.1	10.1	12.7
Beaufort-Delta	20.3	16.1	12.3	12.0	9.8	9.3
Sahtu	22.9	25.2	18.4	14.7	12.2	10.2
Deh Cho	28.3	21.9	14.4	9.3	8.3	8.2
South Slave	11.7	9.0	7.1	7.2	5.1	4.9
North Slave	48.6	46.8	39.8	26.7	24.8	22.9
Yellowknife	5.7	4.9	5.4	5.1	4.2	4.0

Source: 1981, 1986, 1991, 1996 and 2001 – Census; 2004 – NWT Community Survey (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004). na = not available.

The percentage of NWT households with six or more persons was more than twice the percentage of Canadian households; however, the gap between Canada and the NWT decreased between 1981 and 2001. NWT smaller communities had a higher percentage of households with six or more people than was recorded for the NWT as a whole. The highest percentage was in the region of North Slave with 22.95% in 2004. The highest percentage was recorded in Wekweti (27.85%) while other communities with percentages of 20 or higher included Colville Lake, Paulatuk, Rae Lakes, Rae-Edzo, and Wha Ti (2004). Lowest rates were reported in Nahanni Butte (2.8%), Fort Resolution (2.9%) and Yellowknife (4%).

8.4.6 Families and Children

8.4.6.1 Lone Parent Families

The percentage of all families that are lone parent families is gathered from the national census and is available for NWT communities, Canada, the provinces and territories. A summary of the data collected for Canada and the NWT is provided in Table 8.4-14.

TABLE 8.4-14
PERCENTAGE OF LONE PARENT FAMILIES

Area	1986	1991	1996	2001
Canada	12.7	13.0	14.5	15.7
NWT	16.3	15.5	16.3	21.0
NWT smaller communities	17.7	18.7	21.4	28.3
Beaufort-Delta	19.9	19.8	22.2	28.9
Sahtu	17.3	19.4	19.1	27.8
Deh Cho	18.9	17.7	16.8	19.5
South Slave	22.9	17.4	17.0	22.7
North Slave	17.6	18.6	17.0	29.8
Yellowknife	12.6	12.2	13.6	15.8

Source: Census (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

In 2001, the percentage of lone parent families was five percentage points higher in the NWT than in Canada, while the NWT smaller communities rate was seven percentage points higher than NWT. The Beaufort-Delta, Sahtu and North Slave regions had the highest rates while Yellowknife had the lowest. Rates for Canada, NWT and NWT smaller communities all increased between 1986 and 2001. The 2001 percentages were highest in Colville Lake and Trout Lake (50%) and the communities of Aklavik, Fort McPherson, Lutsel K'e, Tsiigehtchic and Wha Ti had rates of 35% or higher. The lowest 2001 rates were recorded in Fort Liard (14.3%) and Yellowknife (15.8%).

8.4.6.2 Children Living in Low Income

This indicator measures the percentage of children living in families with income below the after-tax low income measure. This is a measure of relative income, that is 50% of the adjusted media family income, re-calculated annually at a national level and adjusted for different family sizes. Data for Canada and the NWT are summarized in Table 8.4-15.

TABLE 8.4-15
CHILDREN LIVING IN LOW INCOME

Area	1997	1998	1999	2000	2001	2002
Canada	22.8	21.7	21.6	22.3	21.4	22.6
NWT	24.5	23.3	23.9	24.2	20.3	23.0
NWT smaller communities	32.4	29.2	30.5	30.6	26.0	31.2
Beaufort-Delta	32.2	29.8	30.1	31.7	27.4	28.9
Sahtu	23.7	21.3	14.9	13.4	21.2	22.0
Deh Cho	31.3	23.9	26.3	25.0	28.4	23.1
South Slave	24.9	26.6	25.8	23.4	22.8	26.6
North Slave	31.3	30.1	27.3	25.5	25.2	30.7
Yellowknife	16.5	15.0	17.1	16.8	12.2	14.6

Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

From 1997 to 2002, the percentage of children living in low income families was slightly higher in the NWT than in Canada. In the same time period, the NWT smaller communities rate was six to eight percentage points higher than the NWT rate. The highest regional rate was in North Slave. In 2002, the highest community rate was in Paulatuk (42.9%) with the communities of Aklavik, Fort McPherson, Fort Providence and Tuktoyaktuk having rates of 35% or higher. The lowest rates in 2001 were in Norman Wells (10%) and Yellowknife (14.6%).

8.4.6.3 Child Protection Investigations

This indicator is based on the number of reported child investigations as recorded by the NWT Department of Health and Social Services. Data are available annually for the NWT and a summary of this information for the three year period between 2000 and 2003 is presented on Table 8.4-16. There are no community data or comparable data for other parts of Canada.

TABLE 8.4-16
NUMBER OF CHILD PROTECTION INVESTIGATIONS

Area	2000-01	2001-02	2002-03
NWT	2646	2385	2649

Source: NWT Health & Social Services (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

Over the three year periods for which data are presented, the numbers for 2000/01 were very similar to 2002/03 but 2001-02 data approximately 10% lower.

8.4.6.4 Population Dependency Ratios

This indicator is the ratio of the combined child population (aged 0 to 14) and/or the combined population (aged 60 and over) to the working age population (aged 15 to 59). This ratio is presented as the number of dependents for every 100 people in the working age population.

Those who are 60 and over or under 15 are more likely to be dependent on those of working age. As well they may have additional need for health care services.

The data are available annually, for NWT communities and other parts of Canada. Tables 8.4-17 and 8.4-18 summarize the data for i) those less than 15 years of age and ii) those 60 or older respectively.

TABLE 8.4-17
POPULATION DEPENDENCY RATIO (LESS THAN 15 YEARS OF AGE)

AREA	1991	1996	1997	1998	1999	2000	2001	2002	2003	2004
CANADA	32.5	31.8	31.3	30.9	30.4	29.9	29.3	28.8	28.3	27.8
NWT	44.0	42.8	42.1	41.6	40.9	40.3	39.5	38.6	37.5	36.6
BEAUFORT - DELTA	51.2	52.5	51.8	49.7	47.8	46.1	44.7	42.9	42.6	41.0
SAHTU	55.4	56.1	53.8	53.2	52.0	51.6	51.2	49.0	46.5	44.8
DEH CHO	48.6	43.0	43.4	44.0	44.0	43.8	41.7	40.0	39.1	38.5
SOUTH SLAVE	43.8	43.4	44.1	42.3	40.9	40.2	38.6	37.7	36.3	34.9
NORTH SLAVE	67.0	61.6	60.6	60.6	57.5	55.8	54.9	52.3	51.8	52.1
YELLOWKNIFE	36.9	35.5	34.7	34.5	34.6	34.5	34.3	34.1	33.2	32.5

*Number of people less then 15 years old for every 100 people between the ages of 15 and 59
Source: Canadian rates – Statistics Canada; NWT and community rates: NWT Bureau of Statistics (except 1991 – Statistics Canada) (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

TABLE 8.4-18
POPULATION DEPENDENCY RATIO (60 YEARS OF AGE OR OLDER)

Area	1991	1996	1997	1998	1999	2000	2001	2002	2003	2004
Canada	24.7	25.4	25.5	25.6	25.8	25.9	26.1	26.4	26.8	27.1
NWT	7.6	8.2	8.5	8.7	9.0	9.2	9.2	9.6	9.9	10.3
Beaufort -Delta	8.6	10.1	10.7	10.9	11.1	11.1	11.3	11.7	12.4	12.3
Sahtu	11.2	8.8	9.3	10.3	11.0	12.0	12.0	12.8	13.1	12.7
Deh Cho	13.2	13.6	13.9	13.7	14.2	13.7	12.0	12.6	13.4	13.5
South Slave	10.6	13.0	13.8	13.8	13.4	13.7	14.0	14.4	14.6	14.9
North Slave	17.6	14.9	14.2	14.7	15.3	15.2	15.5	15.6	15.3	16.2
Yellowknife	3.6	4.0	4.2	4.4	4.6	5.0	5.2	5.5	5.7	6.3

*Number of people 60 years and older for every 100 people between the ages of 15 and 59
Source: Canadian rates – Statistics Canada; NWT and community rates: NWT Bureau of Statistics (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

The dependency ratio for children 15 years and younger declined between 1991 and 2004 across Canada, the NWT, the NWT smaller communities and all NWT regions. The largest decline was noted in the North Slave region. Conversely, the dependency ratio for those aged 60 years and older increased in the same time period, for Canada, the NWT and NWT communities. The dependency ratio (age 60 and over, 1991-2004) remained fairly stable in the Deh Cho region, decreased in the North Slave region and increased in all others.

In terms of communities, the highest dependency ratio for children was recorded in Colville Lake (67.6 in 2004), with Detah, Tae Lakes, Rae-Edzo, Trout Lake and Tuktoyaktuk reporting ratios of 50 or over. In 2004, the lowest ratios were Fort Smith (31.9), Yellowknife (32.5) and Wekweti (33.0). The highest dependency ratio for adults 60 years and older (2004) was recorded in Tsiigehtchic (31.4) with Aklavik, Colville Lake, Fort McPherson, Fort Resolution, and Wrigley reporting ratios of 20 or over. Lowest ratios were noted in Yellowknife (6.3), Norman Wells (7.0) and Paulatuk (7.5).

8.4.7 Income and Employment

8.4.7.1 Average Employment Income

Average employment income is obtained annually by Statistics Canada, based on taxfiler information. Data for the NWT and Canada are summarized on Table 8.4-19.

TABLE 8.4-19
AVERAGE EMPLOYMENT INCOME

Area	1995	1996	1997	1998	1999	2000	2001	2002
Canada	26,507	26,992	27,969	28,943	29,892	31,426	32,322	32,946
NWT	34,045	33,748	33,364	33,476	35,450	36,187	38,497	41,428
Beaufort-Delta	28,907	27,761	27,099	27,885	29,626	30,326	33,347	34,689
Sahtu	27,626	29,751	28,653	29,764	31,816	32,222	33,885	35,364
Deh Cho	24,450	23,570	23,855	24,317	27,054	26,434	28,035	29,174
South Slave	29,711	28,673	28,978	29,789	32,438	33,309	35,220	37,368
North Slave	17,774	17,399	18,565	18,507	21,032	21,489	24,774	26,703
Yellowknife	40,751	40,118	40,237	40,073	41,870	42,689	45,147	49,172

Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

Between 1995 and 2002, the average employment income in the NWT as a whole was consistently higher than the Canadian rate by between $4500 and $8400, depending on the year. The rates for Canada, the NWT and all regions have increased over the period for which data are presented but the highest increases were noted in the North Slave and Yellowknife regions while the lowest increases were recorded in the Beaufort-Delta and Deh Cho regions.

In 2002, the highest average employment income was recorded in Norman Wells ($55,134) with Yellowknife, Hay River and Inuvik recording averages of $50,000 or more. The lowest average employment incomes was in Wrigley ($21,538) with incomes of under $23,000 being reported in Déline, Fort Providence, Paulatuk, Tsiigehtchic and Wha Ti. In 2002, the NWT smaller communities had an average employment income 41% lower than the rate for the NWT and 27% lower than Canada.

8.4.7.2 Income Disparity

This indicator tracks the percentage of families having less than $30,000 annual income and the percentage of families with more than $75,000 income per year. The data are obtained annually by Statistics Canada, based on taxfiler information. Data for the NWT and Canada are presented on Table 8.4-20 for families making less than $30,000 annually and on Table 8.4-21 for families making more than $75,000 annually.

TABLE 8.4-20
PERCENTAGE OF FAMILIES WITH INCOME LESS THAN $30,000

Area	1994	1995	1996	1997	1998	1999	2000	2001	2002
Canada	32.5	31.7	31.4	30.5	29.0	28.1	26.8	24.3	23.6
NWT	29.1	29.0	29.0	28.5	27.1	26.3	26.2	20.9	19.4
NWT smaller communities	51.1	51.1	51.1	50.7	46.6	42.6	45.8	39.6	40.8
Beaufort-Delta	47.8	48.8	37.9	43.8	39.3	46.1	45.4	38.9	36.8
Sahtu	37.5	46.4	39.3	43.9	42.8	45.3	37.2	31.1	27.7
Deh Cho	47.6	41.5	38.0	40.4	41.1	31.0	36.9	31.3	27.7
South Slave	44.2	43.5	46.1	43.6	47.5	43.0	37.0	31.5	27.5
North Slave	56.9	58.3	57.4	41.9	51.7	45.7	40.9	42.8	36.6
Yellowknife	16.0	16.3	17.5	16.7	16.0	17.4	16.7	12.8	11.4

Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

TABLE 8.4-21
PERCENTAGE OF FAMILIES WITH INCOME GREATER THAN $75,000

Area	1994	1995	1996	1997	1998	1999	2000	2001	2002
Canada	22.7	20.7	21.6	23.1	24.8	26.2	28.9	31.2	33.0
NWT	40.6	38.3	38.0	38.7	38.9	40.6	41.6	47.4	50.4
Beaufort -Delta	27.0	24.7	25.5	23.4	26.1	26.5	28.6	35.4	38.4
Sahtu	25.4	27.1	27.1	23.6	25.5	29.1	33.3	33.9	31.6
Deh Cho	24.3	21.1	17.1	20.3	19.7	22.9	23.9	25.7	30.7
South Slave	32.0	28.8	29.9	29.2	30.9	34.4	35.3	42.8	45.9
North Slave	9.6	7.5	7.3	9.3	8.6	13.3	13.1	23.8	25.0
Yellowknife	57.3	54.0	52.7	53.9	54.2	54.6	55.6	61.0	64.9

Source: Statistics Canada (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

The percentage of NWT families with an annual income of less than $30,000 is lower for the NWT as a whole than for Canada but higher for the NWT communities than both the Canadian and the NWT rate. The rate for the Yellowknife region has been the lowest of all regions since 1994. In 2002, the Yellowknife region rate was half the Canadian rate and almost a quarter of the NWT smaller communities rate. Three regions, the Beaufort-Delta, Sahtu and North Slave, had rates higher than the Canadian rate in 2002. In terms of communities, the lowest rate was recorded in Yellowknife (11.4%) with only four other communities recording less than the NWT rate of 19.4% in 2002, those being Fort Simpson, Fort Smith, Hay River, and Inuvik. The highest rate of incomes less than $30,000 was found in Tsiigehtchic (60%) while rates of 40% or over were found in Holman, Lutsel K'e, Paulatuk, Rae Lakes and Wrigley.

The percentage of NWT families with an annual income greater than $75,000 is higher for the NWT as a whole than for Canada but lower for the NWT smaller communities than both the Canadian and NWT rate. The rate for the Yellowknife region has been the highest of all regions since 1994. In 2002, the Yellowknife region rate was almost double the Canadian rate and almost 30 percentage points higher than the NWT smaller communities rate. Three regions, the Beaufort-Delta, South Slave and Yellowknife, had rates higher than the Canadian rate in 2002. In terms of communities, the highest rate was recorded in Yellowknife (64.9%) with the only other communities recording more than the NWT rate (50.4%) in 2002 being Hay River and Norman Wells. The lowest rate of incomes more than $75,000 was found in Fort Resolution (14.3%) while rates of 20% or less were reported in Fort Good Hope, Tulita and What Ti.

8.4.7.3 Employment Rate

This indicator is measured as the percentage of person 15 years and over that are employed at a job or business. The information is collected by Statistics Canada, the NWT Labour Force Survey and the NWT Community Survey. Data for Canada and the NWT are presented on Table 8.4-22.

TABLE 8.4-22
PERCENTAGE OF PERSONS 15 YEARS AND OVER AND EMPLOYED AT A JOB OR BUSINESS

Area	1986	1989	1991	1994	1996	1999	2001	2004
Canada	59.6	62.1	59.7	58.4	58.5	60.6	61.2	62.4
NWT	66.2	65.0	69.3	65.7	68.2	67.5	69.7	67.8
NWT smaller communities	45.1	37.4	48.2	41.1	50.2	47.1	49.9	47.7
Beaufort-Delta	58.8	56.7	59.0	54.3	59.0	60.1	60.4	59.6
Sahtu	53.8	55.1	54.4	53.4	62.2	62.3	61.4	62.1
Deh Cho	47.9	44.9	54.0	46.3	54.3	52.4	58.1	53.4
South Slave	65.5	60.3	68.3	62.9	66.0	66.2	67.5	64.2
North Slave	31.3	26.6	38.1	30.7	37.4	33.0	45.0	37.3
Yellowknife	83.0	83.3	82.9	81.5	80.0	79.5	80.8	79.7

Source: Statistics Canada (except NWT and community data for 1989, 1994 and 1999 - NWT Labour Force Survey; 2004 - NWT Community Survey) (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

In 2004, the NWT employment rate was just over five percentage points higher than Canada's rate, while the NWT smaller communities rate was 20 percentage points lower than the NWT rate. Employment rates have been slowly increasing since 1986 for all areas indicated in the above table except for South Slave and Yellowknife, where slight drops were noted between 1986 and 2004. The North Slave region had the lowest employment rate of 37.3%, almost 40 points lower than the NWT rate in 2004.

The community of Norman Wells had the highest employment rate (86.4%) followed closely by Yellowknife (79.7%), Inuvik (74.9%), Hay River (69.6%), Enterprise (67.2%) and Fort Simpson (65.2%). Between 1986 and 2004, four communities registered increases of more than 20 points, those being Colville Lake, Lutsel K'e, Tsiigehtchic and Wekweti. Lowest employment rates in 2004 were reported in Wrigley (33.6%), Fort McPherson (34.3%) and Rae-Edzo (34.9%).

8.4.8 NWT Economy

8.4.8.1 Gross Domestic Product (GDP)

Table 8.4-23 presents real GDP at market prices in millions of chained (1997) dollars. Real GDP reflects changes in the quantities of goods and services produced not price changes.

TABLE 8.4-23
GROSS DOMESTIC PRODUCT AT MARKET PRICES, 1999-2003 IN MILLIONS OF CHAINED (1997) DOLLARS

	Canada	NWT
1999	969,740	2,267
2000	1,020,786	2,338
2000 Annual Change (from previous year)	5.3%	3.1%
2001	1,040,388	2,881
2001 Annual Change	1.9%	23.2%
2002	1,074,516	2,997
2002 Annual Change	3.3%	4.0%
2003	1,092,891	3,515
2003 Annual Change	1.7%	10.6%

Source: Statistics Canada (as reported in NWT Bureau of Statistics, Statistics Quarterly Volume 26 No.4 December 2004)

In 2003, the NWT economic growth on a constant dollar basis was 10.6% compared to 1.7% for Canada. The NWT GDP growth in 2003 was largely attributed to mining, oil and gas activity, which experienced a 75.7% increase in GDP. This increase and the 25.0% decrease in GDP for construction can be attributed in large part to the start of operations at Diavik and the completion of construction.

Note: Separate GDP estimates for Nunavut and the Northwest Territories became available from Statistics Canada commencing in 1999.

8.4.8.2 Consumer Price Index

The consumer price index is a measure of the average change in consumer prices over time. Table 8.4-24 compares 'all items data' between Yellowknife and Canada.

TABLE 8.4-24
CONSUMER PRICE INDEX – YELLOWKNIFE AND CANADA
(ALL ITEMS AND PERCENTAGE CHANGE)

	Yellowknife		Canada	
	All Items	% Change from previous year	All Items	% Change from previous year
2004	119.1	0.6	124.6	1.8
2003	118.4	1.8	122.3	2.8
2002	116.3	2.9	119.0	2.2
2001	113.0	1.6	116.4	2.5

Source: Statistics Canada (as reported on the NWT Bureau of Statistics Website http://www.stats.gov.nt.ca/indicators.otp#cpi)

The consumer price index for the NWT increased by 0.6% between 2003 and 2004 while Canada's index changed by 1.8% in the same period.

8.4.9 Aboriginal Culture

8.4.9.1 Aboriginal People 15 Years and Over Able to Speak an Aboriginal Language

This indicator measures the percentage of Aboriginal people 15 years of age and over who are able to conduct a conversation in an Aboriginal language. The data are collected through the community labour force survey and community survey, conducted by the NWT Bureau of Statistics.

TABLE 8.4-25
PERCENTAGE OF ABORIGINAL PEOPLE 15 YEARS AND OVER ABLE TO SPEAK AN ABORIGINAL LANGUAGE

Area	1989	1994	1999	2004
NWT	55.6	50.1	45.1	44.0
NWT smaller communities	73.9	67.2	62.8	61.9
Beaufort-Delta	34.4	28.8	27.5	24.8
Sahtu	85.6	68.3	64.0	58.4
Deh Cho	78.4	70.3	65.0	61.7
South Slave	38.9	37.8	32.3	34.0
North Slave	95.9	95.6	96.4	93.7
Yellowknife	36.6	33.5	21.9	25.3

Source: 1989, 1994 and 1999 - NWT Labour Force Survey; 2004 - NWT Community Survey (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004)

In 2004, the percentage of Aboriginal people able to speak an Aboriginal language was 18 points higher in NWT small communities than in the NWT as a whole. This difference has remained fairly stable since 1989. In terms of regions, the North Slave has a very high percentage (93.7%) of Aboriginal people who can speak an Aboriginal language while the Beaufort-Delta and Yellowknife regions have the lowest (24.8% and 25.3% respectively). The percentage appears to be declining across time in all areas reported in the above table, but the most dramatic decline appears to be in Sahtu where between 1989 and 2004, there was a drop of 27 percentage points. In terms of communities, the highest 2004 rates were in Rae Lakes (98.5%), Wha Ti (96.9%), Wekweti (96.1%), Trout Lake (95.3%) and Déline (95.8%) and Rae-Edzo (93.1%). The lowest rates were in Paulatuk (7.4%), Inuvik (17.6%), and Aklavik (19.3%).

8.4.9.2 Use of Harvested Meat and Fish

This indicator measures the percentage of households that reported most or all of their meat or fish to be harvested in the NWT. The data are collected from the NWT Labour Force Survey and the NWT Community Survey and are summarized on Table 8.4-26 for 1994, 1999 and 2004.

TABLE 8.4-26
USE OF HARVESTED MEAT AND FISH

Area	1994	1999	2004
NWT	15.5	21.3	17.5
NWT smaller communities	36.4	48.7	45.5
Beaufort-Delta	32.8	36.5	32.6
Sahtu	25.3	43.4	32.1
Deh Cho	22.0	27.1	33.0
South Slave	15.8	18.5	15.7
North Slave	15.8	57.6	41.2
Yellowknife	5.9	8.3	5.1

Source: 1994 and 1999 - NWT Labour Force Survey; 2004 - NWT Community Survey (as reported in NWT Bureau of Statistics, Social Indicator Regional Level Data, 2004).

The percentage of households using harvested meat or fish increased between 1994 and 2004 in both the NWT as a whole and in the NWT smaller communities. The region of North Slave showed the greatest increase, rising by 25 percentage points between 1994 and 2004 to 41.2% with a 1999 rate of over 40 points higher than the 1994 rate before declining to the 2004 rate. Turning to communities, the highest 2004 rate of 84.4% was in Colville Lake followed by Kakisa at 76.9% and Trout Lake at 71%. In the same year, the lowest rates were in Yellowknife (5.1%), Enterprise (7.4%) and Hay River (8.6%). Between 1994 and 2004, rate increases of 20 points or more were recorded in Fort Resolution, Hay River Reserve, Kakisa, Nahanni Butte, Rae-Edzo and Wrigley.

8.5 SUMMARY OF THE TRENDS

The population of the NWT has been increasing since 2001, following several years of minor population decline or little growth. This increase is attributed to migration since birth rates decreased and death rates increased between 1992 and 2003. Yellowknife is a key destination for migrants, a trend that is reflected in the increased urbanization rates in the NWT.

The economy of the NWT appears to be strong. The NWT GDP is increasing at a higher rate than that of Canada. The average employment income, the percentage of families with income greater than $75,000 and the percentage of persons 15 years and over who are employed are all greater for the NWT than for Canada.

The measures indicating Aboriginal culture reveal that between 1989 and 2004 there was a significant decline in the percentage of Aboriginal people 15 years and older able to speak an Aboriginal language (almost seven percentage points). However, between 1994 and 2004, there was a slight increase in the use of harvested meat and fish in the NWT.

A number of indicators reveal a higher incidence of social problems in the NWT than in Canada. These include the following:

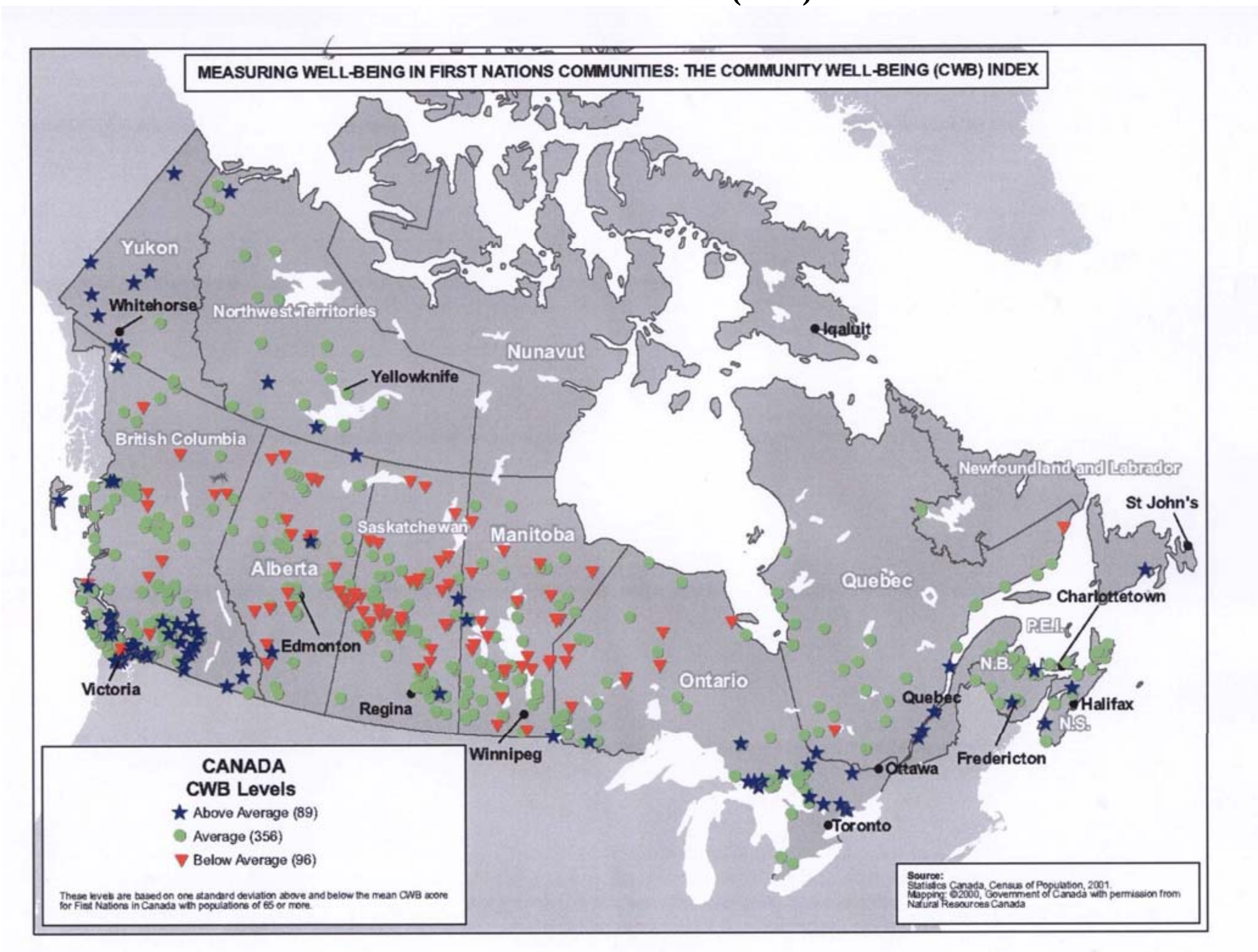
- The NWT violent crime rate is dramatically higher than Canada's. For instance in 2003, the NWT rate was 600% higher than the rate for Canada as a whole.
- In 2003, the NWT three year average rate for juvenile male crime was almost 230% higher than Canada's rate while the NWT three year average rate for juvenile females was 340% higher.
- In 2001, the percentage of households with six or more persons was 3.1 for Canada, 7.2 for the NWT and 10.1 for NWT smaller communities.
- The 2001 percentage of lone parent families was 15.7% for Canada and 21.0% for the NWT.
- Between 1997 and 2002, the percentage of children living in low income in the NWT was quite close to the Canadian rate. However, the NWT smaller communities rates were consistently five to ten percentage points higher than Canada.
- Income disparity in the NWT is also much higher than in Canada – almost 17 points higher in 2002.

In conclusion, the measures indicate that although the NWT population and economy are growing, the social well-being measures indicate higher than national rates of social problems. Most of these problems appear even more pronounced in the NWT smaller communities and are more associated with the Aboriginal population.

Disparities in socio-economic conditions between the Aboriginal and non-Aboriginal populations of Canada are not new and are well documented. These disparities include significant differences in educational attainment, employment, income, housing, levels of social assistance, rates of incarceration and substance abuse, etc. (Armstrong, 1999, Kendall, 2001). The causal factors of socio-economic underdevelopment are numerous, complex and debated. Factors cited by various parties include unemployment, location, culture, loss of land and resources, cultural genocide, job market discrimination and lack of self-determination (Kendall, 2001). Furthermore, there is likely significant regional variation in the level and pattern of underdevelopment and the factors behind it in Canada.

While no comparative analysis was conducted with the Aboriginal population in other parts of country, research work on socio-economic well-being in First Nations communities across Canada does offer some insight. A Community Well Being Index which combines several key indicators of socio-economic well-being into a single score has been developed by INAC (O'Sullivan and McHardy, 2004). The index consists of four equally weighted components including education, labour force, income and housing. As shown in Figure 8.5-1, all of the NWT First Nations communities scored average or above average in comparison to First Nations communities across Canada. While this index should only be considered as one possible measure of community well-being it does provide some sense of comparative analysis.

FIGURE 8.5-1
COMMUNITY WELL-BEING INDEX LEVELS FOR FIRST NATIONS COMMUNITIES ACROSS CANADA (2001)



8.6 VALUED COMPONENTS AND FUTURE DIRECTION FOR CIMP

The MVRMA is clearly intended to address potential impacts to both the bio-physical and human environments, as indicated in the following definition provided in Section 111:

> *"impact on the environment" means any effect on land, water, air or any other component of the environment, as well as on wildlife harvesting, and <u>includes any effect on the social and cultural environment or on heritage resources.</u>*

The CIMP Working Group has incorporated this definition into the Five-Year Work Plan and, as such, will consider the unique social and cultural realities of the NWT. This approach is consistent with messages heard throughout the Audit process; specifically the need for greater emphasis on the evaluation and, in particular, the mitigation of adverse social and cultural impacts experienced by Aboriginal communities.

The attention and resources allocated by the CIMP to the collection of social and cultural information must be commensurate with the level of concern Aboriginal communities have with respect to how they are being impacted. By doing so, the CIMP should assist other components of the environmental management regime to better incorporate the "human component" into their decision-making.

At the heart of the matter respecting 'community well-being' is that CIMP has not yet identified a definition of community well-being.[36] While a draft set of valued components and indicators was developed for the purposes of the Audit, the indicators selected may not be agreed to by residents of the NWT or the major stakeholders in CIMP.

Community wellness is a term that has been created in order to assess the overall health of a community. However, what is and what is not a healthy community can vary depending on the values espoused and the objectives of an individual community. For example, for a community that wishes to produce a more traditional lifestyle, lower incomes and a high rate of unemployment or underemployment (as traditionally measured) may not necessarily be viewed as negative indicators. For other communities, low incomes and a high rate of unemployment may send off alarm bells of what needs to be fixed. Different cultures generate different moralities and values, undoubtedly containing many overlapping features but often specifying different virtues and conceptions of good. The different values espoused by communities are neither right nor wrong but rather simply exist as is. Therefore the most important element of

[36] In order to understand community wellness it is important to define what is a "community" for the purposes of analysis. The most comprehensive source of social and economic data is the Census. The Census is organized in a geographical hierarchy that allows analysis down to a low level of geography (e.g., dissemination areas, communities, etc.). It is suggest that future analysis of community wellness occur at three different levels – the NWT, First Nations territories and individual communities.

trying to determine community wellness is for communities to decide what values are important to them and to then benchmark/monitor actual socio-economic performance against these values. A broad range of VCs and indicators can be selected in order to capture the range of conceptions of community wellness within the diverse cultures of the NWT.

The current CIMP document for the Valued Component Human Health and Community Wellness identified the following Gaps and Recommendations. As an Audit team we have prepared a response to each of these.

Gaps	**NWT Audit Team Response**
Is the purpose of the NWT CIMP simply to monitor change or are there specifically identified goals that we are trying to achieve?	The purpose of CIMP with respect to Community Wellness should be to monitor change with respect to a series of clear goals in mind.
Need to understand the scope and parameters of the data to be collected.	There is already a significant number of social measures available and studies completed. Development of clear goals for gaps in the existing work will provide direction for this gap.
Need to re-structure the approach so that human health and community wellness indicators are separated. This will permit the relevant parties to more effectively identify key indicators.	Concur
Recommendations	
Separate Human Health and Community Wellness. Establish two distinct sub-committees to focus on separate substantive areas for monitoring within the NWT CIMP.	Concur
Implement a workplan that works towards identification of key indicators (at least conceptually) within each area: Human Health and Community Wellness.	Concur
Once each sub-committee identifies their key indicators, have a joint meeting to identify overlaps, if any, to ensure efficiency and effectiveness of subsequent data gathering.	Concur

The above set of gaps and recommendations needs to be completed as soon as possible.

Outlined in Table 8.6-1 is a list of valued components and indicators, which can be used as the basis for more direction in the CIMP program. The VCs and indicators of social and economic well-being (e.g., income, education, crime) are based on professional opinion and consultation undertaken during the Audit. None of the VCs are weighted in terms of their overall importance to community wellness, but it is suggested that concerns about social problems and the preservation of Aboriginal culture should receive the foremost attention.

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TABLE 8.6-1
VALUED COMPONENTS, INDICATORS, RATIONALE AND STATUS OF KNOWLEDGE/GAPS/CHALLENGES

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
Economy, Employment and Income	GNP and Gross Regional/Local Income Changes in economic sector composition. Percent of income derived from traditional economic activities (e.g., trapping or fishing). Traditional versus modern economy. Population dependency ratios. Average income Income by source (employment, transfer payment, other) Labour force change Unemployment Rate Seasonal versus full time employment Local versus external employment Income Disparity Changes and Opportunities for local businesses. Community Well-Being Index for First Nations	Most of these economic indicators are standard measures that are either directly available or derivable from the census. Economic measures such as income and employment rate and income disparity demonstrate the community's ability to be self-reliant and have the financial resources to pursue individual and community level objectives. Community well-being index which combines several potential VCs should be a useful comparative tool with Aboriginal communities across the country.	State of Knowledge: The government of the NWT analyzes a significant amount of data on the economy, and employment at income various geographical levels. The Strategic Research and Analysis Directorate of INAC has developed a community well-being index and has assessed all First Nation communities across Canada. Gaps: A full understanding of the shift from traditional economy to modern economy is not well known. Assessing local business changes may require individual surveys. Challenges: Traditional activities supported communities prior to the wage economy, but many of these activities lack an economic

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
			valuation (e.g., hunting for food) and therefore standard economic measures to not provide a full picture of the importance of traditional activities. Census data in small communities may be limited due to response rates and release of data by Statistics Canada.
Population	Population change Population Mobility – Intra-Territorial and Inter-Provincial	Population and population change are critical socio-economic indicators for a variety of reasons. Population mobility helps to identify the significance of the "transient" population.	State of Knowledge: Population and population mobility data is readily available. Gaps: Census data provides the data but does not identify the reasons for population change and migration. This requires expert analysis and community input. Challenges: Population data earlier than 1991 is not separate from Nunavut making historical analysis more difficult. Census data in small communities may be limited due to response rates and release of data by Statistics Canada.

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
Families and Children	Shelter admissions Number of lone parent Families Income of females Children Living in Lone Income Child protection investigations. Changes in women's lifestyles.	Shelter admissions and child protection investigations are an important indicator of family breakdown and impacts on women and children. Number of lone parent families are an important indicator of family breakdowns and need for social support. Income of females may provide an indication of independence.	State of Knowledge: Most of these indicators of family and children are tracked at various levels of geography in the Census and by the GNWT. Gaps: Changes in women's lifestyles because of increased levels of development requires more investigation. Census data is of some but limited use in this area. Challenges: Census data in small communities may be limited due to response rates and release of data by Statistics Canada.
Aboriginal Culture	Percent of Aboriginal People Able to Speak an Aboriginal Language. Percent of Aboriginal People who Speak an Aboriginal Language at Home. Use of harvested meat and fish. Percent of diet provided by country foods. Percent of the population that hunts, fishes and traps for sustenance. Percent of the population that	Ability and use of Aboriginal languages are powerful indicators of culture being perpetuated. Use and composition of diet is an important indicator in change to lifestyles. Changes in cultural practices may also provide an indication of culture preservation.	State of Knowledge: Census provides excellent data on use of Aboriginal languages. GNWT provides some data on use of harvested meat and fish. Gaps: Changes in cultural practices are not addressed. Challenges: Need to define and develop

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
	hunts, fishes and traps for sport/leisure. Changes in cultural practices. Religious practice by denomination (e.g., aboriginal spirituality as per census).		methodology as to changes in Aboriginal cultural practices. Census data in small communities may be limited due to response rates and release of data by Statistics Canada.
Housing	Percentage of Households in Core need Percentage of Households with 6 or more persons. Housing affordability	Households in core need is fairly indicative of the need for suitable, adequate and affordable housing. Housing affordability is an important indicator of housing cost relative to income.	State of Knowledge: Housing statistics are readily available. Gaps: None Challenges: Census data in small communities may be limited due to response rates and release of data by Statistics Canada.
Crime and Safety	Violent Crime Rate by Detachment Rate of Junvenile Crime Shelter Admissions.	These are all important measures of crime and safety in communities.	State of Knowledge: Data is generally available. Gaps: None Challenges: Census data in small communities may be limited due to response rates and release of data by Statistics Canada. Interpretation as to factors behind

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
			high rates of crime in particular communities in NWT needs to be assessed.
Education	Percentage of population with at least high school. Percentage of population with some post-secondary training or education. Availability and change in training programs	Educational attainment is an important indicator of the ability to function in society and the economy.	State of Knowledge: Education is well researched in the census. Gaps: Availability of training programs in communities is not specifically tracked but data should be available. Challenges: Census data in small communities may be limited due to response rates and release of data by Statistics Canada.
Community	Crime Rates Capabilities of existing social organizations Population Dependency Ratios Income Disparity Attitudes towards development. Community infrastructure and services (e.g., local health clinic, sanitation) Public involvement in decisions affecting community, land and resource base.	Crime rates are important indicators of social deviance and social problems. Population dependency ratios are a good indicator of the sustainability of the good community in terms of working population to non-working population. Income disparity is an important indicator of differential incomes at the community level.	State of Knowledge: Crime rate, population dependency and income disparity are tracked by the census. Gaps: Attitudunal work is non-existent except in specific projects. Challenges: Census data in small communities may be limited due to response

Potential Valued Components	Potential Indicators of Valued Components	Rationale	State of Knowledge/Gaps/Challenges
		Presence of community infrastructure is an indicator of community investment and the prevalence of basic services. Degree of public involvement provides an indication of how the public feels it can impact decisions.	rates and release of data by Statistics Canada. Attitudunal and degree of public involvement require qualitative analysis.

It is our conclusion that the Gaps and Recommendations section of the Human Health and Community Wellness section of the CIMP document focuses primarily on process and provides little direction on the major social questions facing the NWT. Throughout the Audit the team heard major concerns about the impacts of development on the way of life of the NWT's Aboriginal peoples. In many places, the loss of traditional way of life and the social impacts of development outweighed the concerns on the natural environment. The high incidence of social problems in the NWT, particularly in smaller communities and associated with the Aboriginal population are a testament to the challenges being faced by the Aboriginal community.

The NWT is experiencing significant development pressure on lands and resources that is largely borne on the Aboriginal population that lives closest to the land and relies on these natural resources. It should therefore not be surprising that Aboriginal peoples may be sceptical about the benefits and impacts of development and/or outright opposed to it.

Given this context there is an urgent need to better understand how Aboriginal communities are changing. More specifically, does further development of the NWT lead to an increased social erosion of Aboriginal values and culture and a higher incidence of social problems? And if so can some impacts be mitigated and how?

The Government of Canada has indicated that there are broad national interests in resource development in the NWT. At the same time Aboriginal communities will use the regulatory process to slow down and/or stop resource development because of real or perceived impacts on their communities, way-of-life and peoples. If there is a desire for resource development to occur and do this in a way that allows for Aboriginal communities to develop in the way they desire, it is critical to better understand how development impacts and changes them.

While the socio-economic data presented in the Environmental Trends report does provide a clear indication of social problems and a window into change in Aboriginal culture and lifestyle there is a need to better understand the problems at a community level. Specifically, it is critical to more clearly elaborate on the socio-economic changes occurring and the causation factors behind those changes.

More specifically it would be useful for CIMP to establish long-term monitoring programs to evaluate social changes in Aboriginal communities in the NWT and benchmark/evaluate these against development pressures. Useful indicators would include measures of:

- Use of Aboriginal languages;
- Changes in Aboriginal cultural practices;
- Changes in quantity and quality of trapping, fishing, hunting and gathering activities;

- Changes to traditional and non-traditional economy;
- Changes in family, clan and community structure; and,
- Changes in social problems (list out key social indicators).

These studies should occur in each of the First Nations territories of the NWT in order to provide insight into unique cultural differences and practices.

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