

Research Needs Survey

Online Survey Results

CANADIAN CLIMATE IMPACTS AND ADAPTATION RESEARCH NETWORK *NORTH REGION*

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Prepared by
Claire Eamer, C-CIARN Yukon Coordinator
Northern Climate ExChange
Northern Research Institute, Yukon College
Box 2799, 500 College Drive
Whitehorse, Yukon, Canada Y1A 5K4

Research Needs Survey, Online Survey Results

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Introduction

The C-CIARN North Online Research Needs Survey was administered through the C-CIARN North website in the first part of 2003, closing in early October. The purpose of the survey is to help develop a broad sense of the research needs related to climate change impacts and adaptation in Canada's North. The Online Survey is part of a larger C-CIARN North initiative that involves community-based surveys in each of the three northern territories, a literature review of existing expressions of research needs, and a number of other methods such as topic-focused online workshops.

The Online Survey is based closely on the Northern Climate ExChange Gap Analysis Project, which reviewed the state of knowledge regarding climate change in the North according to 16 natural and human systems. For purposes of assessment, each system was subdivided into a number of aspects. For each aspect, the Gap Analysis Project assessed the state of baseline knowledge (both knowledge of the system before climate change and knowledge about the fundamental mechanisms operating in the system) and the state of knowledge about several different impacts (temperature change, precipitation change, other and indirect impacts) of climate change. Recognizing that a knowledge gap is not necessarily an important knowledge need, C-CIARN North then undertook the next step – to ask where, in light of the current state of knowledge, it is most important to focus research time and resources in the near future.

The survey is complex and was aimed primarily at researchers, managers, and policy makers. Respondents were given a brief indication of the state of knowledge in the various aspects of the systems and asked to rate the importance of improving that state of knowledge. They were also asked to rate the importance of learning more about sample impacts and to suggest other potential impacts that require research. Respondents were not asked to fill out the whole survey, but only those systems that interested them or that they felt competent to discuss.

Please note that the NCE Gap Analysis Project Summary Report, along with a CD containing component reports, is available from the Northern Climate ExChange, Northern Research Institute, Yukon College, P.O. Box 2799, 500 College Drive, Whitehorse, Yukon, Y1A 5K4, or online at <http://yukon.taiga.net/knowledge/gap.html>.

Participant Information

Number of respondents:	88
Substantive responses:	74
Personal information only:	14 *

** One requested that the online survey be emailed to him for later return. A second requested the community version of the survey. A third said she felt her residence outside the region made it inappropriate for her to contribute a response.*

Participants by Geography

The geographical distribution of respondents to the survey reflects, to some degree, the manner in which it was advertised (see Table 1). It was flagged on the C-CIARN North website and promoted heavily through the C-CIARN North newsgroup on the Canadian Polar Commission's web service. At the time of the online survey, this newsgroup reached 120 subscribers, most of them members of the C-CIARN's national roster and many of them government or academic researchers resident outside the North. Many, of course, are based in Ottawa, a fact reflected in the relatively high representation from Ontario. The survey was also promoted through personal email contact by C-CIARN North coordinators (particularly the Yukon coordinator, which explains

the large Yukon representation). Despite the fact that the online survey was promoted nationally and aimed at pulling in researchers and policy makers who are often not resident in the North, the proportion of northern respondents is reasonably high at 47.4%.

Table 1

<i>Location</i>	<i>Number</i>	<i>% of Total</i>
Northwest Territories	5	5.7
Nunavut	5	5.7
Yukon	31	35.0
Alberta	5	5.7
British Columbia	2	2.3
Manitoba	3	3.4
New Brunswick	1	1.1
Nova Scotia	2	2.3
Ontario	17	19.3
Québec	8	9.1
Saskatchewan	5	5.7
Alaska	1	1.1
Texas	1	1.1
Unknown (US)	1	1.1

Participants by Category

Participants were encouraged to identify as many categories as they deemed appropriate, some identifying as many as four categories that they felt described their interest in climate change research. As a result the numbers in Table 2 represent considerable duplication, such as those who identified themselves as both academics and researchers or both government employees and researchers. Nevertheless, it is clear that a substantial proportion of the respondents are engaged in research, either through academic institutions or government. The private sector is less strongly represented, which indicates a need to come up with new approaches to engage its interest. While aboriginal governments and institutions are fairly lightly represented here, the community-based surveys do much to redress that balance.

Table 2

<i>Category</i>	<i>Number</i>	<i>% of Total</i>
Researcher	46	52.3
Fed/Terr/Prov government	41	46.6
Academic	33	37.5
Individual	15	17.0
Non-government organization	9	10.2
Municipal government	6	6.8
Private sector	6	6.8
Researcher and stakeholder	5	5.7
Stakeholder	4	4.5
Aboriginal government	2	2.3
Co-management agency	2	2.3
Environmental educator	1	1.1
Land claim organization	1	1.1
Project manager	1	1.1
Technical publisher	1	1.1

Participant Concerns by System

Participants were asked to identify which of the 16 natural and human systems interest them. Responses ranged in number from one system to all (see Table 3). The strongest interest was in the Boreal, Fresh Water, and Tundra systems. Among human systems, the strongest interest was in Energy, Infrastructure, and Transportation – areas in which impacts and mitigation are already current topics. It is worthwhile noting that, although many of the respondents to this survey live outside the North and are engaged in research into natural rather than human systems, more than a third of respondents identified Community Health as an interest, indicating a strong sense of the relationship between the environment and the health of northerners and northern communities.

Table 3

<i>System</i>	<i>Number</i>	<i>% of Total</i>
Boreal	50	56.8
Tundra	48	54.5
Fresh Water	45	51.1
Energy	36	40.9
Infrastructure	35	39.8
Transportation	35	39.8
Marine	30	34.1
Fisheries	30	34.1
Forestry	30	34.1
Community Health	30	34.1
Coast	29	32.9
Mining	28	31.8
Waste management	28	31.8
Hunting & Trapping	27	30.7
Tourism	25	28.4
Agriculture	14	15.1

Respondents by System

Not all participants who expressed an interest in a system went on to fill out the survey for that system. This is understandable, in that most people have a broader interest than their immediate area of expertise. This also probably reflects the relative complexity of the survey, which demanded a level of familiarity with the system and an investment of time to complete each system survey.

The heaviest participation in the survey was in the three predominantly land-based natural systems – Boreal, Fresh Water, and Tundra. There was less participation in the Coastal and Marine systems, possibly reflecting, at least in part, the Yukon bias among northern participants. Among the human systems, the heaviest participation was in Infrastructure, Transportation, and Energy – sectors that tend to be the responsibility of more senior levels of government. The sectors most closely tied to community life and the community level of economy and governance, such as Community Health, Hunting & Trapping, and Tourism, are lightly represented in this survey.

Table 4 shows a summary of actual survey response, by system.

Table 4

<i>System</i>	<i>Respondents</i>
Boreal	38
Fresh Water	25
Tundra	23
Infrastructure	20
Transportation	17

<i>System</i>	<i>Respondents</i>
Energy	15
Marine	14
Mining	12
Waste Management	12
Coast	11
Forestry	9
Community Health	9
Fisheries	6
Agriculture	5
Tourism	5
Hunting & Trapping	5

Report Structure and Approach

Structure of Report

The structure of the survey itself was based on the NCE Gap Analysis Project, which looked at the state of knowledge in 16 different systems under the following categories: Baseline Knowledge, Impacts of Temperature Changes, Impacts of Precipitation Changes, Other Climate & Indirect Impacts. (See the Matrix Maker, <http://yukon.taiga.net/matrix/>, for detailed results.) To avoid excessive complexity, we combined the latter three categories under the broader heading of Impacts of Climate Change and provided respondents with a range of ratings for the current state of knowledge, reflective of ratings in the original three subdivisions. For each aspect of the various systems, we provided a sample impact with a view to stimulating thought about specific results of climate change.

Respondents were told the current state of knowledge about both baseline information and the impacts of climate change for various aspects of the system, as reported in the NCE Gap Analysis Project (NCE, 2002), and asked to rate the importance (high, medium, or low) of further research in that aspect. A broadly applicable potential issue was identified for each aspect, and respondents were asked to rate the importance of further research on that issue. Respondents were then asked to add any issues they consider particularly important.

In reviewing the survey results, it is important to keep in mind that the number of respondents varies widely from system to system. The most substantive responses came in the natural systems with the broadest application across the North (Boreal, Fresh Water, and Tundra) and in the human systems that tend to be the responsibility of higher levels of government (Infrastructure, Transportation, and Energy). Other systems of more clearly local interest – such as agriculture, fisheries, and hunting and trapping – drew much lighter response.

Survey responses for each of the 16 systems are analyzed separately in the following pages. Each analysis begins with a summary of survey responses and a numerical rating of survey responses that serves as a quick guide to the relative importance respondents placed on various potential research needs within the system. Following the numerical rating is a table with a detailed overview of responses to the system survey. Another table provides a selection of respondents' comments on the sample issues provided in the survey.

Special Notes

Numerical Tables

Purely for purposes of comparison, the Low, Medium, and High ratings in each system have been assigned a numerical value in order to calculate an overall rating for each category of research within the system.

Please Note: This assessment is significant only as a method of comparing values within each of the 16 systems composing the survey; it has no validity outside the individual system. In addition, this rating is not adjusted to reflect the actual number of respondents within the system. Therefore, a rating of 55 in the Tundra system reflects the input of up to 22 individuals. The same rating in the Agriculture system reflects the input of up to 5 individuals.

Ratings are assigned the following values:

- Low = 25
- Medium = 50
- High = 75

Method: The numbers of lows, mediums, and highs for each category were added, and then divided by the total number of votes in that category, providing an average rating out of a possible total of 75. Ratings above 60 have been highlighted in the tables.

Other Issues

The final table in each section contains a listing of other issues raised by respondents. Since these issues often reflect the individual respondent's areas of interest and expertise, the table contains a column showing how respondents identified themselves and their roles – for example, researcher and academic, municipal government, or aboriginal government. For the sake of space, the categories have been assigned identifying letters as set out in the following listing:

Key to Respondent Categories

- a. Aboriginal government
- b. Academic
- c. Co-management agency
- d. Environmental educator
- e. Fed/Terr/Prov government
- f. Individual
- g. Land claim organization
- h. Municipal government
- i. Non-government organization
- j. Private sector
- k. Project manager
- l. Researcher
- m. Researcher/stakeholder
- n. Stakeholder
- o. Technical publisher

1. The Boreal System

Fifty (57% of total) respondents indicated an interest in the boreal system. Of those, 38 filled out some or all of the boreal system survey sheet.

All responses to the boreal system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Boreal System Survey Responses

Distribution

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “high” or “medium” by 25 of 32 respondents.
- *Knowledge about impacts of climate change: fair to very poor.* Need for research rated “high” or “medium” by 30 of 32 respondents.

Sample issue:

- *Northward expansion of the boreal system:* Need for research rated “medium” by 18 respondents; remainder split between “high” and “low”. Comments mentioned potential impact on the broader ecosystem.

Vegetation

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by two-thirds of respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by almost all respondents.

Sample issue:

- *The increasing risk of forest fire:* Need for research rated “high” by 17 of 29 respondents; only 4 rated it “low”. Comments cited threat to life and property, impact on forest regeneration and wildlife habitat.

Mammals

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by two-thirds of 30 respondents; 8 rated it “high.”
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “medium” by just over half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Species shifts due to changing habitat:* Need for research rated “high” or “medium” by all respondents. Comments cited the impact on country foods, animal health, and the ability of animals to adapt.

Birds (species, ranges, habitat health, migration patterns, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by most respondents.
- *Knowledge of the impacts of climate change: poor to very poor.* Need for research rated “medium” by more than half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Potential introduction of new bird species or a new mix of bird species into the boreal system:* Need for research rated “medium” by more than half; only 3 rated it “low”. Comments referred to potential for disease dissemination, and that range fluctuations are normal.

Terrestrial Invertebrates (insects, spiders, bugs, etc.)

Baseline and impacts research:

- *Baseline knowledge: poor.*
- *Knowledge of the impacts of climate change: poor.* Need for research rated “medium” for both baseline knowledge and climate change impacts by about half; remainder split between “high” and “low”.

Sample issue:

- *Possible appearance of new kinds of insect pest:*. Need for research rated “high” or “medium” by almost all respondents. Related issues cited include impact of forest pests, impact of parasites and insects on wildlife, and potential of invertebrates as indicators of climate change.

Carbon Cycling (effect of system on greenhouse gas levels)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by most respondents.
- *Knowledge about the impact of climate change: fair to very poor.* Need for research rated “high” or “medium” by most respondents.

Sample issue:

- *Increasing numbers of trees might store more carbon dioxide, one of the primary greenhouse gases:* Need for research rated “high” or “medium” by majority respondents. Comments cited lack of understanding of carbon cycle related to specific boreal tree species and their possible responses to climate change.

Water and Nutrient Cycling (how water & nutrients circulate in system)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by 11 respondents, with remaining 14 split between “high” and “low”.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by most respondents.

Sample issue:

- *Warmer water could affect some aquatic species:* Need for research rated “medium” by more than half; remainder split between “high” and “low”. Comments refer to broader issues of water in the ecosystems.

Permafrost and Land Stability (melting permafrost, landslides, erosion)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “high” or “medium” by most respondents.
- *Knowledge of the impacts of climate change: good to very poor.* Need for research rated “high” or “medium” by most respondents.

Sample issue:

- *Increased risk of landslides and slumpage:* Need for research rated “high” or “medium” by majority. Comments cited potential impacts of landslides and slumpage on human infrastructure, vegetation, water courses, and other aspects of physical environment.

Other Issues

- Potential vulnerability of several specific populations of trees adapted to current climate conditions
- Climate change impacts on terrain and relationship to land use planning
- Potential impacts of changes in the water cycle and changes in oceanic temperature oscillations
- Feedbacks and linked impacts within the boreal ecosystem
- Impacts of changes on human society, particularly aboriginal communities

Numerical Rating of Research Needs

Boreal System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Distribution	52	59	48
Vegetation	50	58	65
Mammals	55	52	59
Birds	49	50	53
Terrestrial Invertebrates	48	49	56
Carbon Cycling	52	54	52
Water and Nutrient Cycling	50	59	51
Permafrost and Land Stability	53	58	58

Detailed Overview of Responses

Aspect of the Boreal Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Distribution (portion of North covered by boreal ecosystem)	Good	High: 10 Medium: 15 Low: 7	Fair to Very Poor	High: 14 Medium: 16 Low: 2	Northward expansion of boreal system	High: 6 Medium: 18 Low: 8
Vegetation (kinds, health, and distribution of plant life)	Good	High: 6 Medium: 18 Low: 6	Fair to Poor	High: 11 Medium: 18 Low: 1	Increasing risk of forest fires	High: 17 Medium: 8 Low: 4
Mammals (species, ranges, habitat health, mix of species, etc.)	Fair	High: 8 Medium: 20 Low: 2	Fair to Poor	High: 7 Medium: 18 Low: 5	Species shifts due to changing habitat	High: 11 Medium: 19 Low: 0
Birds (species, ranges, habitat health, migration patterns, etc.)	Fair	High: 2 Medium: 21 Low: 3	Poor to Very Poor	High: 5 Medium: 16 Low: 5	New species / change in species mix	High: 6 Medium: 17 Low: 3
Terrestrial Invertebrates (insects, spiders, bugs, etc.)	Poor	High: 5 Medium: 11 Low: 7	Poor	High: 5 Medium: 12 Low: 6	New kinds of insect pests	High: 7 Medium: 12 Low: 2
Carbon Cycling (effect of system on greenhouse gas levels)	Fair	High: 6 Medium: 16 Low: 4	Fair to Very Poor	High: 8 Medium: 14 Low: 4	More trees might store more carbon dioxide	High: 7 Medium: 13 Low: 5

Aspect of the Boreal Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Water and Nutrient Cycling (how water & nutrients circulate in system)	Good	High: 7 Medium: 11 Low: 7	Fair to Poor	High: 12 Medium: 9 Low: 3	Warmer water could affect some species	High: 6 Medium: 14 Low: 5
Permafrost and Land Stability (melting permafrost, landslides, erosion)	Good	High: 9 Medium: 17 Low: 5	Good to Very Poor	High: 13 Medium: 15 Low: 3	Increased risk of landslides, slumpage	High: 11 Medium: 17 Low: 2

Potential Issues: Selected Ratings and Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Boreal System	Potential Issue	Respondent Rating	Comment
Distribution	Northward expansion of boreal system	High	Streamflow change
		High	Unknown potential rates of expansion, differential impacts on species and ultimately humans.
		High	Has major implications for state of the environment.
		High	The biological "bottlenecks" that will control species expansion are virtually a black box, and many current models are based on unvalidated assumptions about species response to changes in physiological ranges. Additionally, tree margins should be one of the places where we first observe clear indications of climate-driven changes, and may provide a great deal of important information that could be applied to less marginal ecosystems.
		High	To preserve the actual specific biodiversity of tundra and taiga (including wildlife).
		Medium	Rate of change and nature of succession impacts.
Vegetation	Increasing risk of forest fires	High	Severe economic impact - communities are at risk.
		High	Need to understand a great deal more about additive effects and interactions between other disturbance agents that may be sensitive to climate change (e.g., pest outbreaks) and fire disturbance.
		High	Risks to communities, timber values, costs of suppression

Aspect of Boreal System	Potential Issue	Respondent Rating	Comment
		High	"Risk" is a value-laden term but fire frequency is a key process in boreal forest renewal and has the potential to fundamentally change the habitat patterns and distribution. This will obviously affect wildlife distribution and abundance.
		High	While fire is a natural part of the landscape cycle, climate change may result in larger, hotter and more devastating events.
		High	If the fires increase with the increase of the temperature, the biodiversity won't be able to regenerate fast enough. In the North the regeneration takes longer.
		High	Major impact on ecosystem.
		High	Fire is a natural process but, with increased fire and global warming, impact on forests and underlying permafrost (where present) could be immense.
		High	Could result in dramatic changes to wildlife habitat, increased risk to property, change in carbon budget (from sink to source).
		High	Shifts in annual means (precipitation, temperature) may have major rapid impacts on fire and insect attack.
		High	Risk to community
		High	Very slow regeneration
Mammals	Species shifts due to changing habitat	High	Could result in serious changes in the distribution and proportion of wildlife habitat, challenging a species' ability to adapt to rapidly changing conditions.
		High	Shifts in species range and associations will influence the pathogen communities of these species (e.g., introduction of new pathogens). Changes in the pathogen/parasite communities may have effects on the health of the animals.
		High	Traditional food sources disappear as migration patterns change.
		High	Increased scarcity of many species demands timely research and policy options.
		High	Many species have range limits, either altitudinally or longitudinally in the boreal; it's the shifts of individual species of birds, animals or plants that will lead to an eventual shift in the distribution of the boreal ecosystem. We have a better chance of seeing shifts over a measurable time frame or distance if we focus [on species].

Aspect of Boreal System	Potential Issue	Respondent Rating	Comment
		High	In the North, some researchers expect that the temperature will increase [up to] 10 degrees Celsius within 100 years. With 10 degrees more, the habitat will completely change and most of the species living in the North will disappear. Even if we can actually do something to reduce pollution and greenhouse gas emissions, we won't be able to stop the actual warming up, which could take until 300 years for the contaminants in the atmosphere to get through the end of their cycle. I think it is unrealistic to say that arctic species will be able to shift or to adapt as fast as the increase of the temperature goes. If one day we are confronted with this reality, we will have to create an artificial environment to preserve their lives. We already have lots of knowledge about species that we can use but the priority has always been money instead of life. That is why we have to face a decreasing quality of life in terms of what the life should be - the respect and the right of animals to live like us.
		High	Changes in country foods
		High	Recent theories of habitat selection have been tested on boreal mammals and allow rigorous tests of environmental change on distribution and abundance.
		Medium	Expect most can adapt and disperse, but new diseases may cause rapid changes in distribution and abundance. Ability to adapt to new conditions, if different from old, largely unknown. Global organic contaminant redistribution may also affect species.
		Medium	Species adaptation is a natural, associated consequence for mammals (e.g., range extension) but I suspect there are lots of things we aren't noticing such as changes in insects, bacteria.
		Medium	It is clear that patterns of wildlife species distribution and abundance have been changing over the last century as northern climates warm and habitats change. Ongoing rather than intensive research is needed to monitor current changes and predict future shifts.
Birds	New species / change in species mix	High	Canadian Wildlife Service's mandate is the conservation and management of migratory birds.
		High	This issue is not so high in my mind, but research on the potential changes in bird habitat would be important to understand [how] changing conditions could threaten a number of species.
		High	Disease dissemination.
		Low	Not sure this is necessarily a problem as range fluctuations are a natural association.
Terrestrial Invertebrates	New kinds of insect pests	High	Only one aspect. Need to look at entire food chain as an integrated system and also consider that we don't know very much about bugs and bacteria at all.

Aspect of Boreal System	Potential Issue	Respondent Rating	Comment
		High	Shifts in distribution may have major, possibly short-term impact on vulnerable trees species. E.g. Southwest Yukon and spruce beetle outbreak or similar outbreak throughout much of Northern British Columbia.
		High	Invertebrates are very sensitive indicators of climate change. Additionally, they are important vectors for a variety of pathogens and parasites of mammalian species. Their abundance and distribution will influence disease occurrence and severity in wildlife.
		High	Potential interactions with other disturbance agents.
		High	Effect on vegetation mortality, hence forest fuel loadings, e.g. spruce bark beetle (Haines Junction, Yukon)
		Medium	West Nile disease, spruce bark beetle.
Carbon Cycling	More trees might store more carbon dioxide	High	Major component for implementation of the Kyoto Protocol.
		High	Wetlands drying up would change from carbon trap to carbon producer.
		High	We presently have no hard data on carbon content in northern trees; nor do we know how tree biodiversity may alter the carbon balance.
		High	Negative and positive feedback loops are likely important but poorly understood.
		High	How the carbon budget reacts to climate change is important as we need to know whether we can expect positive or negative feedback mechanisms in the boreal forest to the carbon budget, as positive feedback could accelerate climate change.
		High	Policy implications
		Low	Not likely in north.
Water and Nutrient Cycling	Warmer water could affect some species	High	Perceived direct high economic costs related to water.
		High	Knowledge base needs immediate supplementing.
		High	Effects on wetland could be important to waterfowl and waterbirds. Changing atmospheric/land surface balance requires more study.
		High	Variable hydrologic regimes in relatively flat landscapes are tightly linked to carbon dynamics
		High	Permafrost melting and increased soil water availability could set the stage for successful forest regeneration, often limited by water non-availability.
Permafrost and Land Stability	Increased risk of landslides, slumpage	High	There is also increased risk of damage to the root systems of vegetation when more liquid water is available for rapid freezing during the period of growth.
		High	Economic consequences.

Aspect of Boreal System	Potential Issue	Respondent Rating	Comment
		High	Permafrost instability could have serious consequences and economic costs because a large part of the territory [Yukon] is in the discontinuous permafrost zone already. Coastal erosion along the Beaufort Sea will become an even greater problem as well. Some communities like Dawson are also at a point where any further warming will create major structural problems.
		High	Impact on infrastructures.
		High	Removal of current constraints on erodibility of surficial materials from permafrost expected to be significantly reduced, and exacerbated by impacts of surface disturbance from forest fires, dramatically increasing erosion, slope failures, and supply of sediments to rivers. This could significantly increase sediment inputs to rivers draining the Cordillera as well as Mackenzie Valley Plains areas. This could significantly change the sediment regime of the Mackenzie River and Delta, as well as sediment outputs to the Beaufort Sea.
		High	Our knowledge of the distribution and character of permafrost through the discontinuous permafrost zone is very poor. There are only a few very localized areas that are studied (Wolf Creek and Mayo area). As oil and gas, as well as forestry development, grows within the boreal system, we need to quantify the risks.
		High	Impacts on oil and gas development, roads, forestry and fish habitat. Big economic impacts.
		High	Thawing of frozen ground, change in river water level, change in drainage pattern.
		Medium	Impacts due to tailing pond thawing, etc. Pollution problems may defrost and realize themselves.
		Medium	Clay cliffs in downtown Whitehorse [are vulnerable].

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
e	The distribution of permafrost in mountainous and hilly terrain.	Medium
f,a,b,i	Impacts of climate change on land management decisions.	High
f,a,b,i	Impacts of climate change on First Nation economies.	High
f,a,b,i	The impact of climate on the occurrence and effects of pathogens/parasites in wildlife (change in epidemiology, introduction of new species, increased abundance).	High
l,b,f	There are, or at least once were, exceptionally large economically important conifers growing in central Yukon (e.g., Pelly River valley). These trees are physiologically adapted to the northern environment, but we do not understand much of anything about them or how they may react to climate change.	High

Respondent Category (see key on page 6)	Issue	Priority
l,b,f	The finest, largest and some of the oldest specimens in Canada of balsam poplar (<i>Populus balsamifera</i>) occur in the Mackenzie River valley. They have been little studied and we can only guess how climate change may affect them, hence everything connected to them.	High
l,b,f	White birch (<i>Betula papyrifera</i>) occurs coast to coast to coast, but the northern ecotypes are undoubtedly special in terms of their physiological adaptations. They have been little studied and we can only guess how climate change may affect them, hence everything connected to them.	High
l,b,f	Very old (>1000 years) specimens of dwarf Alberta spruce (<i>Picea glauca</i> var <i>albertiana</i>) occur on south-facing flanks of glaciated valleys in the Yukon and NWT. Other than for a few dendrochronology studies, almost nothing is known of the silvics of these very special trees.	High
m,e	Oceanic temperature oscillations may occur more frequently or cease to occur with climate change. What impact will this have on our climate, marine, freshwater and terrestrial habitat and the species dependent on it?	High
e	Changes in water cycle affect the magnitude and frequency of freshet/precipitation/flood events. These in turn affect infrastructures with severe potential damages. Proper predictions on frequency and magnitude of these hydrological events in light of climate change need to be conducted.	High
n,l,e	Much improved understanding of linkages between climate/climate change/forest fires/impacts on vegetation, wildlife, and use by northerners is required to define climate change impacts and adaptation strategies.	High
b,f	Ecosystem response to climate change and subsequent feedback into climate change.	High
b,l	Changes in northern vegetation on surface reflectance is much more important than carbon storage.	High
b,l	Changes to water regime will have dramatic impact on community infrastructure, fishery, recreation, etc.	High
l	Comprehensive understanding of key conceptual issues linking behaviour, populations and communities.	High

2. The Fresh Water System

Forty-five (51% of total) respondents indicated an interest in the fresh water system. Of those, 25 filled out some or all of the fresh water system survey sheet.

All responses to the fresh water system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Fresh Water System Survey Responses

Water Levels and Thermal Regimes (rivers, lakes, groundwater levels, temperatures, and interactions)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “high” majority of respondents.

Sample issue:

- *Changes to break-up and freeze-up times:* Need for research rated “high” or “medium” by almost all respondents. Issue linked to human water usage, transportation, wildlife, and broader ecosystem.

Water Cycling (precipitation patterns, streamflow, ice jams, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by 15 of 25 respondents; 8 rated it “high”.
- *Understanding of climate change impacts: fair to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Changing spring run-off timing and amount:* Need for research rated “high” or “medium” by almost all respondents. Issue linked to human and natural systems.

Erosion, Sediment Travel (stream & coastal erosion, sediment, fish habitat)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by most respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by almost all respondents.

Sample issue:

- *Increased sediment flowing into deltas:* Need for research rated “medium” by most respondents. Comments linked issue to Mackenzie River system and delta.

Carbon and Nutrient Cycling (nutrients in water/wetlands, greenhouse gas discharge)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by most respondents.
- *Knowledge of the impacts of climate change: poor.* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Drying wetlands release more greenhouse carbon:* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”. Comments referred to uncertainty about role of issue in larger climate system.

Water Quality (chemicals, metals, biological organisms in water)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by most respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Biological organisms thrive in warmer water:* Need for research rated “medium” by 16 of 23 respondents. Comment referred to many unknowns regarding nature and effects of issue.

Aquatic Vegetation (kinds of plants, distribution, vulnerability to change)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by slightly more than half; rest split between “high” and “low”.
- *Knowledge of the impacts of climate change: poor to very poor.* Need for research rated “medium” by more than half; remainder divided between “high” and “low”.

Sample issue:

- *Changing water levels lead to changing plants:* Respondents split fairly evenly on need for research. Comments emphasized link with biodiversity and community structure.

Aquatic Invertebrates (insects and smaller creatures living in water bodies)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “low” or “medium” by most respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “medium” by more than half; balance of remainder tilted slightly toward low.

Sample issue:

- *Climate change could affect food sources for fish:* Need for research rated “medium” by just under half of respondents; rest divided between “high” and “low”.

Vertebrates (Fish and Amphibians) (animals that spend most of their lives in water)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by two thirds of respondents.
- *Knowledge of climate change impacts: poor to very poor.* Need for research rated “high” or “medium” by most respondents.

Sample issue:

- *Fish are very sensitive to water temperature:* Need for research rated “high” or “medium” by most respondents. Comments cited importance of fishing in traditional societies, regulation change.

Birds (Waterfowl and Shorebirds) (ducks, geese, swans, shorebirds)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by three quarters of respondents, with remaining quarter rating it “low”.
- *Understanding of the impacts of climate change: poor.* Need for research rated “medium” by three quarters of respondents; remainder rated it “low”.

Sample issue:

- *Spring nesting conditions affect bird populations:* Need for research rated “medium” by majority of respondents.

Other Issues

- Potential impacts of permafrost degradation and ground ice melt on hydrological system
- Impacts of glacier melt on timing and quantity of runoff
- Hydroelectric development to offset fossil fuel cutbacks
- Implications for pipeline stream crossings, etc.

Numerical Rating of Research Needs

Fresh Water System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Water Levels and Thermal Regimes	62	67	61
Water Cycling	56	61	60
Erosion, Sediment Travel	51	56	51
Carbon and Nutrient Cycling	55	51	49
Water Quality	55	57	53
Aquatic Vegetation	50	50	45
Aquatic Invertebrates	43	48	50
Vertebrates (Fish and Amphibians)	53	55	55
Birds (Waterfowl and Shorebirds)	44	42	44

Detailed Overview of Responses

Aspect of the Fresh Water Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Water Levels and Thermal Regimes (rivers, lakes, groundwater levels, temperatures, and interactions)	Fair	High: 12 Medium: 12 Low: 0	Fair to Poor	High: 17 Medium: 8 Low: 0	Changes to break-up and freeze-up times	High: 12 Medium: 12 Low: 1
Water Cycling (precipitation patterns, streamflow, ice jams, etc.)	Fair	High: 8 Medium: 15 Low: 2	Fair to Very Poor	High: 12 Medium: 11 Low: 1	Changing spring run-off timing and amount	High: 12 Medium: 11 Low: 2
Erosion, Sediment Travel (stream & coastal erosion, sediment, fish habitat)	Fair	High: 4 Medium: 18 Low: 3	Poor to Very Poor	High: 7 Medium: 17 Low: 1	Increased sediment flowing into deltas	High: 3 Medium: 19 Low: 2
Carbon and Nutrient Cycling (nutrients in water/wetlands, greenhouse gas discharge)	Fair	High: 8 Medium: 9 Low: 4	Poor	High: 6 Medium: 11 Low: 5	Drying wetlands release more greenhouse carbon	High: 5 Medium: 11 Low: 6
Water Quality (chemicals, metals, biological organisms in water)	Fair	High: 6 Medium: 17 Low: 1	Poor to Very Poor	High: 9 Medium: 13 Low: 2	Biological organisms thrive in warmer water	High: 5 Medium: 16 Low: 2

Aspect of the Fresh Water Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Aquatic Vegetation (kinds of plants, distribution, vulnerability to change)	Fair	High: 5 Medium: 12 Low: 5	Poor to Very Poor	High: 4 Medium: 13 Low: 4	Changing water levels means changing plants	High: 5 Medium: 7 Low: 9
Aquatic Invertebrates (insects and smaller creatures living in water bodies)	Fair	High: 2 Medium: 12 Low: 8	Fair to Very Poor	High: 4 Medium: 13 Low: 6	Change would affect food source for fish	High: 6 Medium: 11 Low: 6
Vertebrates (Fish and Amphibians) (animals that spend most of their lives in water)	Fair	High: 5 Medium: 15 Low: 2	Poor to Very Poor	High: 7 Medium: 14 Low: 2	Fish very sensitive to water temperature	High: 7 Medium: 14 Low: 2
Birds (Waterfowl and Shorebirds) (ducks, geese, swans, shorebirds)	Fair	High: 0 Medium: 15 Low: 5	Poor	High: 0 Medium: 14 Low: 6	Spring nesting conditions affect populations	High: 1 Medium: 12 Low: 5

Potential Issues: Selected Ratings and Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent’s reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Fresh Water System	Potential Issue	Respondent Rating	Comment
Water Levels and Thermal Regimes	Changes to break-up and freeze-up times	High	Drinking water system, private wells.
		High	Vital aspect of environment of already depauperate fauna.
		High	One of the most important aspects of northern hydrology, with important implications for the ecosystem.
		High	This is only one of the more obvious problems. We do not have a good inventory of Yukon lakes and groundwater conditions nor do we know how climate change could influence flood events and, in conjunction with vegetation/permafrost changes, affect run-off and groundwater recharge.

Aspect of Fresh Water System	Potential Issue	Respondent Rating	Comment
		High	From my plant physiology perspective, substantial temporal shifts in these times could have either quite positive or highly destructive effects on plant survival.
		High	Ecological and economic impacts.
		High	Freeze-up and break-up times (and character) are already demonstrably changing due to climate change. These will increasingly impact transportation (i.e. winter roads, all-weather roads, via permafrost changes impacting on road stability, etc.).
		High	Of great importance for many users of the water resource systems - changes could have far reaching impacts.
		High	Flooding, hydroelectric.
		High	Impacts to near-shore communities and riparian ecosystems need to be looked at closely.
		Medium	Traditional migration of mammals affected, thus hunting affected.
		Medium	Transport route for traditional hunting and for winter ice road transport.
Water Cycling	Changing spring run-off timing and amount	High	VERY critical to nutrient delivery in terrestrial and aquatic ecosystems.
		High	Water management planning.
		High	Water supply, fishery, hydroelectric.
		High	Direct impact on many ecosystems and communities.
		High	Changing river regimes in some parts of the North (SW NWT, Yukon, other locations) may increase tendency of rivers to produce flood events in early, mid-, or late winter periods, when such events have not been common in the past. This would lead to new hazards of flooding, via ice jams, etc.
		High	Ecology, infrastructure and economic impacts (tourism, roads, pipelines etc.).
		High	Phenological uncertainty.
		High	Timing of runoff affects flooding and overall water availability for water supply, etc.
		High	Spring runoff dominates northern hydrology.
		High	Impact of major flood events on infrastructures.
		Medium	Loss of permafrost would mean many lakes in permafrost terrain may disappear - with them, water sources for communities.
		Medium	Water quality effects.
Erosion, Sediment Travel	Increased sediment flowing into deltas	High	Mackenzie hazard.
		High	Erosion of soils currently underlain by permafrost expected to increase.... Increased sediment load likely to affect major tributaries, the main channel of the Mackenzie River, and the Mackenzie Delta, with more sand & gravel bars, more navigation problems, etc.

Aspect of Fresh Water System	Potential Issue	Respondent Rating	Comment
		High	Deltas are dependent on balance of sediment input/output.
		Medium	Increased sediment flow can be positive or negative, depending on consequences.
		Medium	Drinking water quality.
Carbon and Nutrient Cycling	Drying wetlands release more greenhouse carbon		Potentially a very important feedback mechanism to greenhouse warming.
		High	Or capture more carbon as bogs experience warmer temperatures.
		High	Such balances/budgets are central to forecasting the consequences of climate change.
		High	Serious effects on carbon capture.
		High	Impact of climate on northern wetlands not well understood, but has potential of being an important feedback process.
		Low	Cycling rates low in north.
Water Quality	Biological organisms thrive in warmer water	High	Many unknowns. This is my specific work area.
		High	May require a water treatment plant.
		High	Bound to drive significant community shifts and potential biodiversity loss.
		Medium	Water quality could deteriorate, due to increased sediment inputs, vegetation change, etc.
Aquatic Vegetation	Changing water levels means changing plants	High	Understanding the ecophysiological factors regulating biodiversity is essential for wise management.
		High	Need to anticipate changes in community structures.
Aquatic Invertebrates	Change would affect food source for fish	High	Country foods and tourism impacts.
		High	Species-poor food-web bases may shift as these groups tend to respond rapidly to water temperature and quality changes.
		High	Traditional hunting.
Vertebrates (Fish and Amphibians)	Fish very sensitive to water temperature	High	May result in need for rule changes regarding wastewater discharge, fishing quotas.
		High	Fisheries values are a key environmental indicator in Yukon.
		High	Arctic freshwater fish fauna is already depauperate and clearly sensitive to all of these impacts, probably already operating within narrow environmental tolerances.
		Medium	Traditional hunting.
		Medium	May impact how we develop land. If temperature changes cause more creeks to be fish-bearing, may restrict development and activity.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
a,n,i,g	Degradation of permafrost and establishment of a greater groundwater system could have significant impact on current drainage patterns and water source availability throughout northern communities. This could also have significant impact on water quality.	High
a,n,l,g	Permafrost degradation will mean surface water and groundwater effects could have serious consequences for water quality.	High
l,e,b	Changes in glacier melt contributions to river systems, increases in peak flows.	High
f,e	Groundwater quantity/quality has implications for the entire aquatic ecosystem.	High
l,b	Terrain destabilization and sedimentation created by permafrost degradation.	High
b,l	Combined effects of changing snow supply, frozen soil, vegetation cover on water supply.	High
b,l	Pipeline crossing of small to medium basins under changing hydrology.	High
b,l	New hydroelectric to offset oil burning.	High
b,l	Increased demand for northern water from southerners. Must assess implications should demands occur.	High
l,e,b	Interactions between sea level change, spring runoff, local climate change, and ice jamming are not well known for the Mackenzie Delta.	High
l,e,b	Impact of changing climate on permafrost-dammed lakes is not well known. Rapid drainage of these lakes is normal. However, the future rate of lake drainage events is not well known. Such events have important implications for northern systems.	High
l,e,b	Impact of changing vegetation types (expansion of forest northward or change from tundra to shrub tundra) has major implications.	High

3. The Tundra System

Forty-eight (54.5% of total) respondents indicated an interest in the tundra system. Of those, 23 filled out some or all of the tundra system survey sheet.

All responses to the tundra system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Tundra System Survey Responses

Distribution (amount and location of land included in system)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “low” or “medium” by three quarters of respondents.
- *Knowledge of impacts of climate change: fair to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Treeline advance into the tundra zone:* Need for research rated “medium” by just over half of respondents. Comments linked issue to broad changes in ecosystem and need to understand them.

Permafrost and Land Stability (extent, location, vulnerability)

Baseline and impacts research

- *Baseline knowledge: good.* Need for research rated “high” or “medium” by all respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” by more than half of respondents, and “medium” by remainder.

Sample issue:

- *Melting permafrost might trigger landslides:* Need for research rated “high” or “medium” by majority of respondents. Issue linked to infrastructure security, changes in drainage, possible flooding.

Glaciers (both alpine and High Arctic glaciers, role in climate, changes)

Baseline and impacts research

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *State of knowledge about climate change impacts: fair to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Retreating glaciers change landscape.* Need for research rated “medium” just over half of respondents; one quarter rated it “high”. Comments mentioned hydrological changes and feedback impacts into the climate system as areas of particular concern.

Energy, Nutrient and Carbon Cycling (how energy, nutrients, carbon move through system)

Baseline and impacts research

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Drying tundra could release greenhouse gas:* Need for research rated “high” or “medium” by majority of respondents. Comments mentioned the lack of basic knowledge about tundra ecosystems.

Water Cycling (how snow and rain move through the tundra system)

Baseline and impacts research

- *Baseline knowledge: poor.* Need for research rated “high” or “medium” by almost all respondents.
- *Knowledge of climate change impacts: fair to poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *More evaporation leading to less moisture in the soil:* Need for research rated “high” or “medium” by almost all respondents. Comments noted broad implications of moisture change within tundra system.

Vegetation (Including Phenology) (kinds and range of plants, also seasonal changes or phenology)

Baseline and impacts research

- *Baseline information: good.* Need for research rated “high” or “medium” by majority of respondents.
- *Knowledge about climate change impacts: fair to poor.* Need for research rated “high” or “medium” by most respondents.

Sample issue:

- *Earlier green-up increases nutrients in spring forage:* Need for research rated “high” by just under half of respondents; remainder split between “medium” and “low”. Comments linked issue with shifts in seasonal timing for vegetation and wildlife, and need for long-term monitoring.

Caribou (ranges of various herds and subspecies, health, trends, habitat)

Baseline and impacts research

- *Baseline information: good.* Need for research rated “medium” by majority of respondents.
- *Knowledge about climate change impacts: fair to poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Shifts to caribou ranges:* Need for research rated “high” by more than half of respondents. Issue linked with importance of caribou as a country food and a part of northern culture.

Other Ungulates (sheep, goats, muskox, moose, etc.)

Baseline and impacts research

- *Baseline information: fair.* Need for research rated “medium” by majority of respondents.
- *Information about climate change impacts: poor to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Sample issue: possible increase in parasites and insect pests.* Need for research rated “high” or “medium” by all respondents. Comments cited sensitivity of host-parasite systems to small temperature changes, potential threat to muskoxen, and impact on the quantity and quality of country foods.

Other Animals (bears, wolves, furbearers, small mammals, birds, etc.)

Baseline and impacts research

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Snow depth affects small mammals.* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”. Comments referred to other vulnerable animals, other impacts of snow regimes, and general paucity of studies on animals in this grouping.

Other Issues

- Need better understanding of ecological and evolutionary processes in order to understand and predict impacts
- Impacts of insect harassment, new parasites and pathogens on caribou

- Change from tundra to shrub tundra can happen quickly and has implications for entire system
- Need better understanding of links between hydrology, permafrost, terrain functions, vegetation changes

Numerical Rating of Research Needs

Tundra System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Distribution	48	55	45
Permafrost and Land Stability	62	66	56
Glaciers	56	61	53
Energy, Nutrient and Carbon Cycling	56	54	54
Water Cycling	62	63	62
Vegetation	54	57	54
Caribou	49	54	62
Other Ungulates	54	56	62
Other Animals	56	51	53

Detailed Overview of Responses

Aspect of Tundra System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Distribution (amount and location of land included in system)	Good	High: 5 Medium: 8 Low: 7	Fair to Very Poor	High: 9 Medium: 8 Low: 5	Treeline might advance into tundra	High: 3 Medium: 11 Low: 7
Permafrost and Land Stability (extent, location, vulnerability)	Fair	High: 10 Medium: 11 Low: 0	Fair to Poor	High: 14 Medium: 8 Low: 0	Melting permafrost may trigger landslides	High: 9 Medium: 8 Low: 4
Glaciers (both alpine and High Arctic glaciers' role in climate changes)	Fair	High: 6 Medium: 13 Low: 1	Fair to Very Poor	High: 8 Medium: 12 Low: 0	Retreating glaciers change landscape	High: 5 Medium: 12 Low: 3
Energy, Nutrient and Carbon Cycling (how energy, nutrients, carbon move through system)	Fair	High: 6 Medium: 9 Low: 2	Fair to Poor	High: 5 Medium: 10 Low: 2	Drying tundra could release greenhouse gas	High: 5 Medium: 11 Low: 2

Aspect of Tundra System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Water Cycling (how snow and rain move through the tundra system)	Poor	High: 10 Medium: 8 Low: 1	Fair to Poor	High: 10 Medium: 9 Low: 0	More evaporation, less moisture in soil	High: 10 Medium: 8 Low: 1
Vegetation (Including Phenology) (kinds and range of plants, also seasonal changes or phenology)	Good	High: 5 Medium: 11 Low: 2	Fair to Poor	High: 8 Medium: 7 Low: 3	Earlier green-up increases nutrients in spring forage	High: 8 Medium: 5 Low: 5
Caribou (ranges of various herds and subspecies, health, trends, habitat)	Good	High: 1 Medium: 14 Low: 2	Fair to Poor	High: 5 Medium: 10 Low: 2	Shifts to caribou ranges	High: 9 Medium: 7 Low: 1
Other Ungulates (sheep, goats, muskox, moose, etc.)	Fair	High: 4 Medium: 12 Low: 1	Poor to Very Poor	High: 6 Medium: 9 Low: 2	Possible increase in parasites/insect pests	High: 8 Medium: 9 Low: 0
Other Animals (bears, wolves, furbearers, small mammals, birds, etc.)	Fair	High: 4 Medium: 13 Low: 0	Poor to Very Poor	High: 4 Medium: 11 Low: 3	Snow depth affects small mammals	High: 5 Medium: 8 Low: 3

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Tundra System	Potential Issue	Respondent Rating	Comment
Distribution	Treeline might advance into tundra.	High	Direct feedback to climate change through changes in albedo, and on carbon balance. Impacts on caribou through loss of lichen by shading from taller vegetation. Changes in snow distribution.
		High	Shrubs more likely.
		High	Absolutely crucial to understand how a dramatic ecosystem shift from tundra to trees will affect tundra biological elements.
		Medium	Impact limited.

Aspect of Tundra System	Potential Issue	Respondent Rating	Comment
		Low	The treeline is very far from the Nunavut National Parks.
Permafrost and Land Stability	Melting permafrost may trigger landslides.	High	This has geotechnical, geomorphic, and ecological implications.
		High	Stability issues with infrastructure using permafrost.
		High	And change drainage.
		High	This is only one consequence; it will affect vegetation, transportation, resource exploration.
		High	Limited vegetation and simple structure of soils, especially in marine areas, means the tundra is particularly prone to climate change. This is already negatively impacting Cambridge Bay and other communities, and may require extensive remediation or even relocation of communities and industrial facilities.
		High	Economic consequences with pipeline development.
		High	Obvious.
		High	And cause flooding.
		High	Subsidence of areas with ice-rich permafrost is a greater problem, impacting drainage and therefore carbon balance. Impacts on infrastructure will also be important.
		Medium	It is important to understand at what point the active layer becomes unstable - for building new infrastructure, maintenance of existing infrastructure, for people living out on the land (safety), to understand landslides as an ecological disturbance factor, to protect cultural resources (e.g., archeological sites).
Glaciers	Retreating glaciers change landscape.	High	Will impact the landscape and hydrology.
		High	Related hydrological changes.
		High	Basic mass balance of arctic glaciers is very poorly studied. The change in albedo when glaciers retreat will have direct feedbacks to climate.
		High	How much CO2 will be released from melting glaciers.
		High	In the eastern Arctic, glaciers are a major element of the landscape, affecting the availability of moisture, climate patterns, distribution of wildlife and plants, the volume of freshwater entering the oceans, the volume of sediments entering the oceans and freshwater systems – i.e., a large effect on the islands of the Arctic.
		Medium	? limited knowledge (sic) - Canadian glaciers expected to have only local & downstream effects, other than Kluane and High Arctic areas. Continuing shrinkage of the Columbia Icefields will affect downstream water supply, if precipitation continues to decrease with climate change.
Energy, Nutrient and Carbon Cycling	Drying tundra could release greenhouse gas.	High	Or capture more!

Aspect of Tundra System	Potential Issue	Respondent Rating	Comment
		High	There are no published studies of these impacts on Canadian tundra ecosystems. The issue is complicated by soil moisture changes, which are linked to changes in precipitation regimes, and changes in these regimes are very poorly represented in models. Experimental and gradient studies are needed.
		High	Again affects carbon sequestering ability.
		High	To date there have been intensive studies in very few locations. A better understanding needs to be developed across the Arctic in different types of tundra systems with different energy regimes.
		Low	We don't have the other basic knowledge first before getting this specific.
Water Cycling	More evaporation, less moisture in soil.	High	Has wide-ranging impacts from permafrost thermodynamics to ecology.
		High	How will CO2 content of snow and rain change?
		High	Impact on vegetative cover and erosion control.
		High	Not necessarily, could result in more rainfall and wetter soils from permafrost melting.
		High	Less soil moisture will seriously affect the other components of the ecosystem (plant growth, natural regeneration, wildlife food availability).
		High	Noted aspects need study; also, changes in surface topology (depressions, erodibility, subsidence, etc.) could significantly change character of tundra terrain storage and movement of water, erosion, etc. This could lead to major soil erosion, landscape change, especially in near-coast areas underlain by marine sediments.
		High	Don't understand vegetation [moisture] needs, which all other biota depend on.
		High	Moisture availability is one of the primary drivers of vegetation distribution and abundance - thus terrestrial productivity and wildlife distribution and abundance.
		High	And then [our] water supply [could] change.
		High	This is far too simplistic an issue. Drying will occur in some areas, while others will become much wetter. Snowfall will increase in the shoulder seasons in some areas, while rainfall is predicted to increase in others. The link to permafrost changes will also alter hydrological regimes. There is a great need for studies on the links between water, energy, carbon and nutrient balances in tundra systems.
Vegetation	Earlier green-up increases. nutrients in spring forage	High	Food chain implications with changes in biomass.
		High	Changes in species distributions will change the nutrient, carbon and energy balance of the systems. However, there is very little long-term research on these issues in Canadian tundra systems.
		High	Also increases risk of early spring frost kill, but to what extent?

Aspect of Tundra System	Potential Issue	Respondent Rating	Comment
		High	How will this, in turn, affect the availability of the forage to wildlife later in the growing season - if wildlife has become attuned to a particular sequence of events, disruption in timing of events could have large impacts.
		High	Major shifts will occur. We need this monitoring absolutely!
		High	Effects on migration patterns of wildlife.
Caribou	Shifts to caribou ranges.	High	Changes in ranges and range use may change exposure to pathogens, ultimately affecting health of caribou.
		High	Major contributor to arctic ecosystem.
		High	Impacts of vegetation change are poorly known. Taller, denser shrubs will likely shade lichens and result in lichen declines throughout the ranges of the herds. How well caribou will adapt to this and the many other changes in tundra systems is very poorly known.
		High	Food source for communities disappear.
		High	Traditional hunting and distance to hunt.
		High	Caribou are a staple food for a number of people living in area.
		High	Consequences for local communities.
		High	Country food impacts.
		Medium	Question - would caribou behaviour be a good indicator for monitoring climate change?
Other Ungulates	Possible increase in parasites and insect pests.	High	Host-parasite systems are very sensitive to climate change. Small changes in temperature may have pronounced effect on levels of parasitism and other pathogens.
		High	Muskox may disappear.
		High	Muskoxen are endemic to the Canadian Arctic. Impacts of changes in tundra systems and increases in parasites are very poorly known. Baseline data on their numbers and distribution in the High Arctic is also lacking.
		High	Effects on quality of meat.
		High	Consequences for country food.
		High	Range extensions also bring new diseases and since these species already host a variety of parasites, it is reasonable to hypothesize that increases will occur.
		High	Country food quality and human health impacts.
Other Animals	Snow depth affects small mammals.	High	Polar bear rely on stable climate.
		High	Changes in snow regimes will affect the entire system. Potential changes in vegetation and prey species, and in parasite/disease will impact these species, but there are very few studies on any of these species.
		High	Impact on the food chain.
		Medium	Snow depth is only one aspect.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
j	We cannot know all and never will. Therefore a risk assessment approach which looks at collective consequences of climate change across ecosystems may be worth exploring.	medium
l	Need to expand basic understanding of ecological and evolutionary processes as they influence tundra organisms. Less emphasis on components, and more emphasis on conceptual understanding.	high
j	Food chain relationships for all species will change.	high
l	Increased insect harassment of caribou.	medium
j,b,i,l	Effects of climate change on parasites and pathogens of caribou and subsequent effect on health of caribou.	high
l	Mismatch between timing of snow melt and arrival of migrant birds.	medium
b,l	Blowing snow changes in response to shrub change will affect water supply and spring runoff as well as soil moisture.	high
l,b	The impact of snow depth and timing on the terrain, hydrological, and ecological systems.	high
l,e,b	Potential change in vegetation from tundra to shrub tundra can occur quickly and has been documented in other northern regions. This change in vegetation can have significant implications for hydrology, water resources and aquatic ecosystems.	high
l,e,b	The links between landslides, hydrology, and drainage of permafrost-dammed lakes are not well known. If the rate of lake drainage increases, it will have significant implications for the northern system.	high

4. The Coast System

Twenty-nine (33% of total) respondents indicated an interest in the coast system. Of those, 11 filled out some or all of the coast system survey sheet.

All responses to the coast system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Coast System Survey Responses

Land Stability and Erosion (impacts of storm waves, melting permafrost, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *The threat to coastal communities and structures:* Need for research rated “high” by majority of respondents. Comments linked risk to housing, transportation, cultural heritage, resource development.

Vegetation (kinds, health, and distribution of plant life)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “medium” by majority of respondents.
- *Knowledge of the impacts of climate change: poor to very poor.* Need for research rated “medium” by all respondents.

Sample issue:

- *Potential changes to habitat for land and ocean species:* Need for research rated “medium” by majority of respondents.

Invertebrates (species, ranges, habitat health, mix of species, etc.)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *The difficulty of monitoring change in the short term:* Need for research rated “medium” by most respondents. Comments cited lack of knowledge about invertebrates and their function in ecosystems.

Birds (species, ranges, habitat health, migration patterns, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by all respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “medium” by all respondents.

Sample issue:

- *Changes in the productivity of species:* Need for research rated “medium” by all respondents.

Nutrient and Water Cycling and Sedimentation (physical processes that shape the coast system)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “high” by most.

- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Reduced sea ice might lead to increased ship traffic in the North.* Need for research rated “high” by half of respondents. Comments focused on broad impacts of reduced sea ice.

Other Issues

- Changes in ocean are inextricable from changes in coastal zone
- Public safety issues related to unpredictability of weather and ice systems
- Reduced ice could affect primary production
- Increased access of mammalian carnivores to nesting shore/water birds

Numerical Rating of Research Needs

Coast System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Land Stability and Erosion	58	62	69
Vegetation	50	50	54
Invertebrates	53	53	56
Birds	50	50	50
Nutrient and Water Cycling and Sedimentation	69	65	58

Detailed Overview of Responses

Aspect of the Coast Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Land Stability and Erosion (impacts of storm waves, melting permafrost, etc.)	Fair	High: 3 Medium: 6 Low: 0	Fair to Poor	High: 5 Medium: 5 Low: 0	Threat to coastal communities/structures	High: 7 Medium: 2 Low: 0
Vegetation (kinds, health, and distribution of plant life)	Poor	High: 0 Medium: 6 Low: 0	Poor to Very Poor	High: 0 Medium: 7 Low: 0	Changes to habitat for land and ocean species	High: 1 Medium: 6 Low: 0
Invertebrates (species, ranges, habitat health, mix of species, etc.)	Poor	High: 1 Medium: 7 Low: 0	Poor to Very Poor	High: 1 Medium: 8 Low: 0	Hard to monitor change in shorter term	High: 2 Medium: 6 Low: 0

Aspect of the Coast Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Birds (species, ranges, habitat health, migration patterns, etc.)	Fair	High: 0 Medium: 6 Low: 0	Poor	High: 0 Medium: 8 Low: 0	Changes in productivity of species	High: 0 Medium: 8 Low: 0
Nutrient and Water Cycling and Sedimentation (physical processes that shape the coast system)	Poor	High: 3 Medium: 1 Low: 0	Poor to Very Poor	High: 3 Medium: 2 Low: 0	Less sea ice could increase ship traffic	High: 3 Medium: 2 Low: 1

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Coast System	Potential Issue	Respondent Rating	Comment
Land Stability and Erosion	Threat to coastal communities/structures	High	Permafrost melting affects housing.
		High	Can affect transportation, traditional lifestyle and threaten infrastructure.
		High	Coastal erosion due to permafrost decay, wave erosion, etc., a major problem along Arctic coast, and some communities.
		High	Not significant in the Yukon context at this point. More relevant to resource development, such as oil and gas.
		High	How communities might adapt, and what strategies are most appropriate
		High	Damage/loss of community infrastructure; loss of cultural artifacts/history as a result of coastal erosion; impacts of coastal erosion on nearshore habitats for fisheries.
Invertebrates	Hard to monitor change in shorter term	High	Agree, but this may be because we know so little already and generally do not attach much importance to such science.

Aspect of Coast System	Potential Issue	Respondent Rating	Comment
		High	These organisms form an important trophic level in freshwater and marine environments. Baseline knowledge of population / community ecology is minimal or absent. Difficult to predict impacts of climate change on these communities, given the absence of knowledge.
Nutrient and Water Cycling and Sedimentation	Less sea ice could increase ship traffic.	High	Affecting ocean circulation patterns, currents and ice distribution. Modify water masses' stability.
		High	Wide-ranging environmental impacts.
		High	Importance of sea ice not only for economic or tourist implications, but also for the potential feedback effects on the climate system.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
l	Spread of mammalian carnivores will menace shorebird communities.	Medium
j	Can't separate coast from ocean. Each will affect the other. For example, more open water can increase storms eroding more shoreline. More shoreline erosion can create new beaches/spits that are attractive to shorebirds. Warmer waters may increase marine mammal activity.	Medium
l,b	Increased variability and unpredictability of weather and ice systems -- safety issues for hunting and transportation (i.e. traveling between communities).	High
m,e	Because less ice could modify the water circulation, it can have an impact on primary production.	High

5. The Marine System

Thirty (34% of total) respondents indicated an interest in the marine system. Of those, 14 filled out some or all of the marine system survey sheet.

All responses to the marine system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Marine System Survey Responses

Sea Level (general sea level, tidal patterns, storm surges, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Knowledge of the effects of climate change: poor to very poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *Sample issue: more open water means bigger waves.* Need for research rated “high” or “medium” by most respondents. Issue linked to coastal erosion and threats to coastal infrastructure.

Sea Ice (extent, degree of annual melting, landfast ice, multiyear ice)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “high” by most respondents.

Sample issue:

- *Sample issue: poor sea ice could make hunting difficult.* Need for research rated “high” or “medium” by most respondents. Issue linked to impact on traditional diet, community health, public safety.

Ocean Cycling, Geology and Oceanographic Features (ocean currents, geology of ocean bed, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Temperature change can cause a shift in ocean currents:* Need for research rated “high” or “medium” by majority of respondents. Comments cited impacts on arctic ecosystems, northern hemisphere climate.

Vegetation and Invertebrates (marine plants, plankton, small organisms, etc.)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “high” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Changes in ice cover affect ice algae:* Need for research rated “high” or “medium” by majority of respondents. Issue linked to potential disruption of food chain, lack of understanding of marine food web.

Fish (species mix, distribution, including fish in commercial and food fisheries)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by most respondents.

- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *The growth rate of fish is related to sea temperature:* Need for research rated “medium” by majority of respondents. Comments cited the impact on multiple populations and lack of knowledge about non-commercial marine species.

Marine Mammals (whales, seals, walrus, narwhals, polar bears)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *Polar bears rely on extensive sea ice:* Need for research rated “high” or “medium” by almost all respondents. Comments referred to public safety concerns related to hungry bears, impact on traditional hunting patterns, and vulnerability of all marine mammals to changes in sea ice.

Nutrient Cycling (how nutrients move through plants, animals, and physical features of marine system)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “high” or “medium” by all respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Many component species of the system are sensitive to temperature change:* Need for research rated “medium” by majority of respondents. Comments noted need to identify appropriate indicators of change for this aspect of the marine system.

Other Issues

- A variety of concerns related to changes in the sea ice regime and impacts on marine organisms
- Increased traffic through the Northwest Passage – social, economic, environmental, sovereignty issues
- New species and changes in species mix in oceans
- Impacts on migrating species, including birds, fish, and marine mammals

Numerical Rating of Research Needs

Marine System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Sea Level	62	67	58
Sea Ice	65	71	57
Ocean Cycling, Geology and Oceanographic Features	60	61	62
Vegetation and Invertebrates	65	65	62
Fish	59	62	59
Marine Mammals	52	67	57
Nutrient Cycling	59	59	55

Detailed Overview of Responses

Aspect of the Marine Ecosystem	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Sea Level (general sea level, tidal patterns, storm surges, etc.)	Fair	High: 6 Medium: 7 Low: 0	Poor to Very Poor	High: 9 Medium: 4 Low: 0	More open water means bigger waves	High: 5 Medium: 7 Low: 1
Sea Ice (extent, degree of annual melting, landfast ice, multiyear ice)	Fair	High: 9 Medium: 3 Low: 1	Fair to Very Poor	High: 12 Medium: 2 Low: 0	Poor sea ice could make hunting difficult	High: 7 Medium: 5 Low: 1
Ocean Cycling, Geology & Oceanographic Features (ocean currents, geology of ocean bed, etc.)	Fair	High: 6 Medium: 6 Low: 1	Poor	High: 8 Medium: 4 Low: 2	Temperature change can cause shift of ocean currents	High: 7 Medium: 5 Low: 1
Vegetation and Invertebrates (marine plants, plankton, small organisms, etc.)	Poor	High: 9 Medium: 3 Low: 1	Poor to Very Poor	High: 8 Medium: 5 Low: 0	Change in ice cover affects ice algae	High: 7 Medium: 5 Low: 1
Fish (species mix, distribution, including fish in commercial and food fisheries)	Fair	High: 4 Medium: 7 Low: 0	Fair to Poor	High: 6 Medium: 6 Low: 0	Growth rate related to sea temperature	High: 4 Medium: 7 Low: 0
Marine Mammals (whales, seals, walrus, narwhals, polar bears)	Good	High: 2 Medium: 8 Low: 1	Fair to Very Poor	High: 9 Medium: 2 Low: 1	Polar bears rely on extensive sea ice	High: 4 Medium: 6 Low: 1
Nutrient Cycling (how nutrients move through plants, animals, and physical features of marine system)	Poor	High: 4 Medium: 7 Low: 0	Poor	High: 4 Medium: 7 Low: 0	Many component species sensitive to temperature	High: 3 Medium: 6 Low: 1

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent’s reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Marine System	Potential Issue	Respondent Rating	Comment
Sea Level	More open water means bigger waves.	High	Coastal infrastructure and communities
		High	Infrastructure, traditional economy, ecosystem impacts.
		High	Identifying potential amounts of sea level rise to determine communities' vulnerability, and their susceptibility to storm-surge rise.
		High	Direct impacts on coastline erosion resulting in damage/loss of community infrastructure and cultural artifacts. Impacts on access to marine environments for hunters and fishers. Impact on nearshore marine environments - erosion/deposition of sediment and organic materials in nearshore environments.
		High	These changes will have opposite effects to the natural state (isostatic rebound) and will certainly change the natural path of development of coastal ecosystems.
		Medium	This is an important issue but really comes under changes in sea ice distribution rather than sea level. Higher sea level plus more open water means more coastal erosion.
Sea Ice	Poor sea ice could make hunting difficult	High	Health of indigenous communities.
		High	Safety issues for hunters traveling on the sea ice, break-up / freeze-up timing, and potential climate feedbacks due to albedo and current effects.
		High	Changes in species distribution and abundance.
		High	This will be a major factor soon.
		High	Lack of hunting opportunities affects subsistence hunting and income generation from guiding (e.g. polar bear hunts); longer open water will impact entire marine ecosystem from plankton through to seals and polar bears.
		High	May also encourage increased shipping, coming with its own suite of problems.
Ocean Cycling	Temperature change can cause shift of ocean currents	High	Climate of the arctic islands is very closely linked with the conditions of the ocean.
		High	Affect the entire Northern Hemisphere climate
		High	Importance of currents in determining ice conditions, local marine animal life, and local climate.
		High	Changes in species' distribution and abundance.
		High	Will affect the capacity of the ocean to serve as a sink for greenhouse gases.

Aspect of Marine System	Potential Issue	Respondent Rating	Comment
		High	The patterns of seasonal current play a vital role in productivity, winter habitat (ice-free areas) and other key aspects of the arctic marine environment.
Vegetation and Invertebrates	Change in ice cover affects ice algae	High	Exponential effect on rest of system.
		High	Importance in food chain.
		High	Knowledge levels are very poor now, so situation will only get worse.
		High	Effects on food chains if the lowest levels are detrimentally impacted, lack of knowledge on invertebrate and algae roles.
		High	Affect primary productivity and seasonal fluxes.
		High	Changes in ice distribution will affect the entire food web and will have impacts on all ice-adapted species.
		High	The foundation for all aquatic ecosystems; changes in the timing of phytoplankton blooms, the quantity of phytoplankton and/or the species composition of the plankton will impact aquatic food chains directly.
Fish	Growth rate related to sea temperature.	High	Arctic cod - central species for the entire marine food web.
		High	Impact on local fisheries and species diversity.
		High	Affects trophic food web all the way to 'hunted' species.
		High	Little known about the distribution, life history, ecological tolerances etc... of most Arctic marine species, with the exception of the few commercial and food fishes.
Marine Mammals	Polar bears rely on extensive sea ice	High	Public safety hazard. More hungry bears on land for longer periods, with effects on reproduction and survivability. This, in turn, affects quotas and community economics.
		High	Impacts on animal habitat and seasonal migration routes, as well as the potential impact on Inuit communities still actively hunting particular animals.
		High	Other marine mammals adapted to arctic conditions rely on sea ice for food availability and limiting competition from other species.
		High	As top predators, polar bears probably exert pressure on the entire food web.
Nutrient Cycling	Many component species sensitive to temperature	High	Small changes may have large effects.
		High	Find appropriate indicators of nutrient cycling if direct investigations are not feasible or too complex.

Aspect of Marine System	Potential Issue	Respondent Rating	Comment
		High	Competitive ability with other species adapted to warmer temperatures and currently living further south will impact trophic system and reduce arctic species distribution and abundance.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
1	Effect of increases in marine traffic with more open water in the Arctic.	Medium
1	Mismatch between sea ice break-up and breeding of marine birds and marine mammals.	High
1	Change in food web structure as a result of changes in sea ice distribution and timing will affect all marine birds and mammals.	High
1,e	Change in sea ice cover is key to climate change in the High Arctic. If there is more open water in the fall and winter, then there will be more snow and this will impact land mammals and land transportation.	High
1	Variability in sea ice extent and seasonal fluxes.	High
1	Migration paths of marine mammals that use the arctic ice waters if sea ice extent changes dramatically.	High
1	Changes in species' distribution and abundance relative to different trophic groups. For example, marine birds may be better able to adapt to changes than marine mammals.	High
1,b	Sea ice - By controlling the radiative balance through the albedo effect, sea ice dynamics could determine the rate at which the entire Northern Hemisphere will warm up. Field data on ice thickness, properties and distribution are crucial to complement satellite observations.	High
1,b	Sea ice - The potential opening of the Northwest Passage will transform intercontinental shipping and the industrial and geopolitical context of the Arctic Ocean. Anticipating when the NW Passage will become ice-free in the summer months is of tremendous importance in the development of a national strategy to maintain sovereignty in and protect the environment of the Canadian Archipelago.	High
1,b	Vegetation (i.e. algae) and invertebrates - By determining light penetration and sea surface temperature, ice cover dynamics affect not only ice algae but the whole suite of plankton algae and animals. Key taxa that feed the unique vertebrate fauna of the Arctic Ocean, such as copepods, amphipods and Arctic cod depend to a variable extent on sea ice.	High
1,b	Nutrient cycling - With a reduction in sea ice cover extent and seasonal duration, nutrients could replace light as the factor limiting primary production in the Arctic Ocean. There is an urgent need to identify better the sources of nutrients in the upper layer of the Arctic Ocean and how these sources will be affected by climate change (e.g. change in ice cover, circulation, vertical mixing, river runoff).	High
1,b	Arctic Ocean climate and new species - Changes in oceanic circulation, temperature and sea ice cover will favor the displacement of Arctic species by boreal species. Already, there are reports of unprecedented penetration of Pacific salmon species in the Arctic Basin, or the displacement of Arctic cod by sand lance in Hudson Bay. Such shifts in species assemblages will affect the food web, creating both negative impacts and new opportunities in the fishing activities and industry of the North.	High

6. The Agriculture System

Fourteen (15% of total) respondents indicated an interest in the agriculture system. Of those, 5 filled out some or all of the agriculture system survey sheet.

All responses to the agriculture system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Agriculture System Survey Responses

Agricultural Capability (the viability of agriculture in a region)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” or “low” by majority of respondents.
- *Knowledge of the effects of climate change: fair to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *The growing season may increase in length:* Need for research rated “medium” or “low” by all respondents.

Quality and Quantity of Harvested Species (both plants and animals)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” or “low” by most respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “medium” by half respondents; other split between “high” and “low”.

Sample issue:

- *Less moisture could affect feed quality:* Need for research rated “medium” by majority of respondents.

Changes in Species Harvested (what plants and animals are suited to the North)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” or “low” by most respondents.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “medium” by half of respondents; others split between “high” and “low”.

Sample issue:

- *New conditions might suit new crops:* Need for research rated “medium” by majority of respondents.

Marketing and Business (land base, infrastructure, supply sources, markets)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” or “low” by all respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “medium” or “low” by all respondents.

Sample issue:

- *Infrastructure, such as an abattoir, is needed for commercial agriculture:* Need for research rated “medium” by majority of respondents.

Other Issues

- How climate change might affect the species farmed and the transmission of pathogens from farmed species to wild species

Numerical Rating of Research Needs

Agriculture System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Agricultural Capability	44	56	44
Quality and Quantity of Harvested Species	44	50	44
Changes in Harvested Species	44	50	44
Marketing and Business	38	44	44

Detailed Overview of Responses

Aspect of the Agriculture System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Agricultural Capability (the viability of agriculture in a region)	Good	High: 1 Medium: 1 Low: 2	Fair to Very Poor	High: 1 Medium: 3 Low: 0	Growing season may increase in length	High: 0 Medium: 3 Low: 1
Quality and Quantity of Harvested Species (both plants and animals)	Good	High: 1 Medium: 1 Low: 2	Fair to Very Poor	High: 1 Medium: 2 Low: 1	Less moisture could affect feed quality	High: 0 Medium: 3 Low: 1
Changes in Species Harvested (what plants and animals are suited to the North)	Good	High: 1 Medium: 1 Low: 2	Fair to Poor	High: 1 Medium: 2 Low: 1	New conditions might suit new crops	High: 0 Medium: 3 Low: 1
Marketing and Business (land base, infrastructure, supply sources, markets)	Good	High: 0 Medium: 2 Low: 2	Fair to Very Poor	High: 0 Medium: 3 Low: 1	Need infrastructure, like abattoir, for commercial agriculture	High: 0 Medium: 3 Low: 1

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Agriculture System	Potential Issue	Respondent Rating	Comment
Agricultural Capability	Growing season may increase in length	Medium	Local food source potential

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
j,b,i,l	How will changes in climate affect the health of domestic species?	Low
j,b,i,l	How will changes in climate affect the type of species farmed and what potential pathogens will be transported to the north with new domestic species?	High
j	Interchange of diseases between domestic animals and wildlife	High

7. The Mining System

Twenty-eight (32% of total) respondents indicated an interest in the mining system. Of those, 12 filled out some or all of the mining system survey sheet.

All responses to the mining system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Mining System Survey Responses

Accessibility to Sites and Minerals (location of deposits, winter roads, all-weather roads, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge of the effects of climate change: fair to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *A shorter season for ice roads could increase costs:* Need for research rated “high” or “medium” by majority of respondents. Comment noted that increased costs make it harder to attract investment.

Mining Impacts on Surrounding Environment (permafrost, streams, wildlife, vegetation, vulnerability, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by half of respondents; rest split between “high” and “low”.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Increased evaporation could affect the function of tailings ponds:* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”. Comment pointed to impact of climate change on structural integrity of existing tailing ponds and abandoned mine clean-up.

Reclamation of Mines: Quality and Efficiency (costs, technology, methods, land use, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “medium” by just over half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Permafrost degradation could affect long-term containment measures:* Need for research rated “high” or “medium” by all respondents. Issue linked to Giant mine in Yellowknife and to future building standards.

Other Issues

- Climate change may complicate mining practices, but won't change fundamental business of mining

Numerical Rating of Research Needs

Mining System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Accessibility to Sites and Minerals	54	54	55
Mining Impacts on Surrounding Environment	52	50	48
Reclamation of Mines: Quality and Efficiency	53	50	63

Detailed Overview of Responses

Aspect of the Mining System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Accessibility to Sites and Minerals (location of deposits, winter roads, all-weather roads, etc.)	Fair	High: 3 Medium: 8 Low: 1	Fair to Very Poor	High: 4 Medium: 6 Low: 2	Shorter season for ice roads could increase costs	High: 4 Medium: 5 Low: 2
Mining Impacts on Surrounding Environment (permafrost, streams, wildlife, vegetation, vulnerability, etc.)	Fair	High: 3 Medium: 5 Low: 2	Poor to Very Poor	High: 2 Medium: 6 Low: 2	Increased evaporation could affect function of tailings ponds	High: 2 Medium: 5 Low: 3
Reclamation of Mines: Quality and Efficiency (costs, technology, methods, land use, etc.)	Fair	High: 2 Medium: 6 Low: 1	Poor	High: 2 Medium: 5 Low: 2	Permafrost degradation could affect long-term containment measures	High: 5 Medium: 5 Low: 0

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Mining System	Potential Issue	Respondent Rating	Comment
Accessibility to Sites and Minerals	Shorter season for ice roads could increase costs	High	Current operational season for roads being maintained by use of new technology/techniques of road building (low tire pressure/impact vehicles to build roads, new spray technology for ice bridges at ferry crossings, etc). Increasing traffic loads may not be supportable in future, as ice road seasons continue to shrink.
		High	Could jeopardize economy.
		High	Increased costs mean financing will go elsewhere and be difficult to attract back. Global market for those bucks.
Mining Impacts on Surrounding Environment	Increased evaporation could affect function of tailings ponds.	High	Tailings pond operations potentially susceptible to climate change, especially as some new mines propose total containment. Engineering considerations are including measures to counter potential permafrost decay, but the magnitude of changes and effectiveness of preventive measures is in some doubt.
		High	Proper assessment of water balance is essential for contaminant management and reclamation; the data and design standards are changing in light of climate change.
		Low	What is the issue here? A greater concern would relate to structural integrity of existing tailing ponds and abandoned mine clean-up.
Reclamation of Mines: Quality and Efficiency	Permafrost degradation could affect long-term containment measures	High	Known to be a significant issue for the containment of arsenic trioxide at Yellowknife's Giant Yellowknife Mine, this could be an issue at other mines currently operational or shut down.
		High	More work needs to be done in this area.
		High	Many sites currently use the 100-year predictions in planning. We may be all gone, but in 200 years we could have a mess on our hands.
		Medium	Since Yukon permafrost is weak, any mine infrastructure is currently built on thawed soil and proper compaction; it increases the upfront cost but reduces the risk of failure.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
j	Climate change may make it more difficult to access mineral deposits and complicate mining processes including reclamation, thus increasing costs, but it won't change the business of mining.	Low

8. The Tourism System

Twenty-five (28% of total) respondents indicated an interest in the tourism system. Of those, 5 filled out some or all of the tourism system survey sheet.

All responses to the tourism system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Tourism System Survey Responses

Distribution of Tourism and Recreation Areas (where are the best locations for tourism)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” or “low” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “medium” by most respondents.

Sample issue:

- *Changes like slumping could affect recreation areas:* Need for research rated “medium” by majority of respondents.

Number and Timing of Visitors (seasonal tourism, carrying capacity of facilities, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Warmer winters could affect the kind and number of winter tourists:* Need for research rated “medium” or “low” by all respondents.

Consumptive Wilderness Activities (hunting, fishing, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” or “low” by all respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *If prey ranges change, hunters will have to follow:* Need for research rated “medium” or “low” by all respondents.

Non-consumptive Wilderness Activities (wildlife viewing, wilderness travel, ecotourism)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “medium” or “low” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “medium” by most respondents.

Sample issue:

- *Possible changes in avalanche patterns could affect skiers and others:* Need for research rated “low” by majority of respondents.

Numerical Rating of Research Needs

Tourism System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Distribution of Tourism and Recreation Areas	40	50	45
Number and Timing of Visitors	45	45	40
Consumptive Wilderness Activities	40	45	35
Non-Consumptive Wilderness Activities	40	45	30

Detailed Overview of Responses

Aspect of the Tourism System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Distribution of Tourism and Recreation Areas (where are the best locations for tourism)	Fair	High: 0 Medium: 3 Low: 2	Poor	High: 1 Medium: 3 Low: 1	Changes like slumping could affect recreation areas	High: 0 Medium: 4 Low: 1
Number and Timing of Visitors (seasonal tourism, carrying capacity of facilities, etc.)	Fair	High: 0 Medium: 4 Low: 1	Fair to Very Poor	High: 0 Medium: 4 Low: 1	Warmer winters could affect kind and number of winter tourists	High: 0 Medium: 3 Low: 2
Consumptive Wilderness Activities (hunting, fishing, etc.)	Fair	High: 0 Medium: 3 Low: 2	Poor to Very Poor	High: 0 Medium: 4 Low: 1	If prey ranges change, hunters have to follow	High: 0 Medium: 2 Low: 3
Non-consumptive Wilderness Activities (wildlife viewing, wilderness travel, ecotourism)	Poor	High: 0 Medium: 3 Low: 2	Poor	High: 0 Medium: 4 Low: 1	Possible change in avalanche pattern, affecting skiers, etc.	High: 0 Medium: 1 Low: 4

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Tourism System	Potential Issue	Respondent Rating	Comment
Distribution of Tourism and Recreation Areas	Changes like slumping could affect recreation areas	Medium	Erodible trails.
Number and Timing of Visitors	Warmer winters could affect kind and number of winter tourists	Medium	Energy consumption could change, may exceed what is supplied by dam.

Other Issues

No other issues were suggested.

9. The Fisheries System

Thirty (34% of total) respondents indicated an interest in the fisheries system. Of those, 6 filled out some or all of the fisheries system survey sheet.

All responses to the fisheries system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Fisheries System Survey Responses

Fresh Water Fisheries (fish living in rivers, lakes, streams)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Knowledge related to climate change impacts: fair to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Species like lake trout require cold water:* Need for research rated “medium” by all respondents.

Anadromous and Marine Fisheries (fish that spend part or all of their lives in the ocean)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *The growth rate of many species is related to temperature:* Need for research rated “medium” by majority of respondents.

Distribution of Commercial and Subsistence Species (where fish that are used by people are located)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *The range of some commercial species might move north:* Need for research rated “medium” by majority of respondents. Comments cited need for better understanding of distributions and ranges.

Recruitment and Growth Rates of Fish (how quickly fish populations and individual fish grow)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by half of respondents; rest divided between “high” and “low”.
- *Knowledge about the impacts of climate change: poor.* Need for research rated or “medium” by all respondents.

Sample issue:

- *Temperature influences the incubation time of eggs for some fish species.* Need for research rated “medium” by majority of respondents. Comment noted need for better understanding of life histories of arctic fish.

Habitat Quality (water quality and quantity, food resources, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Dropping lake levels in some areas may be related to climate change:* Need for research rated “medium” by majority of respondents.

Other Issues

- New diseases and parasites, as well as changes to streams and habitat

Numerical Rating of Research Needs

Fisheries System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Fresh Water Fisheries	54	58	50
Anadromous and Marine Fisheries	54	54	49
Distribution of Commercial and Subsistence Species	54	50	54
Recruitment and Growth Rates of Fish	54	50	54
Habitat Quality	54	54	50

Detailed Overview of Responses

Aspect of the Fisheries System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Fresh Water Fisheries (fish living in rivers, lakes, streams)	Fair	High: 2 Medium: 3 Low: 1	Fair to Very Poor	High: 2 Medium: 4 Low: 0	Species like lake trout require cold water	High: 0 Medium: 6 Low: 0
Anadromous and Marine Fisheries (fish that spend part or all of their lives in the ocean)	Fair	High: 2 Medium: 3 Low: 1	Fair to Poor	High: 2 Medium: 3 Low: 1	Growth rate of many species related to temperature	High: 0 Medium: 5 Low: 1
Distribution of Commercial and Subsistence Species (where fish that are used by people are located)	Fair	High: 2 Medium: 3 Low: 1	Fair to Very Poor	High: 1 Medium: 4 Low: 1	Range of some commercial species may move north	High: 1 Medium: 5 Low: 0

Aspect of the Fisheries System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Recruitment and Growth Rates of Fish (how quickly fish populations and individual fish grow)	Fair	High: 2 Medium: 3 Low: 1	Poor	High: 0 Medium: 6 Low: 0	Temperature influences incubation time of eggs for some fish	High: 1 Medium: 5 Low: 0
Habitat Quality (water quality and quantity, food resources, etc.)	Fair	High: 2 Medium: 3 Low: 1	Poor to Very Poor	High: 1 Medium: 5 Low: 0	Dropping lake levels in some areas may be related to climate change	High: 0 Medium: 6 Low: 0

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Fisheries System	Potential Issue	Respondent Rating	Comment
Distribution of Commercial and Subsistence Species	Range of some commercial species may move north	High	Current deficiency of understanding of distributions and ranges will make it impossible to monitor the effects of changing temperatures, currents, ice, etc. on the abundance and distribution of these and other (i.e., non-commercial) species.
Recruitment and Growth Rates of Fish	Temperature influences incubation time of eggs for some fish	High	These key life-history characteristics are vital to understanding the population dynamics and assessing risks to Arctic fish taxa.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. The following issue was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
j	We may see new diseases and parasites over time, while other climate change problems, such as increased sedimentation, could change river and stream flow characteristics.	Medium

10. The Forestry System

Thirty (34% of total) respondents indicated an interest in the forestry system. Of those, 9 filled out some or all of the forestry system survey sheet.

All responses to the forestry system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Forestry System Survey Responses

Tree Species Composition (which trees are plentiful, which are rare)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” or “low” by all respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Some tree species might be more vulnerable to climate change than others:* Need for research rated “high” or “medium” by all respondents. Comments noted impact on future composition of forests.

Tree Quality and Productivity (health of trees, how fast they grow and reproduce)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Respondents split among “high”, “medium” and “low” on the importance of further research.

Sample issue:

- *The age balance of trees in the forest could change:* Need for research rated “high” or “medium” by all respondents. Issue linked to wildlife habitat and forest industry.

Forest Fires (how often, how serious, cost of fighting fires)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “high” by just over half of respondents; rest split between “medium” and “low”.

Sample issue:

- *An increased risk of forest fire is likely in many areas:* Need for research rated “high” by majority of respondents. Comments linked it to public safety, cost of fire-fighting, infrastructure loss.

Other Natural Disturbances (flooding, permafrost, snow cover, drought, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge of the impacts of climate change: poor.* Respondents split across “high”, “medium” and “low” in rating importance of further research.

Sample issue:

- *Insect pests might not be killed off by winter cold:* Need for research rated “high” or “medium” by all respondents.

Other Issues

- Feedbacks from reduced snow cover could accelerate climate change
- Genetic diversity could be reduced if trees specifically adapted to northern conditions disappear

Numerical Rating of Research Needs

Forestry System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Tree Species Composition	41	50	62
Tree Quality and Productivity	53	53	59
Forest Fires	47	58	67
Other Natural Disturbances	46	54	53

Detailed Overview of Responses

Aspect of the Forestry System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Tree Species Composition (which trees are plentiful, which are rare)	Fair	High: 0 Medium: 5 Low: 3	Poor to Very Poor	High: 1 Medium: 6 Low: 1	Some tree species may be more vulnerable	High: 4 Medium: 4 Low: 0
Tree Quality and Productivity (health of trees, how fast they grow and reproduce)	Fair	High: 2 Medium: 5 Low: 1	Fair to Very Poor	High: 3 Medium: 3 Low: 2	Age balance of trees in forest could change	High: 3 Medium: 5 Low: 0
Forest Fires (how often, how serious, cost of fighting fires)	Fair	High: 0 Medium: 8 Low: 1	Fair to Poor	High: 5 Medium: 2 Low: 2	Increased fire risk likely in many areas	High: 7 Medium: 1 Low: 1
Other Natural Disturbances (flooding, permafrost, snow cover, drought, etc.)	Fair	High: 0 Medium: 6 Low: 1	Poor	High: 3 Medium: 2 Low: 2	Insect pests not killed off by winter cold	High: 2 Medium: 5 Low: 1

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Forestry System	Potential Issue	Respondent Rating	Comment
Tree Species Composition	Some tree species may be more vulnerable	High	Differential impacts of climate change on tree species will result in changes to forest ecosystems and, ultimately, the species dependent on them.
		High	Physiology research is needed.
		High	Different populations of trees adapted to different conditions may respond uniquely to different climatic signals. We know very little about such geographical trends.
Tree Quality and Productivity	Age balance of trees in forest could change	High	This would have dramatic implications for wildlife habitat and the forest industry.
Forest Fires	Increased fire risk likely in many areas	High	Increased risk to communities; increased cost for fire fighting.
		High	This would threaten infrastructure, communities and property, and could result in dramatic changes to wildlife habitat.
		High	This is a growing public concern.
		High	Economic/social impacts, redistribution of tax dollars.
		High	Top priority item - implications for vegetation, wildlife, use by people, etc.
		High	What are the factors that will be associated with increased fire risk, and how are those factors distributed across the landscape?
Other Natural Disturbances	Insect pests not killed off by winter cold	Medium	This shouldn't be that hard to detect and monitor.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
m,e	Climate changes in the North may result in changes in snow cover. Reduced snow cover would reduce the albedo effect and positively feed increased temperatures, thereby accelerating the impacts of climate change.	High
l,b,f	A genetic base of trees specially adapted to northern conditions could be lost.	High

11. The Hunting and Trapping System

Twenty-seven (31% of total) respondents indicated an interest in the hunting and trapping system. Of those, 5 filled out some or all of the hunting and trapping system survey sheet.

All responses to the hunting and trapping system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Hunting and Trapping System Survey Responses

Caribou (both woodland and tundra herds)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *A change in migration routes affects hunting:* Need for research rated “high” or “medium” by all respondents. Issue linked to vulnerability of communities that depend on caribou.

Other Large Mammals (moose, muskox, elk, deer, sheep, etc.)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by majority of respondents.
- *Knowledge about climate change impacts: poor to very poor.* Need for research rated “medium” by all respondents.

Sample issue:

- *Deer and elk are moving northward:* Need for research rated “high” or “medium” by all respondents. Comments mentioned the possibility of new species' introducing new pathogens.

Furbearers (marten, lynx, muskrat, beaver, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Temperature affects the quality of pelts:* Need for research rated “medium” by all respondents.

Marine Mammals (seals, walrus, whales, polar bears, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Changes in temperature and ice conditions could affect seal pup survival:* Need for research rated “high” or “medium” by all respondents. Issue linked to communities dependent on marine mammals.

Game Birds (migratory waterfowl like ducks and geese, ptarmigan, sea birds)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.

- *Knowledge about the impacts of climate change: poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Spring melting affects the breeding success of waterfowl:* Need for research rated “high” or “medium” by all respondents.

Accessibility of Game Animals (ease of travel, movement patterns of animals)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Understanding of the impact of climate change: poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Melting permafrost makes travel over land difficult:* Need for research rated “high” or “medium” by all respondents.

Other Issues

- Changes at the ice edge will affect both hunters and hunted
- Some large mammals are adapted to specific current climate conditions and could be very vulnerable
- New parasites could affect quality of pelts

Numerical Rating of Research Needs

Hunting and Trapping System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Caribou	44	69	62
Other Large Mammals	44	50	60
Furbearers	50	58	50
Marine Mammals	62	67	67
Game Birds	62	58	58
Accessibility of Game Animals	62	62	62

Detailed Overview of Responses

Aspect of the Hunting and Trapping System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Caribou (both woodland and tundra herds)	Good	High: 0 Medium: 3 Low: 1	Fair to Very Poor	High: 3 Medium: 1 Low: 0	Change in migration routes affects hunting	High: 2 Medium: 2 Low: 0
Other Large Mammals (moose, muskox, elk, deer, sheep, etc.)	Good	High: 0 Medium: 3 Low: 1	Poor to Very Poor	High: 0 Medium: 4 Low: 0	Deer and elk moving northward	High: 2 Medium: 3 Low: 0

Aspect of the Hunting and Trapping System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Furbearers (marten, lynx, muskrat, beaver, etc.)	Fair	High: 0 Medium: 3 Low: 0	Poor to Very Poor	High: 1 Medium: 2 Low: 0	Temperature affects quality of pelt	High: 0 Medium: 3 Low: 0
Marine Mammals (seals, walrus, whales, polar bears, etc.)	Fair	High: 1 Medium: 1 Low: 0	Poor to Very Poor	High: 2 Medium: 1 Low: 0	Temperature/ice could affect seal pup survival	High: 2 Medium: 1 Low: 0
Game Birds (migratory waterfowl like ducks and geese, ptarmigan, sea birds)	Fair	High: 1 Medium: 1 Low: 0	Poor	High: 1 Medium: 2 Low: 0	Spring melt timing affects breeding success of waterfowl	High: 1 Medium: 2 Low: 0
Accessibility of Game Animals (ease of travel, movement patterns of animals)	Fair	High: 1 Medium: 1 Low: 0	Poor	High: 1 Medium: 1 Low: 0	Melting permafrost makes land hard to travel over in fall	High: 1 Medium: 1 Low: 0

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Hunting and Trapping System	Potential Issue	Respondent Rating	Comment
Caribou	Change in migration routes affects hunting	High	Perceived high reliance of many communities on caribou hunting makes it important to determine whether changing migration routes will render caribou inaccessible.
		High	Aboriginal people will have to relocate with herds they depend on.
Other Large Mammals	Deer and elk moving northward	High	Mixing of species causes transmittal of disease.
		High	Northern movement of deer and elk may increase competition among ungulates and may bring new pathogens.

Aspect of Hunting and Trapping System	Potential Issue	Respondent Rating	Comment
Marine Mammals	Temperature/ice could affect seal pup survival	High	Many communities are coastal, and heavily reliant on marine mammal populations, thus impacts on such populations (e.g. changing ice regimes) are of great importance as they could severely impact local communities.
Game Birds	Spring melt timing affects breeding success of waterfowl	High	Waterfowl migration routes and timing are important to community seasonal harvest, thus major changes in such patterns could drastically affect local harvesting patterns or accessibility.
Accessibility of Game Animals	Melting permafrost makes land hard to travel over in fall	High	Changing routes could affect animals and people alike. Learning more about both impacts would be very important.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
a,n,i,g	Changes in ice edge could have effects on sea mammals and on the hunters that harvest them.	High
e	In the Yukon, mountain goats are only found in our wetter regions, and/or may be quite closely associated with late-melting snow patches. If the snow patches were to disappear, the vegetation may change and no longer be lush enough to support the relatively sedentary goat populations.	Medium
j,b,i,l	Furbearers: Will there be a change in ectoparasites and endoparasites that will affect quality of pelts?	Medium
e	Warmer autumns (late snow) can make sheep more vulnerable to hunting as they move to winter range and rutting areas. May require refinement of hunting regulations.	Low

12. The Community Health System

Thirty (34% of total) respondents indicated an interest in the community health system. Of those, 9 filled out some or all of the community health system survey sheet.

All responses to the community health system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Community Health System Survey Responses

Traditional Pursuits and Subsistence Harvest (importance, harvest patterns, vulnerability of change)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by half of respondents; rest split between “high” and “low”.
- *Knowledge about the impacts of climate change: poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Land management planning must consider climate change:* Need for research rated “medium” by most respondents. Comment noted that land use planning could be invalidated by climate change.

Community Demographics (nature of population, patterns of change)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Future job options may vary under climate change:* Need for research rated “medium” by majority of respondents. Issue linked to city planning.

Nutrition and Human Health (healthy food sources, quality of country foods, lifestyle patterns, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by half of respondents; rest split between “high” and “low”.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *Hot summer weather is hard on those not used to it:* Need for research rated “medium” or “low” by majority of respondents. Issue linked to broader impacts on nutrition and human health.

Employment and Economic Issues (job availability, cash/noncash economy, possible changes)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Prices are affected by transportation changes related to climate change:* Need for research rated “medium” by majority of respondents. Comments cited importance of oceans to transportation.

Air and Water Quality (impact of air and water on human health)

Baseline and impacts research:

- *Baseline knowledge: fair.* Respondents split evenly on importance of baseline research.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *There could be a decline in air quality problems related to fossil fuel emissions:* Need for research rated “medium” by majority of respondents.

Land Stability and Flood Frequency (flood preparedness, infrastructure stability, building techniques)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by all respondents.
- *Knowledge of the impacts of climate change: fair to poor.* Need for research rated “high” by majority of respondents.

Sample issue:

- *There are indications that the scale of floods is increasing in some areas:* Need for research rated “high” or “medium” by all respondents. Comments cited effects on property and public safety.

Other Issues

- Mental and social stress resulting from the unfamiliarity and unpredictability of new climatic conditions
- Public safety issues related to unsafe ice crossings, slumpage, flooding, etc.
- Nutritional problems related to reduced access to traditional foods

Numerical Rating of Research Needs

Community Health System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Traditional Pursuits and Subsistence Harvest	50	56	50
Community Demographics	61	54	50
Nutrition and Human Health	44	58	41
Employment and Economic Issues	54	57	57
Air and Water Quality	50	61	43
Land Stability and Flood Frequency	61	68	61

Detailed Overview of Responses

Aspect of the Community Health System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Traditional Pursuits and Subsistence Harvest (importance, harvest patterns, vulnerability of change)	Fair	High: 2 Medium: 4 Low: 2	Poor	High: 3 Medium: 5 Low: 1	Land management planning must consider climate change	High: 1 Medium: 7 Low: 1
Community Demographics (nature of population, patterns of change)	Fair	High: 4 Medium: 2 Low: 1	Poor to Very Poor	High: 2 Medium: 4 Low: 1	Future job options may vary under climate change	High: 1 Medium: 5 Low: 1
Nutrition and Human Health (healthy food sources, quality of country foods, lifestyle patterns, etc.)	Fair	High: 1 Medium: 4 Low: 3	Poor	High: 5 Medium: 2 Low: 2	Hot summer weather hard on those not used to it	High: 1 Medium: 3 Low: 4
Employment and Economic Issues (job availability, cash/noncash economy, possible changes)	Fair	High: 2 Medium: 4 Low: 1	Poor	High: 2 Medium: 5 Low: 0	Prices affected by transportation changes related to climate	High: 2 Medium: 5 Low: 0
Air and Water Quality (impact of air and water on human health)	Fair	High: 2 Medium: 2 Low: 2	Poor	High: 4 Medium: 2 Low: 1	Decline in air quality problems related to fossil fuels	High: 0 Medium: 5 Low: 2
Land Stability and Flood Frequency (flood preparedness, infrastructure stability, building techniques)	Fair	High: 3 Medium: 4 Low: 0	Fair to Poor	High: 5 Medium: 2 Low: 0	Indication that scale of floods increasing in some areas	High: 3 Medium: 4 Low: 0

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments

provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Community Health System	Potential Issue	Respondent Rating	Comment
Traditional Pursuits and Subsistence Harvest	Land management planning must consider climate change	High	Current and anticipated uses can all be invalidated by climate change, e.g. land important as caribou pasture now could experience vegetation change and no longer be used for such a purpose.
Community Demographics	Future job options may vary under climate change	High	City planning depends on ability to predict growth trends.
Nutrition and Human Health	Hot summer weather hard on those not used to it	High	I'm not sure this is the most pressing issue under this heading, but the larger issues of access to traditional foods, impacts of decreased access to such foods, and how that may be affected by climate change are central to community and individual health.
Employment and Economic Issues	Prices affected by transportation changes related to climate	High	Oceans are our economic lifeline.
		High	Current tenuous state of many local economies (boom-bust, and transfer-payment dependant).
Land Stability and Flood Frequency	Indication that scale of floods increasing in some areas	High	These items have the potential to be catastrophic events, and will likely appear very suddenly, as opposed to some of the other longer-term effects anticipated.
		High	Clay cliffs, dam [in Whitehorse] under greater pressure.
		High	Potential community health implications of damage to infrastructures, and social and economic related impacts of this damage (and its relationship to health) are reality in some regions, not a prediction (damage from flood and erosion).

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
i	Mental health & wellness issues. One of the most common responses I have heard from indigenous peoples when asked about the impacts on them of climate change is the bewilderment and dislocation felt by community members because they can no longer predict weather, or weather-related events (such as freeze-up or break-up events), with any degree of accuracy. Given the attachment to the land some indigenous people still feel, this inability to connect with the natural rhythms amounts to an estrangement from the land. It is my belief that the mental and spiritual problems that may flow from this need to be addressed, firstly by being recognized as a climate change impact.	High
l,n,c,b	Changes in ice stability and distribution and weather predictability and related risks to human safety while on the land / ice for travel or subsistence activities.	High

Respondent Category (see key on page 6)	Issue	Priority
l,n,c,b	Research into public education processes (communication and awareness). We know little of how to engage communities (various ages, etc.) on these issues effectively and mobilize communities to develop internal capacity to take action on their own.	High
a,n,i,g	No mammals to hunt; people used to traditional foods will turn to the store-bought stuff. That already has and could have even more widespread health implications.	Medium
j,b,i,l	Safety of country foods - effect of climate change on occurrence of zoonotic diseases.	Medium

13. The Energy System

Thirty-six (41% of total) respondents indicated an interest in the energy system. Of those, 15 filled out some or all of the energy system survey sheet.

All responses to the energy system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Energy System Survey Responses

Hydro Power (potential sites, water levels, run-off, impact on surroundings)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by majority of respondents.
- *Understanding the impact of climate change: poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Projecting future streamflows is difficult.* Need for research rated “high” or “medium” by majority of respondents. Comments noted importance of hydro power in the North and effect of increased sedimentation on dams.

Fossil Fuels (diesel, gas, oil, natural gas, costs and impacts)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge about the impacts of climate change: fair to poor.* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”.

Sample issue:

- *Changes in Beaufort Sea ice could affect the recovery of fossil fuels in the region.* Need for research rated “medium” by majority of respondents. Comments noted dependence on fossil fuels and need to move away from them.

Alternative Energies (wind, solar, microhydro, etc.)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “high” or “medium” by majority of respondents.
- *Knowledge about the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Alternative energy sources may become more viable.* Need for research rated “high” or “medium” by all respondents. Comments cited importance of alternative energy for a sustainable future.

Transportation of Energy (pipelines, transmission lines, trucks, ships)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Pipeline design for unstable permafrost.* Need for research rated “high” or “medium” by majority of respondents. Comments noted cost of transporting fossil fuels and potential impacts of pipeline failure.

Other Issues

- How will icefield melt rates affect water/hydro resources in drainage basins?
- Potential release of large quantities of methane resulting from permafrost melting
- Impact of linear developments (pipeline, powerline) on boreal forest ecosystem
- Contribution of fossil fuel exploration and development to Canada's greenhouse gas emissions

Numerical Rating of Research Needs**Energy System**

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Hydro Power	50	58	60
Fossil Fuels	46	52	52
Alternative Energies	57	62	63
Transportation of Energy	59	59	55

Detailed Overview of Responses

Aspect of the Energy System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Hydro Power (potential sites, water levels, run-off, impact on surroundings)	Good	High: 1 Medium: 11 Low: 1	Poor	High: 5 Medium: 7 Low: 1	Projecting future streamflows difficult	High: 7 Medium: 7 Low: 1
Fossil Fuels (diesel, gas, oil, natural gas, costs and impacts)	Fair	High: 2 Medium: 8 Low: 4	Fair to Poor	High: 4 Medium: 7 Low: 3	Changes in Beaufort Sea ice could affect recovery of fossil fuels	High: 3 Medium: 9 Low: 2
Alternative Energies (wind, solar, microhydro, etc.)	Poor	High: 7 Medium: 4 Low: 3	Poor to Very Poor	High: 8 Medium: 5 Low: 1	May become more viable, economically and technologically	High: 8 Medium: 7 Low: 0
Transportation of Energy (pipelines, transmission lines, trucks, ships)	Fair	High: 6 Medium: 7 Low: 1	Fair to Very Poor	High: 6 Medium: 7 Low: 1	Pipeline design for unstable permafrost	High: 5 Medium: 7 Low: 2

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Energy System	Potential Issue	Respondent Rating	Comment
Hydro Power	Projecting future streamflows difficult	High	Hydro should remain # 1 energy resource. Need to sustain its use.
		High	Effects on watersheds - implications for fauna/flora.
		High	Reliance on hydropower.
		High	Proper hydrological assessment of small and large river systems needed for proper costing of infrastructures and liabilities.
		High	Difficult to predict changes in precipitation.
		High	Sedimenting of dams, a major concern in all dam projects, could significantly reduce the lifespan of hydro projects.
Fossil Fuels	Changes in Beaufort Sea ice could affect recovery of fossil fuels	High	Coastal erosion on Yukon North Slope - more research required.
		High	City design for transportation requires a lot of fossil fuels.
		Low	We need to move away from fossil fuels anyhow.
Alternative Energy	May become more viable, economically and technologically	High	Absolutely fundamental in the long run for a sustainable society.
		High	Have to break away from fossil fuel dependency if going to deal with climate change.
		High	A solid understanding of the NWT's renewable energy potential will pave the way for the installation of appropriate RE technologies.
		High	Reduce consumption of fossil fuels.
		High	More investment in alternative energy to offset fossil fuels.
		High	Warmer climate may be opportunity for air-generated power.
		High	Not being tested that much in Nunavut.
		High	With increased transport costs of fossil fuels due to degradation of winter roads, replacement will become more viable alternatives.
		High	Lack of knowledge is very disturbing, given the potential environmental damage an "unstable" pipeline could do.
Transportation of Fuel	Pipeline design for unstable permafrost	High	The cost of transporting energy is a huge issue that, once fully understood, could open the door for local energy production.
		High	The impact of failures (e.g. pipelines) could be catastrophic.
		High	Lots of research needs to be started now.
		High	

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
l,d,i	Climate change will affect the Kluane Icefield melt rates. But how? What will be the effect on the watersheds it feeds?	High
l,d,i	Climate change could possibly cause huge amounts of methane to release from permafrost areas of the North. What are the amounts? When will it happen?	High
e	Loss of forest ecosystem services from the clearing of land for linear energy development.	High
l,d,i	Fossil fuel exploration and exportation in the North is contributing to Canada's greenhouse gas emissions - but what are the quantities?	Medium

14. The Infrastructure System

Thirty-five (40% of total) respondents indicated an interest in the infrastructure system. Of those, 20 filled out some or all of the infrastructure system survey sheet.

All responses to the infrastructure system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Infrastructure System Survey Responses

Land Stability (permafrost fragility, slumpage, landslides, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge about the impacts of climate change: fair to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Finding methods to assess the risk of permafrost melt:* Need for research rated “medium” by majority of respondents. Issue linked to the potential costs to large-scale infrastructure.

Structures (buildings, roads, airports, sewers, pipelines, etc.)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by just under half of respondents; remainder split between “high” and “low”.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Developing designs for a progressively warmer climate:* Need for research rated “high” or “medium” by majority of respondents. Comments emphasized importance of planning for change over long term.

Flooding (spring melt, ice dams, extreme events, precipitation changes)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by half of respondents; rest split between “high” and “low”.
- *Knowledge about the impact of climate change: fair to very poor.* Need for research rated “medium” by majority of respondents; remainder split between “high” and “low”.

Sample issue:

- *Standards for building near water might need revision:* Need for research rated “medium” by majority of respondents. Comment noted need for revising standards may arise gradually, with time to adjust.

Other Issues

- Need for long-term observation of the behaviour of existing structures
- Need to develop methods to assess future risk and design for risk and change

Numerical Rating of Research Needs

Infrastructure System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Land Stability	54	58	55
Structures	51	58	57
Flooding	51	50	47

Detailed Overview of Responses

Aspect of the Infrastructure System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Land Stability (permafrost fragility, slumpage, landslides, etc.)	Fair	High: 5 Medium: 11 Low: 2	Fair to Very Poor	High: 8 Medium: 8 Low: 2	Find methods to assess risk of permafrost melt	High: 6 Medium: 11 Low: 2
Structures (buildings, roads, airports, sewers, pipelines, etc.)	Good	High: 5 Medium: 8 Low: 4	Fair to Poor	High: 8 Medium: 8 Low: 2	Develop designs for progressively warmer climate	High: 7 Medium: 9 Low: 2
Flooding (spring melt, ice dams, extreme events, precipitation changes)	Fair	High: 5 Medium: 8 Low: 4	Fair to Very Poor	High: 4 Medium: 9 Low: 4	Standards for building near water might need revision	High: 1 Medium: 13 Low: 3

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Infrastructure System	Potential Issue	Respondent Rating	Comment
Land Stability	Find methods to assess risk of permafrost melt	High	Melting permafrost could have a tremendous impact on the North.
		High	Important road network, important infrastructure related to oil & gas exploration, exploitation & distribution, important infrastructure in communities.

Aspect of Infrastructure System	Potential Issue	Respondent Rating	Comment
		High	Development of the North is increasing, in areas that are already subject to land stability problems (gas field development in Cordillera west of Ft. Liard, along Mackenzie River and in the Mackenzie Delta/Beaufort Sea coast areas).
		High	Consequences for infrastructure replacement on large scale.
		High	Assist in infrastructure upgrading planning.
		Medium	Find methods of assessing the risk of subsidence due to permafrost melt. Permafrost melt, in itself, has less impact on infrastructure.
Structures	Develop designs for progressively warmer climate	High	Little emphasis has been placed on design for change.
		High	New design standards in light of climate change are essential. In light of YESAA [Yukon Environmental and Socio-economic Assessment Act], these predictions need to be developed up front to help modify infrastructure development and reduce maintenance and liabilities.
		High	Infrastructure vital to Yukon economy & quality of life.
		Medium	Mid-term methods of preserving permafrost are known (protect surfaces, install in-ground insulation to preserve permafrost, etc), but longer-term implications of climate change will be harder to deal with.
Flooding	Standards for building near water might need revision	High	New design standards in light of climate change are essential. In light of YESAA [Yukon Environmental and Socio-economic Assessment Act], these predictions need to be developed up front to help modify infrastructure development and reduce maintenance and liabilities.
		Medium	Storm-water runoff standards may have to change with increased precipitation.
		Medium	This shouldn't be a major issue, UNLESS streamflows unexpectedly change significantly due to much higher precipitation (winter snow accumulation, summer rain storms, frequency & size of ice jams, etc). Issue bears watching, but problems expected to be local.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
l,b	Long-term observation of the behaviour of existing structures in [changing climate].	High
l,b	Develop standards and recommendations for risk assessment for [changing climate].	High

Respondent Category (see key on page 6)	Issue	Priority
a,n,i,g	In planning in the North, considerations for how to deal with subsidence due to permafrost degradation around foundation piles need to be addressed now. Building will have to withstand the changes.	High

15. The Transportation System

Thirty-five (40% of total) respondents indicated an interest in the transportation system. Of those, 17 filled out some or all of the transportation system survey sheet.

All responses to the transportation system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Transportation System Survey Responses

Barge/Shipping (important for coastal communities in Nunavut/NWT, communities along Mackenzie River)
Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: fair to poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *The opening of the Northwest Passage could increase ship numbers:* Need for research rated “high” or “medium” by half of respondents; rest split between “high” and “low”. Comments cited lack of capacity to handle an oil spill in the Arctic and the impact of increased open water on the climate system..

Road (highways, local roads, seasonal access to resources, winter roads, ice bridges, ferries)

Baseline and impacts research:

- *Baseline knowledge: good.* Need for research rated “medium” by half of respondents; remainder split between “high” and “low”.
- *Understanding of the impacts of climate change: fair to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Degrading permafrost might increase road maintenance costs:* Need for research rated “high” or “medium” by majority of respondents. Comments cited higher costs, revision of construction standards.

Snowmobile/All-Terrain Vehicles (use: general travel, hunting, fishing, gathering country foods, recreation)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” or “low” by majority of respondents.
- *Knowledge about the impacts of climate change: fair to very poor.* Need for research rated “medium” by just under half of respondents; rest split between “high” and “low”.

Sample issue:

- *Developing engines that emit less pollution and greenhouse gas:* Need for research rated “high” or “medium” by majority of respondents. Comment noted these emissions are insignificant part of global emissions.

Air (range from major airlines to bush planes, floatplanes, helicopters)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” or “low” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Air temperature may affect load capacity:* Need for research rated “medium” or “low” by majority of respondents. Comments noted minimal impact on loads and communities, jet engines may help distribute greenhouse gases into upper atmosphere.

Rail (used now in southern NWT, southwest Yukon, northern Manitoba & Quebec)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Knowledge about the impacts of climate change: very poor:* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Freeze-thaw cycles could damage the rail bed:* Need for research rated “medium” by majority of respondents. Comments noted that rail is of little importance in much of the North.

Other Issues

- Potential increase in freeze-thaw cycles and their impact on roads

Numerical Rating of Research Needs

Transportation System

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Barge/Shipping	45	46	48
Road	50	57	56
Snowmobile/All-Terrain Vehicles	44	48	54
Air	52	42	40
Rail	45	50	48

Detailed Overview of Responses

Aspect of the Transportation System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Barge/Shipping (important for coastal communities in Nunavut/NWT and communities along Mackenzie River)	Fair	High: 1 Medium: 9 Low: 4	Fair to Poor	High: 2 Medium: 8 Low: 4	Opening of Northwest Passage could increase ship numbers.	High: 3 Medium: 7 Low: 4
Road (highways, local roads, seasonal access to resources, winter roads, ice bridges, ferries)	Good	High: 4 Medium: 8 Low: 4	Fair to Very Poor	High: 7 Medium: 8 Low: 2	Degrading permafrost might increase road maintenance costs.	High: 5 Medium: 11 Low: 1

Aspect of the Transportation System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Snowmobile/All Terrain Vehicles (used for general travel, hunting, fishing, gathering country foods, recreation)	Fair	High: 2 Medium: 6 Low: 5	Fair to Very Poor	High: 3 Medium: 6 Low: 4	Develop engines that emit less pollution, greenhouse gas.	High: 4 Medium: 6 Low: 2
Air (range from major airlines to bush planes, floatplanes, helicopters)	Fair	High: 1 Medium: 7 Low: 5	Poor to Very Poor	High: 0 Medium: 9 Low: 4	Air temperature may affect load capacity.	High: 1 Medium: 6 Low: 6
Rail (used now in southern NWT, southwest Yukon, northern Manitoba & Quebec)	Fair	High: 1 Medium: 7 Low: 3	Very Poor	High: 2 Medium: 7 Low: 2	Freeze-thaw cycles may damage rail bed.	High: 1 Medium: 9 Low: 2

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Transportation System	Potential Issue	Respondent Rating	Comment
Barge/Shipping	Opening of Northwest Passage could increase ship numbers.	High	There is very little capacity in the Arctic to deal with a tanker oil spill - and what is the effect of an oil spill on sea ice (and how do you clean it up)?
		High	Besides increased shipping, presence of more open water will have major impact on Arctic and circumpolar climate (the Arctic is a major driver of global climate & changes here need to be better understood).

Aspect of Transportation System	Potential Issue	Respondent Rating	Comment
		High	Duration of the open-water period is increasing, however duration of OPTIMUM barging season on the Mackenzie River (period of non-restricted loads) may decrease. This would be due to greater drawdown of large lakes (Great Slave Lake, Great Bear Lake, Lake Athabasca, etc.) with outlets (and outflows) less restricted by winter ice. This may lead to lower lake levels, and lower 'firm' summer flows from lake outflow on the lower Mackenzie. This could be counteracted by higher summer precipitation in the Cordillera and major upstream tributaries (i.e. Peace/Athabasca, & Liard rivers).
Road	Degrading permafrost might increase road maintenance costs.	High	Very significant funds may be required to mitigate this impact.
		High	Cost per capita.
		High	Vital links between communities & industries.
		High	Alaska indicates that they are already paying more money for maintenance of their roads.
		High	Construction standards to account for climate change.
		Medium	Increased costs of goods.
		Medium	Northern transportation networks are poorly developed but important to further development. Plans for expansion of networks may be compromised by higher costs due to climate change.
		Medium	Impacts on winter ice roads, ice bridges and ferry crossings described elsewhere. Road maintenance could well increase. GNWT already promoting idea of pre-building Mackenzie Highway bridges to maximize duration of winter roads (by eliminating the need for early annual removal of river crossing approaches prior to spring runoff).
Snowmobile/All-Terrain Vehicles	Develop engines that emit less pollution, greenhouse gas.	High	Go to four-cylinder engines now - and maybe follow the European example of restricting where snowmobile/all terrain vehicles can go and what they can be used for.
		High	Impacts are both global (climate change) and local (effects of pollution on lichen, etc.).
		High	Alternative fuel/engines for all fossil-fuel vehicles.

Aspect of Transportation System	Potential Issue	Respondent Rating	Comment
		High	4-stroke incentive policy? Offset increased costs.
		Medium	Increased impact on terrain.
		Medium	While higher polluters, this is a minor part of the CO2 emissions problem.
Air	Air temperature may affect load capacity.	High	Are jet engines distributing climate-change-causing gases high in the atmosphere, thus allowing them to get to work quicker?
		Medium	Reliance on air travel.
		Low	Air temperatures affect load capacity but in minor way.
		Low	Minimal effect. Most communities have airstrips, rather than depending on float or ski-equipped aircraft.
Rail	Freeze-thaw cycles may damage rail bed.	High	Interest in rail link between BC and Alaska.
		Medium	Better design for railways to increase their presence in the North.
		Medium	Rail not very important part of northern transportation industry, as opposed to trucking.
		Medium	Agreed, but NWT use is minimal.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
e	Longer spring and fall seasons may cause greater frequency of freeze-thaw cycles. This would lead to more ice on the highways, greater costs for highway maintenance, and more dangerous driving conditions.	Medium

16. The Waste Management System

Twenty-eight (32% of total) respondents indicated an interest in the waste management system. Of those, 12 filled out some or all of the waste management system survey sheet.

All responses to the waste management system survey are summarized below, with more detail in the following table. The added issues are listed in a separate table, together with the respondent's rating of the importance of the issue. Each of the listed issues was suggested by a single respondent.

Summary of Waste Management System Survey Responses

Waste Treatment (treatment of human and industrial waste before release)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “high” or “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor to very poor.* Need for research rated “high” or “medium” by majority of respondents.

Sample issue:

- *Winter climate conditions might affect winter effluent decomposition:* Need for research rated “medium” by majority of respondents. Comments noted evaporation could affect efficiency of sewage lagoons, warmer winters might help some waste treatment processes.

Waste Storage (landfills, dumps, sewage lagoons, tailings ponds, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the effects of climate change: poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *Permafrost barriers are used in some waste storage deposits:* Need for research rated “medium” by all respondents. Increased precipitation noted as a further issue in security of waste storage deposits.

Waste Transportation (transporting dangerous goods, road conditions, etc.)

Baseline and impacts research:

- *Baseline knowledge: poor.* Need for research rated “medium” by majority of respondents.
- *Knowledge about the impacts of climate change: poor to very poor.* Need for research rated “medium” by majority of respondents.

Sample issue:

- *A shorter winter road season might restrict the movement of waste:* Need for research rated “medium” by majority of respondents.

Contaminants (long-range transport, movement in ecosystem, locally-produced contaminants, etc.)

Baseline and impacts research:

- *Baseline knowledge: fair.* Need for research rated “medium” by majority of respondents.
- *Understanding of the impacts of climate change: poor.* Need for research rated “high” or “medium” by all respondents.

Sample issue:

- *Warmer conditions may affect the movement of contaminants through the system:* Need for research rated “high” or “medium” by majority of respondents. Effects on long-range transport, drinking water noted.

Other Issues

- Dumps and lagoons too close to communities
- Metal wastes accumulating in dumps

Numerical Rating of Research Needs**Waste Management System**

(Medium = 50. Ratings of 60+ are highlighted.)

Aspect	Baseline Knowledge	Climate Change Impacts	Sample Issue
Waste Treatment	62	60	52
Waste Storage	55	58	50
Waste Transportation	45	45	45
Contaminants	52	58	52

Detailed Overview of Responses

Aspect of the Waste Management System	Baseline Knowledge: Current State	Importance of Further Research	Impacts of CC: Current Knowledge	Importance of Further Research	Potential Issues	Priority Ranking (see table below for comments)
Waste Treatment (treatment of human and industrial waste before release)	Poor	High: 5 Medium: 5 Low: 0	Poor to Very Poor	High: 4 Medium: 6 Low: 0	Winter climate conditions may affect effluent decomposition	High: 2 Medium: 7 Low: 1
Waste Storage (landfills, dumps, sewage lagoons, tailings ponds, etc.)	Fair	High: 3 Medium: 6 Low: 1	Poor	High: 3 Medium: 7 Low: 0	Permafrost barriers used in some waste storage deposits	High: 0 Medium: 10 Low: 0
Waste Transportation (transporting dangerous goods, road conditions, etc.)	Poor	High: 0 Medium: 8 Low: 2	Poor to Very Poor	High: 0 Medium: 8 Low: 2	Shorter winter road season may restrict movement of waste	High: 0 Medium: 8 Low: 2
Contaminants (long-range transport, movement in ecosystem, locally-produced contaminants, etc.)	Fair	High: 2 Medium: 8 Low: 1	Poor	High: 4 Medium: 8 Low: 0	Warmer conditions may affect movement of contaminants through environment	High: 2 Medium: 9 Low: 1

Potential Issues: Selected Comments on Sample Issue

Respondents were asked to comment on their rating of the sample potential issue provided for each aspect of the system, particularly if they rated as high the need for further research in that area. Many of the comments provided useful insights into the respondent's reasoning or highlighted particular research needs. All comments are reproduced in the following table.

Aspect of Waste Management System	Potential Issue	Respondent Rating	Comment
Waste Treatment	Winter climate conditions may affect effluent decomposition.	High	Effective waste management is the basis of civilization.
		High	Evaporation of sewage lagoon; impact on effectiveness of lagoon.
		Medium	Actually, it might help. Check out what the City of Whitehorse is doing with its composting program.
Waste Storage	Permafrost barriers used in some waste storage deposits.	Medium	Compost rate, leachate concerns with increased precipitation.
Contaminants	Warmer conditions may affect movement of contaminants through environment.	High	Long-range transport may shift up or down.
		Medium	Effect on drinking water.

Other Issues

Respondents were asked to add any particular issues they feel merit research and to rate the importance of the research. Each of the following issues was suggested by one of the respondents to the Online Survey.

Respondent Category (see key on page 6)	Issue	Priority
f,h	Dumps/lagoons too close to communities pose risk to people.	High
f,h	Metal wastes piling up in dumps... no remediation.	High