

CLIMATE RISKS AND ADAPTIVE CAPACITY IN ABORIGINAL COMMUNITIES FINAL REPORT

AN ASSESSMENT SOUTH OF 60 DEGREES LATITUDE



“Building adaptive capacity requires a strong, unifying vision; scientific understanding of the problems; an openness to face challenges; pragmatism in developing solutions; community involvement; and commitment at the highest political level” (Holmes, 1996 in Smit et al. 2001)

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1 INTRODUCTION

This document reports on the first year of a proposed three-year project to understand the potential consequences and challenges of climate change for Aboriginal communities south of 60° latitude. It is hoped that this report and subsequent outcomes of the project will help to point the way to how such communities may be better enabled and assisted to cope with both the expected and unexpected challenges that lie ahead.

1.1 PROJECT CONTEXT, AND RATIONALE

Aboriginal communities north of the 60th parallel in Canada are the focus of concerted efforts to document current climate changes and to understand processes of these changes (e.g. Arctic Climate Impact Assessment, ArcticNet, Community Adaptation and Vulnerability in Arctic Regions - CAVIAR). Knowledge gained from these studies will assist communities north of 60° to cope with and adapt to the changes in climate, the environment, cultures and economies. Conversely, Aboriginal communities south of 60° are receiving less intensive efforts regarding both the impacts of climate change and their abilities and processes to cope with and adapt to change. This lack of attention has resulted in a dearth of information about the biophysical, economic, social and cultural impacts of climate change south of 60°. Similarly, the capacity of Aboriginal communities south of 60° to adapt to climate impacts with respect to their cultures, social relations, economic wellbeing, and governance remains largely unknown. This relative lack of research and understanding increases uncertainty about possible negative effects and potentially limits the capacity of people and institutions related to Aboriginal communities south of 60° to react and cope effectively.

It is already the case that many Aboriginal communities south of 60° face multiple challenges related to rapid growth in the population with higher proportions of young people, high and rising rates of poverty and unemployment, generally lower education attainment, substandard infrastructure relative to national averages, insufficient and unsafe housing, high food costs especially in remote regions, poor drinking water, lack of employment opportunities, and high rates of diabetes to name a few (Canada 1996). Research in other jurisdictions shows that managing the impacts of climate change affects multiple facets of community life (social, cultural, economic, environmental) often compounding current challenges and stressors (IPCC

2007; Lemmen et al. 2008). The dynamics of these interactions are complex and poorly understood in Canada, perhaps nowhere more so than in Aboriginal communities south of 60°.

Our understanding of the processes and capacities of such communities to adapt is similarly limited. According to Grothmann et al. (2005), the key factor at the individual level affecting the motivation to adapt to climate change impacts is relative risk perception. Relative risk perception refers to the relationship between the perceived threat (in this case the probability of exposure to climate change impacts and associated negative effects) versus the perceived harm or difficulty expected from other challenges, risks and threats (Grothmann et al. 2005)¹. Historically Aboriginal communities have coped with and adapted to multiple challenges and stressors. Many communities take pride in the strength of their membership to organize and cooperate during a crisis and endure the hardship together. One concern is that climate change will increase the frequency and/or magnitude of challenges that may exceed communities' abilities to cope and adapt (Smit and Wandel 2006).

Furthermore, it is well established that there is only so much that individuals can do when it comes to coping, let alone adapting, to the multi-scale impacts of climate change. Beyond the individual perception of risk and motivation to create change there are other factors that influence a community's capacity to change or adapt, such as who has the power to make change, what are the decision-making processes and in whose interest are decisions made. An institutional perspective is helpful here and will be articulated in greater detail below (see Sections 3 & 4). The institutional context occupied by Aboriginal communities south of 60° includes both local, community level institutions² and other governance institutions with which Aboriginal communities interface. Institutions are increasingly recognized as having a prominent role in determining how well or how poorly these communities are able to reduce the negative impacts and take advantage of potential opportunities associated with climate change.

1.2 PROJECT DESCRIPTION AND STRUCTURE OF THE REPORT

¹ For example, how motivated is a community to prepare for coastal erosion relative to the motivation to address the loss of all heat in the school during January.

² Institutions are not only distinct organisations (e.g., administrative agencies), but more broadly they include, sets of regulations, policies, procedures or practices that stipulate behavioural responsibilities for actors, constrain activity, and influence expectations (Keohane 1988).

In the spring of 2008, the Centre for Indigenous Environmental Resources (CIER) completed a report entitled, *Climate Change Adaptation Assessment and Priorities for First Nations South of 60° Latitude* that provided an overview of key climate change impacts and related challenges. In the summer of 2008, CIER and researchers at the University of British Columbia (UBC) partnered to add depth to those initial findings, expand the scope to include Inuit and Métis communities south of 60° (Figure 1) and focus more explicitly on issues of capacity and vulnerability.

The project focuses on Aboriginal communities that are south of 60° latitude in order to address a gap in the research and understanding of climate change and its effects on Aboriginal peoples in Canada. To fulfil this mandate three overarching goals were identified:

- Increase knowledge about climate change impacts on Aboriginal communities south of 60°;
- Increase knowledge about the risks climate change poses to these communities and how these are linked to other challenges and stressors;
- Assess capacity of these communities to respond, manage or otherwise cope with direct and indirect effects of climate change, including the factors that may lead some Aboriginal communities to be more at risk than others.

The objectives of year one were to define and initiate several project elements, some of which will be ongoing, and to develop the conceptual framework and approach to guide the implementation of the project goals set out above. In section 2 of this report we provide a review and synthesis of key climate risks as they relate to Aboriginal peoples south of 60°. The review is based on the earlier report carried out by CIER (2007) and the more recently released national assessment published by Natural Resources Canada, *From Impacts to Adaptation: Canada in a Changing Climate 2007* (Lemmen et al. 2008). The latter report provided a region-by-region assessment of the state of knowledge about how climate change is affecting communities and economic sectors across the country. More importantly, the report sought to prioritize information and experience on adaptation and adaptive capacity. The current project places a similar emphasis in the context of Aboriginal peoples and communities in Canada south of 60°.

Section 3 of the report presents a short discussion and review of the key concepts and terms emerging from the rapidly developing field of global environmental change research and related

fields such as development studies, human health and wellbeing, hazards and disaster research, and natural resource management. These core concepts, vulnerability, adaptive capacity and resilience, are not new but have an increasing importance in research concerned with interactions between human and ecological systems. In the context of climate change they focus attention less on the specific impacts of, for example, increased drought, more extreme weather, or warmer winters. Instead, they direct attention to social (and ecological) factors that influence the extent of potential damage and/or the suite of resources, abilities, knowledge and so on that may equip a place to respond or cope. Institutions are increasingly recognized as having a central role to play in adaptive actions and as such are often central to the building of adaptive capacity and resilience, the reduction of vulnerability, and the implementation of adaptation. But what are the implications of these concepts for policy makers? The desire to reduce vulnerability implies that it can or should somehow be measured; however, this remains a challenge for research. Indicators of vulnerability, adaptive capacity and resilience (see section 3.3) have so far relied heavily on proxy measures and other indirect methods (O'Brien et al. 2004; Vincent 2004). While progress is being made aggregating data at international and national scales, there are usually important contextual issues and challenges with data availability and consistency, especially when attempting to consider these issues at a local level. We argue in the pages below that given the diversity of Aboriginal peoples in Canada, in addition to the range of social, economic, geographic, and ecological conditions that characterize their communities, the problem is best approached from the bottom up.³ Hence, this project approaches the assessment of climate risks and adaptive capacity of Aboriginal people south of 60° through a local lens with an emphasis on local and regional dimensions of vulnerability, adaptive capacity and resilience. Understanding such dimensions and the social processes in which they are embedded will, in our view, provide a solid footing from which to

³ The same applies to the development of vulnerability and/or risk assessment tools, that is, while there are several excellent examples of these tools, their suitability to the Aboriginal context in Canada and specifically in communities south of 60° is not given. As a starting point for the purposes of this report we have provided an initial review of several assessment tools in Appendix 2. The intent is to provide background to later consideration of the feasibility of providing a framework for the development of some form of self- assessment tool(s) that may ultimately be suitable for application in Aboriginal communities and settings related to this project.

consider effective policy and programming responses to climate change for Aboriginal communities south of 60°.

Operationalizing these core concepts and implementing the broader objectives of the project are the focus of section 4. This includes discussion of how an informal research network has been initiated, the process for identification of two types of case studies, and the development of a basic participatory research framework to guide community-based research. Section 5 completes the report with a summary of year one and a brief discussion of the trajectory for year two.

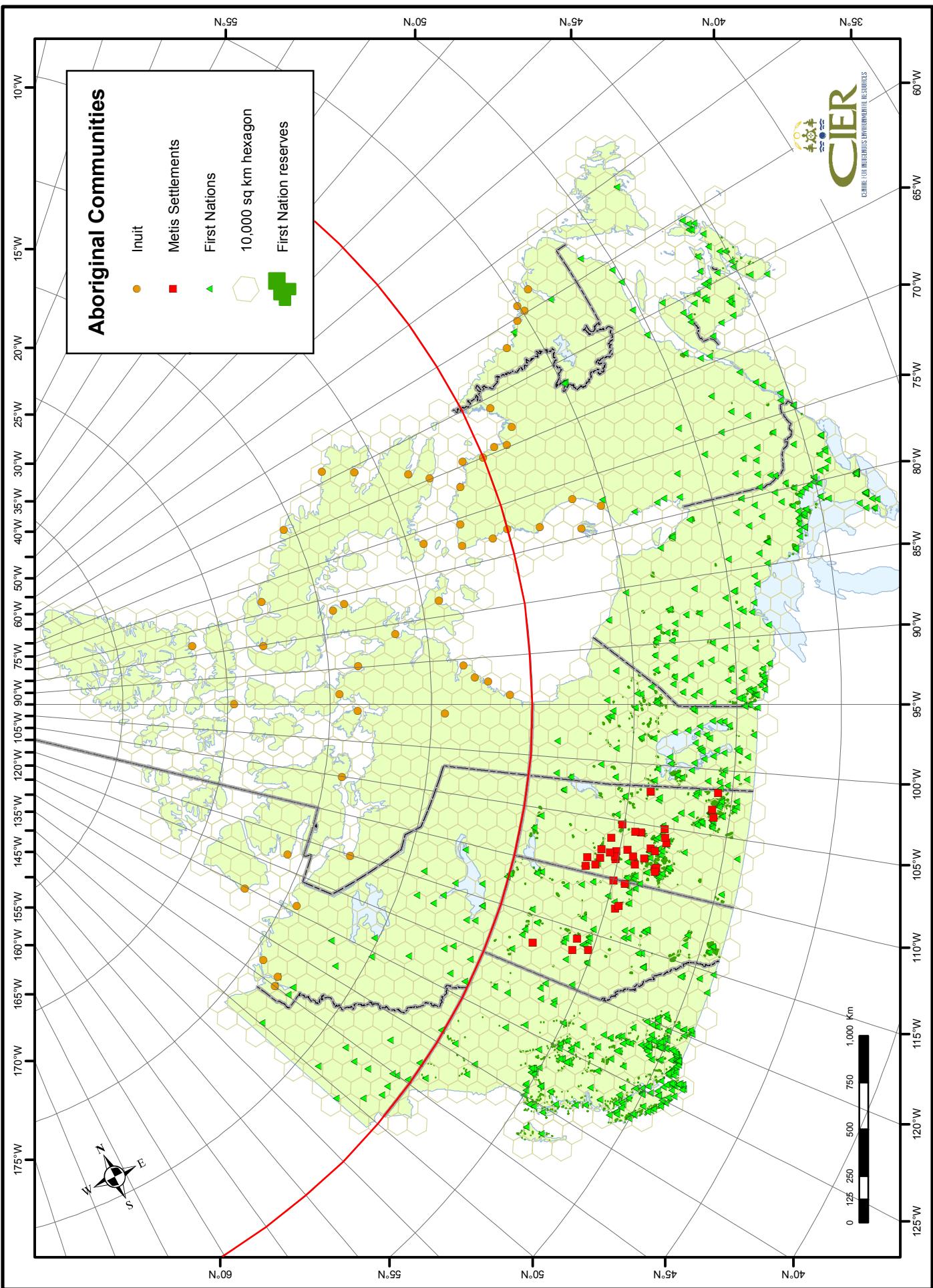


Figure 1. Aboriginal Communities in Canada

2 CLIMATE RISKS AND ABORIGINAL PEOPLES SOUTH OF 60°

The social, economic, and political context of Aboriginal communities is key to understanding the exposures, sensitivities and adaptive capacity of Aboriginal communities. As a first step, it is important to provide an overview of the many challenges Aboriginal communities face that directly relate to the realities of the people who live there. In essence these challenges and realities are elements that affect the vulnerability and adaptive capacity of these communities.

In Canada, the Aboriginal population is comprised of First Nations, Inuit, and Métis. In 2006, over 1.1 million people in Canada self-identified as being an Aboriginal person; this represents 3.8 % of the total Canadian population⁴. The self-identified First Nation population totalled 698,025 individuals, of which 40% (279,210) lived on a reserve. The Métis population totalled 389,785 and the Inuit population totalled 50,485. The Aboriginal population, like many other populations in the world, is moving to urban areas. In 2006, 54% lived in an urban centre, an increase from 50% in 1996.

The Aboriginal population is relatively young as compared to the rest of Canada. In 2006, approximately 50% of the Aboriginal population was under the age of 25 as compared to only 31% of the non-Aboriginal population. Children under 15 years accounted for 30% of all Aboriginal people in 2006, compared with 17% of the non-Aboriginal population.

In relation to education, income and employment, there are lower formal education levels, employment rates and average income levels in Aboriginal communities than in non-Aboriginal communities. Aboriginal peoples rate lower than the general Canadian population on all formal education attainment indicators. In 2006, the high school completion rate for Aboriginal peoples was 52% as compared to 69% for the total Canadian population. The unemployment rate was

⁴ There are three groups of Aboriginal Peoples that are recognized in Canada: First Nations (previously referred to as Indians), Métis, and Inuit. The Indian Act defines an Indian as “a person who, pursuant to this Act, is registered as an Indian or is entitled to be registered as an Indian.” The Act sets out the requirements for determining who is a Status Indian. Métis is defined by the federal government as people of mixed First Nation and European ancestry who identify themselves as Métis people, as distinct from First Nations people, Inuit or non-Aboriginal people. Inuit means “people” in Inuktitut, the Inuit language. Most Inuit live in Nunavut, the Northwest Territory, northern Quebec and Labrador. Each of the three groups, and members within each group, has unique heritages, languages, cultural practices and spiritual beliefs.

14.8% in 2006 for the Aboriginal population, as compared to 6.6% for the total Canadian population. The average individual income among Aboriginal people was \$23,935, as compared to \$35,501 for the Canadian population (Statistics Canada 2008).

However, it is important to note that customary forms of education and economies continue to occur in Aboriginal communities. Informal education (passing on traditional teachings and knowledge by knowledgeable members) and informal economies (e.g. traditional activities such as hunting, fishing, and gathering, as well as practices such as sharing harvest, trading, etc.) take place to different degrees in Aboriginal communities and remain as important cultural, social and economic components of these communities. The value of informal education and economies has not been quantified at a national scale, although, it is thought that these and local knowledge systems may be key factors in building resiliency in Aboriginal communities.

There are many factors that create unique vulnerabilities for Aboriginal peoples such as location, poor socio-economic conditions, poor health status and inadequate infrastructure. Over the past decade, the share of Aboriginal people living in crowded homes has declined. In 2006, 11% of Aboriginal people lived in homes with more than one person per room, down from 17% in 1996 (Statistics Canada 2008). However, housing conditions remain unchanged since 1996 as nearly one in four people continued to live in homes requiring major repairs in 2006. When compared to the Canadian population, Aboriginal people were almost four times as likely as non-Aboriginal people to live in a crowded dwelling. Furthermore, Aboriginal people were three times as likely to live in a dwelling in need of major repairs. Additionally, in 2008, at least 85 of the 615 First Nation water systems are in high risk and there are 106 boil water advisories in various communities (INAC 2008). There are a number of health related challenges in Aboriginal communities including high rates of chronic and contagious diseases and shorter life expectancy.

2.1 IMPACTS OF CLIMATE CHANGE TO ABORIGINAL PEOPLES SOUTH OF SIXTY

While climate change impacts everyone, it has a particularly adverse affect on Aboriginal peoples whose lifestyles are more connected economically and culturally linked to the natural environment. In addition, the unique realities of Aboriginal communities, as noted above, add to the exposures, sensitivities and adaptive capacity of these communities. As a result of compounding factors related to lifestyles and community realities, climate change impacts can

exacerbate, in many cases, the already stressed health, wellbeing and cultural life of an Aboriginal community.

Drawing on the report completed by CIER (2008) *Climate Change Adaptation Assessment and Priorities for First Nations South of 60 Degrees Latitude and the Government of Canada's From Impacts to Adaptation: Canada in a Changing Climate 2007* (Lemmen et al. 2008), a summary overview of current and predicted climate impacts on Aboriginal communities south of 60° are identified along with the regions they apply to (see Appendix 1 for more details of impacts). This is not intended to provide an in-depth review of climate change but rather to highlight the impacts climate change will have on Aboriginal peoples south of 60° nationally. The headings used are based on all facets of a community (social, culture, economic, environmental) merely to serve as a way to highlight what climate change means for Aboriginal communities.

Cultural Impacts

Climate change will raise serious challenges for Aboriginal peoples' traditional culture and way of life that are closely tied to the natural world. Cultural impacts resulting from climate change include:

- Loss of access to the land due to melting ice and thawing permafrost in northern areas (Prairies, Ontario north, Quebec, Atlantic) and floods in coastal areas (B.C., Atlantic, Quebec regions)
- Decreases in safety on the land due to increases in unpredictable weather, extreme weather, and a decline in depth and cover of ice (B.C., Quebec, Prairie regions)
- Loss of traditional foods and medicines due to changing plant and animal ranges, shifting seasons and erratic and/or extreme weather (Atlantic, Quebec, Ontario north, Prairie regions)
- Loss of cultural sites due to sea level rise (B.C. region)

Social Impacts

The social aspect of Aboriginal communities takes into consideration the social conditions and internal characteristics of a community that relate to health and wellbeing. As there is a direct

link between weather, climate, human health and wellbeing, social impacts resulting from climate change include:

Transportation Impacts

- Shorter ice road season (Ontario north and central, Prairie regions)
- More dangerous travel due to decline in depth and cover of ice (Quebec, Prairie regions)
- Loss of permafrost resulting in damage to roads and rail lines (Quebec and Prairie regions)
- More reliance on air cargo for supplies resulting in increased costs (Prairie, Ontario north regions)

Infrastructure Impacts

- Roads more expensive to maintain because of damage from permafrost thaw, extreme weather, changing seasons (Quebec, Prairie regions)
- Increases in flood damage to buildings, roads, bridges, rail lines, etc. (Prairie, B.C., Quebec, Atlantic regions)
- Destruction of piers and docks (Ontario region)
- Slumping of lands from permafrost melt causing damage of buildings, houses, etc. (B.C., Quebec, Prairie regions)

Health Impacts

- Lower health care quality and other services due to limited access (Ontario north, Prairie regions)
- Limited access to and availability of traditional foods (Atlantic, Quebec, Ontario north, Prairie regions)
- Increases in air pollution, water and food borne pathogens (Atlantic, Quebec, Ontario, Prairies, B.C. regions)

Economic Impacts

Many Aboriginal economies are based on both informal (e.g. traditional activities such as hunting, fishing, trapping) and formal (income generating) economies that are often dependent to some degree on natural resources and therefore highly susceptible to climate change and its associated impacts. Economic impacts resulting from climate change include:

- Reduced ability to predict seasons having impacts to various informal and formal economic endeavours, i.e. wine making, trapping, fishing, forestry (Atlantic, Quebec, Ontario central and north, Prairie regions)
- Increased risk to forestry operations due to affects on winter roads, forest fires, insect infestation (Ontario, Prairies, B.C. regions)
- More frequent and prolonged drought and flood events (Prairie region)

Environmental Impacts

Aboriginal peoples have an intimate, long-standing relationship with the land that is interconnected with all aspects of Aboriginal communities including social, cultural and economic facets. Therefore, changes in the environment will result in broad and far-reaching affects on Aboriginal communities. Environmental impacts resulting from climate change include:

- Increased risk to water quantity due to low water levels (Ontario south, Prairies, B.C. regions); flooding (Ontario, Prairies, B.C. regions)
- Increased risk to water quality due to water borne diseases (Ontario north and south regions); decreases in stream flow (Ontario central and north, Prairie regions); and coastal erosion and storm surges (B.C. region)
- Changes in aquatic and terrestrial ecosystems due to warming temperatures: delayed ice formation, earlier break up, invasions of non-native species (Ontario south and north, Prairie regions)
- More frequent and prolonged droughts (Prairie region)

- Increases in forest fires due to drought, high temperatures and spruce budworm (Ontario central and north, Prairies, B.C. regions)

3 UNDERSTANDING VULNERABILITY, ADAPTIVE CAPACITY, AND RESILIENCE

As noted elsewhere in this report (see Section 2 and Appendix 1) climate change impacts are being felt in communities and sectors across the Canadian landscape (Lemmen et al. 2008). However, unlike the Arctic, in regions south of 60° changes are often less explicit, indirect and/or harder to discern from other biogeophysical dynamics. Despite measurable changes and variations in the instrumental record and extensive work on sophisticated climate models and advances in climate science (IPCC 2007), uncertainty remains a prominent feature of climate prediction and impacts scenarios. Furthermore, while planning and preparing for climate change may benefit immeasurably from the input of carefully construed scenarios and scientific models, these are often unavailable or difficult to obtain, especially at the regional or local scale where specific adaptation planning and actions actually take place. In order to overcome this lack of certainty and/or availability of information in the future, climate complimentary approaches and concepts have emerged that help further the understanding of adaptation. These approaches look first at underlying factors such as social and economic conditions, cultural and political context and institutions and how these factors influence the ways in which people respond to climate hazards. The rationale behind the argument, that it is not necessary to know everything about future climate impacts prior to developing response plans and policies, is summed up by researchers from the Tyndall Centre for Climate Change Research at the University of East Anglia in England:

Vulnerability assessments do not require detailed climate information generated by models (which is not available for many parts of the world), and they do not require us to wait until the science of climate “prediction” is more developed. Adaptation policies may therefore be developed despite the uncertainties inherent in the science of climate change - while a detailed knowledge of likely or potential future climate would be desirable, lack of it need not be an impediment to increasing the general resilience of

societies to the types of threat that they may be expected to face in the future. (Adger et al. 2004)

It is this so-called vulnerability-led approach to climate change impacts and adaptation that underlies the core principles and focus of the current project. However, this does not preclude the need in the (near) future for the inclusion of predictive tools to strengthen adaptation planning.

3.1 SUMMARY OF KEY CONCEPTS AND DEFINITIONS

These key concepts; *vulnerability*, *adaptive capacity*, and *resilience* and related terminology such as, *adaptation*, *risk*, *exposure*, *sensitivity*, and *social-ecological system* are not unique to climate change research. Many have been developed and applied in a wide range of fields including food security, natural hazards and disaster management, risk, development studies, health and ecology to name a few (Füssel and Klein 2006, Smit and Wandel 2006, Brooks 2003, Adger 2000). Increasingly, they are used in the context of climate change adaptation research and policy. Below we provide a brief review of the key ideas and main debates behind these concepts and where appropriate discuss how they may be operationalized in the context of Aboriginal communities in Canada south of 60°. In section 3.2 we consider the pressure to produce quantifiable measures of vulnerability, adaptive capacity and resilience and the various approaches and challenges of developing meaningful indicators. We close the section with an argument for the importance of a contextual, bottom-up approach to understanding how adaptive capacity and resilience may be enhanced and vulnerability reduced in the face of climate risks.

Vulnerability

Vulnerability is often defined in relatively negative terms, connoting the absence of ability to cope, weakness in the face of adverse conditions, and susceptibility or potential for harm (cf Adger 2000, Brooks 2003, Adger 2006, Gallopin 2006, Smit and Wandel 2006). For some, vulnerability is the opposite of sustainability (Rudel 2008). Vulnerability is embedded in the United Nations Framework Convention on Climate Change (UNFCCC) in which it states that it is the duty of wealthier nations to assist developing nations and regions with adaptation in order to reduce their vulnerability to the adverse effects of climate change (UNFCCC Article 4.4). The IPCC has consistently defined vulnerability as a function of how much climate change can hurt

(sensitivity) and how able and prepared a place is to respond and cope (adaptive capacity), although, more recently consideration of the specific threats or changes that are faced (exposure) has been included (IPCC 1995, 2001, 2007):

[Vulnerability is] the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC 2001, 2007).

The main limitation of the IPCC definition, however, is that it is too narrow. In fact vulnerability arises due to a multitude of factors and conditions including but not limited to climate change. Vulnerability to climate change or environmental change more generally, cannot be isolated from political, social, historical and economic factors (Adger 2006). This is a particularly salient point with respect to Aboriginal communities in Canada, the context of which is summarized in the preceding sections.

The IPCC definition and related approaches to vulnerability assessment effectively treat vulnerability as an end point (Kelly and Adger 2000). In other words, vulnerability is what is 'left over' after threats have been identified and various responses have been developed, if not actually implemented (Kelly and Adger 2000, Brooks 2003, Adger 2006). As such, this approach may be viewed as relying too heavily on future predictions of impact and harm (Kelly and Adger 2000, Smit and Wandel 2006). Others argue that IPCC definitions have contributed to the confusion of policy makers by representing vulnerability as either or both an outcome (i.e. "end point") and a context in which adaptation takes place (O'Brien 2005)

The hazards or risk literature will often define vulnerability in terms of a measure of the loss of human life (e.g. the most vulnerable population will suffer the highest loss of human life during an environmental crisis/change/event). However, there are other potential negative outcomes of an environmental crisis on a vulnerable population. For example, if a population is highly dependent on one type of economy (e.g. mining or forestry), environmental changes that remove this economy can have disastrous effects on the community, without actually resulting in a loss of human lives. Additionally for Aboriginal communities, vulnerability could be measured in terms of the negative cultural outcomes. For example, if an environmental hazard took place in which Aboriginal community members were no longer be able to hunt traditional

foods, this could lead to a number of negative consequences including: lower nutritional quality of the replacement foods, loss of social interactions during hunt, loss of passing of traditions and knowledge, loss of physical activity, and economic losses from increased cost from buying market foods and inability to trade or share foods.

In contrast, treating vulnerability as a “starting point” for analysis distinguishes between biophysical and social vulnerability (Blaikie et al. 1994, Kelly and Adger 2000, Brooks 2003). Biophysical vulnerability is concerned primarily with the exposure of a social-ecological system to a specific hazard or hazards and its sensitivity to the impacts (social and/or physical) of the hazard(s) (Brooks 2003), for example, if a population lives in an area with a high probability of extreme events such as earthquakes or hurricanes, inundation from sea level rise or drought. Biophysical vulnerability relates to the amount of damage that may be done and as such is sometimes characterized by “outcome” indicators such as mortality or property damage (Brooks 2003).

Social vulnerability takes into consideration the social conditions that either enhance or reduce the susceptibility of a group of people to harm from a hazardous event, as well as, the capacity of the population to respond or cope. Social vulnerability stems from inherent or internal characteristics of a community, for example a high number of single parent households, and as such is viewed as independent of specific impacts or hazards. Examples of factors that effect social vulnerability include food and resource entitlements, equity, poverty, and the role of institutions (Adger 2006).

The separation of biophysical and social types of vulnerability serves a useful conceptual and analytical purpose without losing sight of the interdependency of processes and conditions that make up vulnerability. In the end, it is the dynamic relationship between the conditions to which a community is exposed, how sensitive the community is to the harm posed by such conditions (increasingly referred to by the compound term *exposure-sensitivity*) and the capacity of the community to effectively adapt that determines local vulnerability (Smit and Wandel 2006). Nevertheless, while acknowledging the existence of external biophysical forces, the emphasis on the social construction of vulnerability allows researchers and practitioners a starting point based on analysis of existing conditions rather than relying on attempts to predict adaptive behaviour amid the uncertainty of changing conditions (Kelly and Adger 2000).

There are ongoing debates across multiple disciplines about the precise definition of vulnerability, as can be seen from the preceding discussion. Different uses and conceptualizations arise as much from the disciplinary orientation of researchers as to the policy context in which vulnerability is being applied (Adger 2006, Füssel 2006). Füssel speaks of “vulnerability as a ‘conceptual cluster’ for human-environmental research” (2006) and is concerned about the barriers to understanding created by conflicting terminologies. Yet despite his pessimism, Füssel (2006) argues that proper consideration of the specific purpose and context of vulnerability assessment is one way to surpass problems of definition. We consider elements of his proposed framework in the following section. Adger (2006) is more optimistic and sees the potential for convergence in contemporary usage and application of vulnerability through consistent focus on social-ecological systems. The social-ecological system is an increasingly widely used term which recognizes the existence of human (sub)systems and ecological (sub)systems on multiple scales, but which emphasizes the continuous and multiple mutual interactions between them (Gallopin et al. 2001, Adger 2006). In the context of Aboriginal communities, the concept of the social-ecological system is particularly relevant (see discussions of adaptive capacity and resilience below) not least because of the strong and explicit linkages between culture and environment that is sometimes obscured or forgotten in other contexts. For our purposes, the important qualities to focus on are that vulnerability is dynamic, can vary from stimulus to stimulus and take place at multiple scales. Within each population or community there are likely to be internal factors (e.g. social networks, leadership) and external factors (e.g. national policies) that contribute to its vulnerability.

Adaptive Capacity

A precise definition of adaptive capacity is elusive. As with vulnerability, it is a core concept of global change research and its antecedents, and is similarly beset by multiple interpretations, definitions and applications (Füssel 2006, Gallopin 2006). Nevertheless, there is more in common than not between different definitions of adaptive capacity with respect to how communities respond, cope or adapt to stressors, hazards and other perturbations (Adger 2006, Smit and Wandel 2006). Adaptive capacity embodies the ability of a system to cope, recover or adapt to any hazardous conditions (Smit and Pilifosova 2003, Smit and Wandel 2006) without losing options for the future (Folke et al. 2002). Adger (2006) adds that adaptive capacity also relates to the ability of a system to expand its coping range in the process of responding to the hazardous conditions. Social factors which contribute to the adaptive capacity of a social-

ecological system include society's access to resources as well as the ability of members of a community to come together and act collectively when faced with threats (Adger et al. 2004).

Adaptive capacity is context specific and varies between regions and sectors and across time (Yohe et al. 2003, Smit and Wandel 2006). Smit and Wandel (2006) eschew the notion of measuring or attempting to establish indicators or determinants of adaptive capacity, at least as a starting point for analysis. Rather, they suggest approaching our understanding of adaptive capacity from the bottom-up (i.e. in contrast to a so called top-down approach based on scenarios and modeling), advocating for a dynamic understanding of adaptive capacity at the local level and an emphasis on process. In other words (local) adaptive capacity is best understood in terms of the various features and conditions through which it is shaped.

Brooks (2003) argues that the assessment of adaptive capacity requires understanding both how it – adaptive capacity – is constituted and how it is translated into adaptation, "...in other words, we must understand the adaptation *process*" (2003 emphasis added). The factors determining such processes depend on the nature of the "systems that are adapting" including, for example, questions of scale (i.e. households, communities versus nation states) (Brooks, 2003). The interaction of different systems across different scales is also an important condition of adaptive capacity; therefore, in working with Aboriginal communities it is important to investigate the ways in which both endogenous (internal) and exogenous (external) factors shape adaptive capacity. So, while we may be primarily concerned with assessing local conditions that effect adaptive capacity, consideration of broader social, political and economic forces must also form part of the analysis (Brooks 2003, Vincent 2007).

Finally, beyond questions of scale and approaching adaptive capacity in Aboriginal communities from the ground up, a focus on social institutions is essential. Institutions, especially governance institutions, in effect make adaptive capacity real (Adger 2003) by providing both a context and a process through which adaptations can take place. Elsewhere, we argue that institutions are a key social dimension of understanding the dynamics of social-ecological systems (Matthews and Sydneysmith, forthcoming). Institutions shape how risks are perceived and responded to at both individual and collective levels, and play a central role in how local resources may be activated and mediate potential external interventions (Agrawal 2008), whether these may be positive or negative. Although approached in somewhat different ways, the role of institutions in the process of coping with stress – and in the case of this project with

respect to the implications of climate change impacts and adaptations – is also a useful linkage between the parallel literatures of adaptive capacity and resilience.

Resilience

The concept of resilience emerged primarily from systems ecology and other disciplines concerned with ecosystem dynamics. The systems focus of early commentators led first to recognition and then to explicit incorporation of human agency as a dimension of ecosystem change, and eventually to current and ongoing efforts to understand and explain interdependencies and feedbacks that are constantly at play between social life and ecology (Folke 2006). The concept of social-ecological system is a product of resiliency thinking that is used across a range of disciplines concerned with sustainability, environmental change, natural resources and other fields that grapple with the complex interactions between social and ecological systems.

Contemporary definitions of resilience include, on the one hand, the ability of a system to absorb shocks and disturbance while retaining basic functions and, on the other hand, the ability to reorganize or adjust under conditions of stress without losing essential features including feedbacks (Folke 2006). Similarly, Tompkins and Adger (2004) see resilience as a system's ability to absorb perturbations without losing the capacity to adapt, change or learn. For Smit and Wandel (2006) resilience is one of several terms that capture the way systems, in their case primarily communities, respond and cope with the conditions to which they are exposed. In this sense resilience is close to adaptive capacity or adaptability, robustness, coping ability, and flexibility. For Adger (2000), resilience, or more precisely social resilience, is an antonym of vulnerability, while others see resilience primarily as a subset or factor of adaptive capacity (Folke et al. 2002). On the other hand, regardless of these definitional subtleties, it may be equally meaningful in the practical endeavour of attempting to engage communities in the current project to define resilience as simply “that which bends but does not break”.

Summary

As evident from the discussion above, the relationship between resilience, adaptive capacity and vulnerability is somewhat ambiguous, in part an outcome of the disciplinary origins and perspectives of those attempting to research and apply them. Regardless, the ways in which these concepts are being conceptualized and applied continues to evolve. Clarification of how

each term applies to social-ecological systems and to each other will, over time, improve the rigour of their application in many areas of research and policy concerned with global change, sustainability and so on (Gallopin 2006). For the purposes of the current project however, it may prove useful to adopt a stance similar to the “constructive ambiguity” of sustainable development as presented by Robinson (2004), wherein the uncertain and contested nature of key terminology is embraced and definition and meaning is permitted to evolve organically through repeated use and application in the field. At the end of the project we hope to be able to add substantively to the discussion of these key terms, how they relate to each other, and how they have been actively used in the context of Aboriginal communities south of 60°. In order to begin this process, we turn in the next section to a discussion of our review in Year One of various approaches to the identification and application of appropriate measures, indicators and dimensions of vulnerability, adaptive capacity and resilience.

3.2 MEASURING ADAPTIVE CAPACITY, VULNERABILITY AND RESILIENCE; CAN IT BE DONE?

There is a strong impetus among researchers and policy makers to quantify vulnerability, adaptive capacity and resilience. There is both a practical and professional lure to seek measurable indicators for analytical reasons, for example, to track state changes or to compare across space or time or to assist allocation decisions with respect to resources and other priorities. The following is a critical review of the strengths and weaknesses of attempts to quantify and measure vulnerability, adaptive capacity and resilience. The reader is reminded that while we acknowledge the desirability of indicators, in the context of climate risks and Aboriginal communities south of 60°, the first step is to make a deeper investigation of the social and institutional processes that lie behind, for example, the capacity of these communities to adapt. Ultimately, this approach should provide the necessary foundation from which more robust and meaningful indicators may be developed in the future.

Attempts to identify indicators of vulnerability, adaptive capacity, and resilience focus on different components, either biophysical or social that interact at various scales within a human system. Indicators are “quantifiable constructs that provide information either on matters of wider significance than that which is actually measured, or on a process or trend that otherwise might not be apparent” (Hammond et al. 1995, cited in Vincent 2004). The purpose of using

indicators is to distil complex processes into a form that is usable for researchers and decision-makers to make comparisons across space and time and determine priorities.

Since climate change research is a multidisciplinary issue, there are a number of schools of thought that are used as a basis for addressing climate change, such as natural hazards or political ecology. The theoretical basis of the researchers will determine the nature of indicators proposed. The natural hazards background focuses on the biophysical vulnerability, while the human ecology and political economy disciplines stress the contributions of structures and institutions (e.g. economic, political, and social) on vulnerability (Vincent 2004). The challenge with the social elements of vulnerability, such as social capital, is that 'social capital is not as easy to find, see and measure as is physical capital' (Ostrom 2000).

Some researchers have weighted and aggregated indicators to develop an index of climate change vulnerability or adaptive capacity for specific regions/countries (Alberini et al. 2006; Eakin and Bojorquez-Tapia 2008; Hahn et al. 2009; Vincent 2004). These indices are often required to inform resource allocation and targeting of specific areas/regions of high vulnerability. There have been two main approaches to weighting indicators in the development of indices. One way is to assume all indicators are equal determinants for vulnerability or adaptive capacity and are weighted equally, and the other is to weight different indicators differently based on their relative importance in determining vulnerability or adaptive capacity (Eakin and Bojorquez-Tapia 2008). Some studies have used methods such as multi-criteria decision analysis (MCDA) and fuzzy logic or expert opinions to determine the weights of each indicator (Alberini et al. 2006; Eakin and Bojorquez-Tapia 2008; Vincent 2004). However, Adger et al. (2004) caution the use of aggregated indices, since it is difficult to determine if the weighting of indicators would hold true between groups or nations, and an aggregated index does not show the 'structure' of vulnerability.

Some researchers have used geographic indicators, such as distance of rural communities from the closest service centre, as a way to combine ecological factors with socioeconomic when identifying communities/areas that are more at risk (O'Brien et al. 2004; Swanson et al. 2007). This is applied when looking at vulnerability at the regional level. O'Brien et al. (2004) used maps to look at the two stressors of climate change and economic globalization on the agricultural sector in India. Swanson et al. (2007) overlaid two measures of exposures, precipitation and temperature in the prairies, to identify high risk/exposure areas in the

agricultural sector on the prairies. Other studies have used geographic representations of their data to illustrate comparisons between nations (Haddad 2005; Vincent 2004).

The measures of vulnerability/adaptive capacity will be different depending on the scale, for example individual, household, local, regional, national and global. Many studies on indicators often look at the national scale (Adger et al. 2004, Brooks et al. 2005, Haddad 2005) due to the fact that processes at the national scale (e.g. policies) will have a significant impact on the vulnerability and adaptive capacity at the local level. For example, national level decisions and policies will determine the local people's access to resources. However, it is acknowledged that vulnerability and adaptive capacity are context specific (see Section 3.1) and will be influenced by the diverse geographic and socioeconomic realities operating at the local level, as well as the many interactions and processes taking place in a range of scales (Adger et al. 2004).

The indicators chosen in some studies are specific to a country, region or sector. For example, Swanson et al. (2007) developed many indicators specific to agriculture communities in the prairie regions in Canada. Many indicators may not hold for each region of the country, although some may be regionally specific. In the context of Aboriginal people in Canada, the high diversity of geography/demography, political history (e.g. treaties and/or land claims issues) and economic factors could result in many indicators specific to regions or communities.

There are a number of challenges involved with using indicators. Addressing the complexities of vulnerability or adaptive capacity to climate change by simplifying these issues into measurable indicators runs the risk of losing information in the process. First, exposures, sensitivities and adaptive capacity are not static but change over time. By measuring indicators, you provide a 'snapshot' of vulnerability or adaptive capacity when these concepts are in actuality highly dynamic processes (Adger et al. 2004; Eakin and Bojorquez-Tapia 2008; Smit and Wandel 2006). The processes underlying this dynamism are not well understood. Second, the use of indicators does not incorporate the interaction between the dimensions/indicators that can influence vulnerability and adaptive capacity. The interactions between all factors, both physical and human, are also not well understood. Third, there is no certainty that "all the processes that determine vulnerability can be reliably identified on the basis of current understanding" (Adger and Kelly 2000). Existing indicators do not capture the dimensions of institutional capacity very well.

Another issue stems from the need to choose indicators for which there is quantitative data available. Commonly used indicators such as literacy rate, GDP, and employment rate, are quantitative measures in which data is already collected and available, however, data for Aboriginal communities is often scant and the regional scale is often so coarse as to be irrelevant to a specific community. Other indicators within the dimension of institutional capacity, reflecting more intangible qualitative aspects of vulnerability/adaptive capacity, such as levels of trust between community members, the amount that individuals feel they can influence change in their community, are not readily available. These less tangible, difficult to measure indicators, may be fundamental to the assessment of vulnerability/adaptive capacity and would provide a more complete assessment if these factors were included. Therefore, the development of an index for vulnerability or adaptive capacity would result in an over-emphasis of easily measured factors (e.g. poverty) and under-emphasis of factors such as levels of trust (Kelly and Adger 2000).

When developing indicators, each value must be assessed as to whether it contributes to or inhibits vulnerability or adaptive capacity. It can be a challenge to assign a positive or negative value to some potential indicators of vulnerability/adaptive capacity. For example, the election of Chief and Councillors in most First Nations is for a two-year term. Depending on the situation, this could be considered by the community to contribute either positively or negatively to adaptive capacity. If the elected leadership is not effective, the ability to reconsider these positions after two years provides the First Nation with an opportunity for change. If, on the other hand, the elected leadership is meeting the needs of the community, a short election cycle, with the repeated campaigning and orientation of any new members, can be disruptive.

There is a host of challenges with indicators identified such as the issue with assigning positive or negative values to indicators, accurately weighting indicators, the lack of available data on some fundamental dimensions (e.g. social capital, institutions), and the fact that indicators only provide a snapshot of a highly dynamic process. Specifically, the use of geographic indicators in our study would also be problematic. The potential biophysical parameters that could contribute to greater risk/exposures for Aboriginal communities across Canada are far too diverse to apply in this study and the socio-economic indicators are too coarse to be relevant at the community level. This is why we have chosen to start at the local level in this study (outlined in Section 4.0) to develop dimensions of vulnerability and adaptive capacity. This would help arrive at a more accurate picture of the key elements that contribute to vulnerability and adaptive capacity in

Aboriginal communities, and would serve as the foundation for vulnerability-adaptive capacity assessments in future work.

3.3 DIMENSIONS OF ADAPTIVE CAPACITY, VULNERABILITY AND RESILIENCE

In order to explore the potential dimensions (i.e. not determinants) of vulnerability and adaptive capacity that may be investigated in this research, we reviewed existing literature on common dimensions and indicators (Appendix 3 is a table summarizing dimensions and indicators from various studies). This section introduces these common dimensions and includes additional considerations (e.g. social, cultural, economic) in the context of vulnerability and adaptive capacity of Aboriginal communities. As outlined in the preceding section, the aim of this project is not to develop quantifiable indicators for adaptive capacity or vulnerability in Aboriginal communities rather, the existing literature on dimensions and indicators will serve as a starting point for areas of focus for our primary research. Through our participatory case study approach (detailed in Section 4.0), we aim to understand the conditions and experiences that are important to Aboriginal communities, which help define the dimensions of adaptive capacity and vulnerability. These factors and processes could potentially help to pinpoint broader regional and/or national indicators in future work.

Table 1: Examples of lists of various dimensions of adaptive capacity (adapted from Matthews and Sydneysmith, forthcoming)

IPCC 2001 (as quoted in Albernini et al. 2006)	Smit et al. (2001, quoted in Swanson et al. 2007)	Yohe and Tol (2002)	Brooks and Adger (2004)
<ul style="list-style-type: none"> • Available technological options • Resources • The structure of critical institutions and decision making authorities • The stock of human capital • The stock of social capital including the definition of property rights • System's access to risk spreading processes • Information management and the credibility of information supplied by decision makers • Public perceptions of risks and exposure 	<ul style="list-style-type: none"> • Economic resources • Technology • Information and skills • Infrastructure • Institutions • Equity 	<ul style="list-style-type: none"> • Available resources and their distribution across the population • Structure of critical institutions and the allocation of decision-making authority • Stock of human capital • System's access to risk spreading • Way in which decision-makers maintain and distribute information • Public's attribution of the source of stress • Significance of exposure in the local situation 	<ul style="list-style-type: none"> • Resources • Financial capital • Social capital (e.g. strong institutions, transparent decision-making systems, formal and informal networks that promote collective action) • Human resources (e.g. labour, skills, knowledge and expertise) • Natural resources (e.g. land, water, raw materials, biodiversity)

Institutions and Governance:

Institutions are emerging as one of the crucial links in effective adaptation and are therefore a critical element of adaptive capacity (cf Agrawal 2008, Matthews and Sydneysmith forthcoming). “Governance is not simply government, but includes the complex interactions between and within government, business and ‘civil society’” (Adger et al. 2004).

From such a perspective, institutions are to society what habits are to individuals, namely the largely patterned and taken-for-granted processes whereby things are done within a societal and organizational context. As Portes (2004) notes, institutions are largely seen as cultural constraints, or, to quote O’Riordan and Jordan (1999), “Institutions are the multitude of

means for holding society together, for giving it a sense of purpose and for enabling it to adapt". As such, "institutions have to involve rules, regulations and legitimating devices" (ibid) that constitutes something equivalent to social glue. (Matthews and Sydneysmith, forthcoming)

Institutions that are weak and corrupt will often not be able to adequately respond to a crisis or disaster event. Effectiveness in state institutions, political accountability and transparency, political stability, and internal conflict all impact the vulnerability and adaptive capacity of a group. Institutions determine the entitlements and access to resources and information by local people (Smit et al. 2001). The concept of entitlement, that is, people's command over resources (i.e. their ability to secure income or food) is often central to discussions of vulnerability (Adger et al. 2004). Adaptive capacity is not only a function of the availability of the resources but also access to them, especially by those most vulnerable such as minorities, the poor, children, women (Smit et al. 2001). The success of the political leadership will depend on the perception of good governance at the community level, which will be dependent partly on the effectiveness of communication to the members.

Aboriginal communities have unique governance structures and each community's particular history will influence the effectiveness of their governance structure. As mentioned previously, the local governance format and election cycle length (e.g. 2-yr vs. 4-yr) may help or hinder Aboriginal communities to build resiliency or enhance adaptive capacity. Regarding First Nations specifically, whether it has treaty status or not, the nature of implementation of the treaty or whether the First Nation is negotiating treaty status, is also considered key to affecting resiliency and adaptive capacity. The level of involvement with a tribal council and the level of support available from the tribal council may also affect the resiliency and adaptive capacity of a particular First Nation. The presence of a land use plan and/or a comprehensive community plan may assist local governance in their adaptive capacity. Common indicators for governance or political capital include control of corruption, government effectiveness, political stability, regulatory quality, rule of law, voice and accountability, ability to deliver services, and civic freedom (Adger et al. 2004, Haddad 2005).

Social Capital

Social capital contributes to a group's ability to act collectively, which has been described as an important factor in determining vulnerability (Adger et al. 2004). Social capital has been

described as consisting of “those features of social organisation – such as networks of secondary associations, high levels of interpersonal trust and norms of mutual aid and reciprocity which act as resources for individuals and facilitate collective action”(Lochner et al. 1999 in Adger et al. 2004). This could be observed by the amount of volunteerism among a group of people, the existence and strength of informal networks such as family networks and sports groups. In many Aboriginal communities there are strong ties between immediate and extended family members. However, this sometimes results in clan conflict, which can decrease the general levels of trust between all community members. Social capital would also be influenced by the traditional teachings in a community, which guide the way that people relate to one another. In a study on vulnerability and adaptive capacity in two First Nations in Saskatchewan, Elders identified these teachings as central to increasing the adaptive capacity of the community (Ermine, Sauchyn and Pittman 2008). Some indicators of social capital are the number of community events, participation in organizations, and volunteerism.

Another dimension of vulnerability/adaptive capacity that has been identified is the motivation or attitude of individuals. In other words, what motivates individuals to act and get involved? How much control do individuals feel they have over their lives to influence change around them? This aspect of individuals can have a significant affect on the adaptive capacity of a group (Grothman and Patt 2005; Frankenberger et al. 2002). This can have implications for Aboriginal communities where historical events (e.g. Indian Agents, forbidden cultural practices / language, residential schools, unresolved land claims) have taken control and decision making away from individuals and community leaders. This has created situations of dependency and learned helplessness (see Helin 2008; Peterson, Maier and Seligman 1995) that has negative implications for adaptive capacity, and personal and group motivation. As Aboriginal peoples move toward increased capacity and independence, healing and regaining control at both an individual and community level are helping to create new opportunities for future generations.

Economic

Poverty will strongly determine an Aboriginal community’s ability to cope or adapt to climate change impacts (Smit et al. 2001; Adger et al. 2004). Poor and/or marginalized groups or populations may have to remain in a vulnerable situation partly due to the lack of finances to diversify the income source. Poor regions will face greater risk than more affluent areas because they “tend to have less diverse and more restricted entitlements and a lack of empowerment to adapt” (Smit et al. 2001). Poverty is often connected with poor housing (more

physically vulnerable to weather events), hazard prone locations, poor sanitation, overcrowding, inability to afford or invest in ‘risk spreading’ measures such as insurance, and inability to afford reconstruction (Smit et al. 2001; Adger et al. 2004). Even in wealthy countries such as Canada, Aboriginal peoples are at the extreme low ends of wealth and other quality of life indicators. Economic wealth is often represented by GDP, but this national measure may obscure the increased vulnerability of marginalised populations, such as Aboriginal people. So, it is important to look not only at total wealth but also at the way that wealth is distributed.

Although economic and financial elements are fundamental to discussions of vulnerability and adaptive capacity, it is important to recognize that these are not the only elements that require attention. “Economic resources alone are not sufficient to achieve a range of positive outcomes, including community transformation and development” (Stone and Hughes 2002). The institutional elements operating at the community level are also fundamental to assessments of vulnerability and adaptive capacity.

Also related to the economy is the number of economic sectors that are sensitive to climate, such as agriculture. Agriculture is the major climate-sensitive economic activity across the globe (Adger et al. 2004). Having the majority of economic sectors that are climate dependent, such as agriculture and forestry, the dependence of livelihoods on climate-sensitive activities, increases vulnerability. The diversity of the economy is also seen as a contributor to vulnerability/adaptive capacity. Low diversity means that a community could be heavily influenced by a social-environmental change that affects one of their major economies. Some indicators for this dimension are: GDP per capita, Gini Index/coefficient, debt repayments as a percentage of GDP, agricultural employees, rural population, and agricultural exports (Adger et al. 2004; Alberini et al. 2006; Brooks et al. 2005; Downing and Patwardhan 2004).

Infrastructure and the Built Environment

The quality and location of settlements, commercial and transportation infrastructure will determine the physical vulnerability of a group to certain environmental hazards. Transportation will influence the ability of individuals to leave an affected area or receive assistance or aid (Adger et al. 2004). The quality of the water infrastructure and availability of clean water will impact a group’s vulnerability and is also related to the health dimension (see below) as well. Common indicators include number of roads, population without access to sanitation, and isolation of rural communities. In First Nation communities, there are existing challenges to

infrastructure such as poor housing and poor water facilities (e.g. 106 boil water advisories in First Nation reserves), which would contribute to their vulnerability (Health Canada 2008).

Ecosystem Services

The area (i.e. land and water) available to a group of people will impact their vulnerability and adaptive capacity. Since many areas are proposed to become drier due to the impacts of climate change, existing water shortages will increase vulnerability. Having an excess of available water supplies or the ability to conserve significant amounts of water would be important in decreasing this vulnerability. Land is also an important resource as a greater land base allows people to move or expand settlements or agriculture or take advantage of other food sources. In the past, before Aboriginal peoples were required to live in fixed settlements, they often had seasonal settlements of various sizes (depending on the availability of resources) over a large land base allowing them to respond and adapt to environmental changes. Having access to this land base (which is determined by the treaty or land claim agreements of a particular group) would influence their adaptive capacity. Stressing or destroying ecosystems results in an increased vulnerability of settlements (e.g. increased erosion of land). Already stressed ecosystems would become less able to respond to climate changes and thus people would be less able to make use of them during adaptive responses (Adger et al. 2004). Some indicators for this dimension include: protected land area, percent forest cover, water resources per capita, groundwater recharge per capita, forest change rate, water resources per capita, groundwater recharge per capita, unpopulated land area, and percentage of land in a shared water basin (Adger et al. 2004; Haddad 2005).

Geographic and Demographic

Geographic and demographic qualities of a community will have an impact on their vulnerability to specific natural hazards (Adger et al. 2004). For example, those communities living near/in low lying areas or near coasts will be more vulnerable to sea level rise than those who are not. Communities living in drought prone areas where increased dryness is predicted or forested areas that may see increases in forest fires will also be more vulnerable. Higher density of human populations increases vulnerability, since there is often an increased risk of disease following a disaster. Common indicators for this dimension are: kilometres of coastline, population within 100kilometres of coastline, and population density.

Health and Wellbeing

People who have poor health and are undernourished will be more vulnerable to natural hazards (Adger et al. 2004). People with ill health will require other people to assist them which will result in these people having less time, money and energy that could be spent on other activities such as adaptation planning. Some indicators for this dimension are: health expenditure per capita, disability adjusted life expectancy, calorie intake per capita, AIDS/HIV infection (% adults), health expenditure per capita, public health expenditure, life expectancy at birth, maternal mortality per 100,000, food production index, and food price index.

Education and Knowledge

The least educated and lower skilled groups of people are often the most vulnerable to natural hazards (Adger et al. 2004). Those with a low education often have little political voice and are more likely to depend on climate-sensitive economic activities such as agriculture. The level of literacy in a group or nation determines the ability of these people to have access to and interpret climate change information, which is necessary for high adaptive capacity. Education represents not only basic literacy and knowledge but also having human resources that have additional skills and expertise to assist with issues specific to climate change. The presence of trained and skilled personnel is one way to build adaptive capacity. The real and perceived abilities of a community are rooted in the knowledge and skills of its members. Common indicators for this dimension include: education expenditure, and literacy rate and ratio (female to male).

Some approaches have identified the role of informal education or transmission of traditional knowledge and teachings as a component of adaptive capacity, however many studies do not. In many studies on vulnerability or adaptive capacity, literacy rate is often the sole indicator of education. By focusing only on formal education, these studies do not include local, traditional or land-based knowledge as another form of education. Local knowledge is often best able to solve local problems, because of peoples' experience and history within a specific place. Strengthening and continuing the practise and passing on of this 'informal' education is often essential in assisting communities in becoming more resilient (Ermine, Sauchyn and Pittman 2008; Ford et al. 2006). Measures of 'informal' education are another intangible indicator for which no quantitative measures exist.

Technical

Technical capacity is defined as the “...capacity to exploit science and technology in order to facilitate adaptation” (Adger et al. 2004). Dealing with climate change will require vulnerability and risk assessments, which will require resources, technical skills and expertise. Management of climate change impacts will require various sources of technology at multiple scales (e.g. warning systems, protective structure, settlement redesign, flood control measures) (Smit et al. 2001). Openness to these technologies is also an element of adaptive capacity since openness is required for a country or region to adopt any available technologies (Smit et al. 2001). Indicators for this dimension include: research and development (R&D) investment, scientists and engineers in R&D per million people, and tertiary (i.e. postsecondary education) enrolment.

4 RESEARCH DESIGN

In light of the discussion above, the first steps in assessing vulnerability and adaptive capacity begin at the community level. A primary task of Year One of the Project was to develop a rationale and research design that would help us learn as much as possible about the key factors involved. The goal is to understand the conditions and experiences that are important to communities, which help define the dimensions of adaptive capacity and vulnerability and which might ultimately help to pinpoint specific, measurable indicators in the future.

Several authors argue that it is only meaningful to talk about vulnerability in terms of a specific hazard or range of hazards in relation to specific systems or exposure units (Brooks 2003, Adger et al. 2004). The primary unit of analysis is at the community scale; hence a case study approach is most appropriate (see Section 4.2). The challenge of this approach, however, is trying to get sufficient representation of the full range of conditions and experiences and to capture the diversity of Aboriginal communities south of 60° across the country. As this representation cannot be achieved with case studies alone, we are developing an informal research network to expand the reach of this project (see Section 4.1). Finally, it is increasingly recognized in global environmental change research (and myriad related fields of inquiry) that building adaptive capacity or reducing vulnerability through improved governance or other institutional means depends on a shared learning approach. Such an approach means that while communities may be the unit of analysis they are not simply the objects of study. Rather, they are (hopefully) participants in a process in which information flows both ways and

knowledge is built concurrently, hence the third main feature of this research is the use of a participatory research framework (see Section 4.3)

4.1 INFORMAL RESEARCH NETWORK

The informal research network is envisioned as a vehicle to help the project team engage researchers and other individuals (e.g. scientists, researchers, government employees) with knowledge of specific Aboriginal communities, regions or relevant issues. The purpose of the network was, first to expand the breadth of the project, to ensure that beyond a thorough literature review the project was positioned to gather as much information as possible about work that has been done, and work that is ongoing or anticipated that might contribute to our understanding of vulnerability, adaptive capacity and related climate change issues in Aboriginal communities south of 60°. Second, the purpose is to help identify and contact or gain an introduction to potential case study areas through existing researcher connections with Aboriginal communities or organisations that may be interested in participating directly in this project (see Type I case studies described below). Third, the goal of the informal network is to help identify potential Type II case study participants or locations (see Section 4.2).

The informal research network was initiated in Year One and will continue to be developed over the course of the project. The contacts and information are being built into a database, which may be useful should a more formalized network be sought. It is currently envisioned as “informal” for the simple reason that there are not funds within the current project to properly develop something more formal and to ensure that the expectations of those we might engage do not unduly raise their expectations about what our network may or may not deliver. In other words, we are engaging in extensive “networking” around the issues of concern to this project.

4.2 CASE STUDY TYPES AND REGIONS

In their national scale assessment of vulnerability in India's agricultural sector O'Brien et al. (2004) used case studies to “ground truth” their analysis. The rationale was that even with the existence of reasonably complete data sets and macro scale proxies for measuring vulnerability

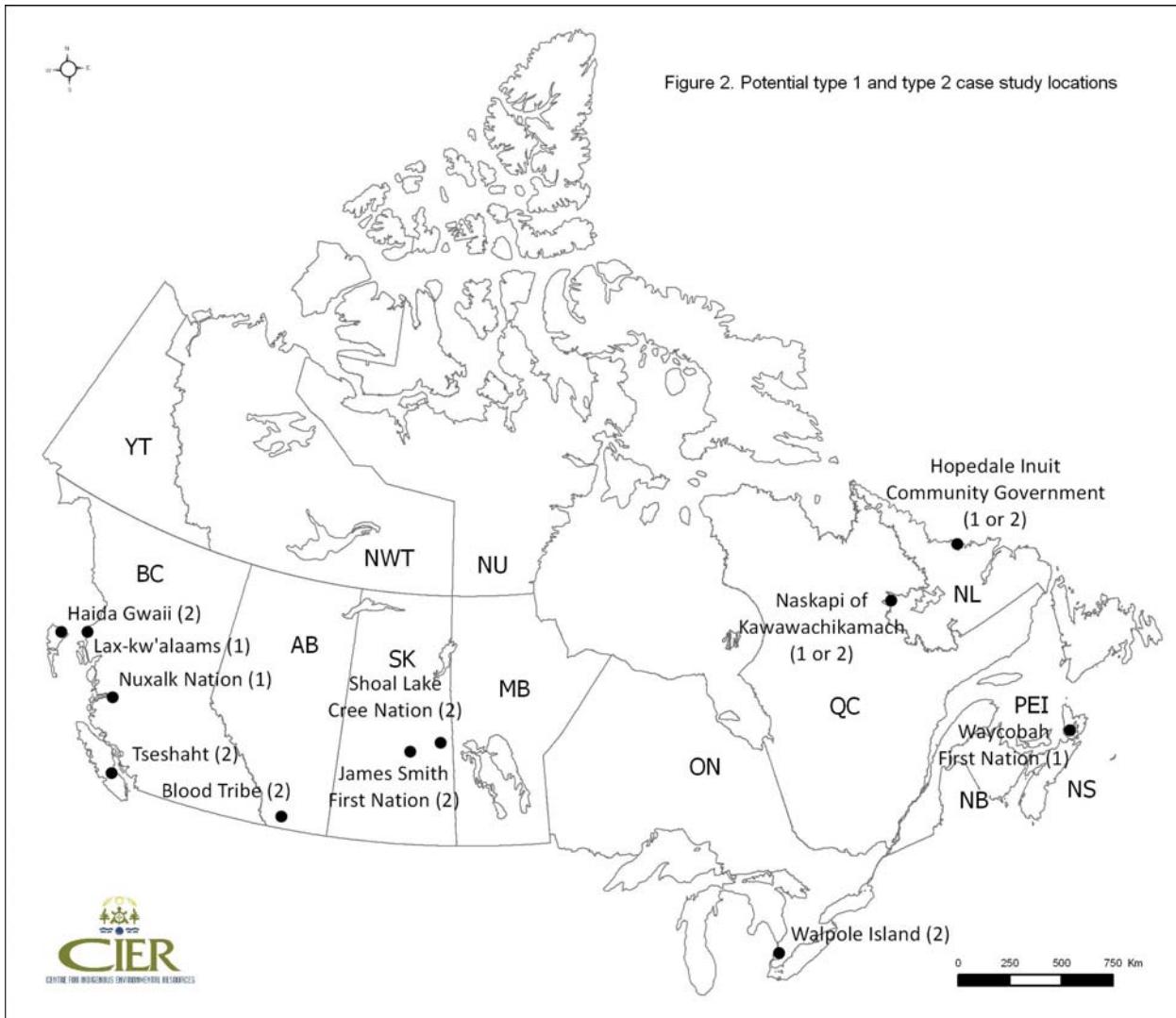
it was still necessary to “identify local level institutions and policies that influence coping and adaptation strategies used by farmers...” O’Brien et al. (2004). In the current project our approach begins with the ground truth.

Case studies helped to illustrate some features of adaptability that were not evident from the macro scale national indices of vulnerability, namely “the effect that institutional barriers or support systems have on local level vulnerability.” Institutional supports enabled adaptation, although notably the benefits were unequally distributed (i.e. favoured larger farmers) (pp. 311).

We gave consideration as to what would constitute a case study location. That is, would a case study include a single community or a group of communities? Would the case study focus only on the community in isolation or would it include the surrounding environment and if so, how much? The practical approach we have adopted is to focus on specific communities within the context of broader “case study areas”. As such, individual communities will be the subject of in depth study but with explicit reference to and input from neighbouring communities, other researchers, non-government organizations and municipal and government representatives.

In order to best capture the range and diversity of Aboriginal communities across the country within the scope of this project, we elected to pursue two types of case studies. Those referred to as Type I case studies will be conducted primarily according to the research design and goals outlined in this report. Type II case studies will be developed from pre-existing work of certain members of the informal research network. If possible, colleagues from the network may build on their existing work to develop outputs more specific to this project. Figure 2 summarizes potential Type I and Type II case study areas.

Within the limited scope of the project it was necessary to determine which communities to focus on as potential case study areas and equally to decide which to exclude. Several concurrent steps were involved. First, potential communities were identified drawing upon the existing knowledge and networks of the research team and results of the CIER (2007) report. Second, some basic parameters or criteria were established to guide us in the selection of case study sites (see below). The goal being to develop practical guidelines that would, as far as possible, ensure balanced representation of Aboriginal communities from the many diverse



regions of Canada while at the same time acknowledging that we would not be able to cover the whole country. However, while aiming to select locations based on criteria, we also recognize the need for flexibility as numerous factors will likely influence whether or not a particular location will be willing and able to participate.

The analysis provided in the CIER 2007 report used regional divisions based on eco-zones (Data provided by Global Forest Watch and Canada Forest Service). Here we are taking into account both biophysical and social dimensions of Canada to help achieve regional balance in the choice of case studies for this project. Broadly speaking, regional categories similar to those developed for the National Assessment (Lemmen et al. 2008) as per Appendix 1 are being used. We will strive to work with a diversity of case study communities that capture the range of impacts that may be experienced by Aboriginal communities south of 60°, for example, mountain pine beetle in B.C., drought on the Prairies or sea level rise in the Atlantic. Similarly, we aim to capture a cross section of different social, political and economic factors that may influence vulnerability and adaptive capacity in different Aboriginal communities such as, the nature of land claims and treaty arrangements, the level of integration with the wider Canadian economy, etc.

Potential case study communities are being identified and considered for inclusion in the project on an individual basis. In addition to the broad distribution being sought around geographic regions, additional criteria for selecting case studies include ecological context, demographics and rural/urban context, livelihoods, local economy and natural resources, governance and institutional context. These are broad categories which of necessity are intended to be “flexible”. Our experience with social research and working with communities tells us that a willingness on the part of the community to work with us critical. While the value of trust and a good working relationship between members of the project team and Aboriginal communities may seem obvious it is often overlooked. In other words, regardless of how well a place may “fit” our selection criteria, community interest or “buy in” is paramount to case study selection. As far as is possible (i.e. with respect to regional representation) we rely on existing relationships with communities, at least in the beginning stages of building up our stock of potential case studies. The informal research network is a way to leverage these relationships and extend the reach of the current project (section 4.1). The participatory framework outlined in the following section is the basis for how we intend to operationalize the case studies.

4.3 PARTICIPATORY RESEARCH FRAMEWORK

The investigation of various key dimensions of vulnerability and adaptive capacity and related conditions of exposure and sensitivity to climate change in Aboriginal communities south of 60° will require a flexible and open approach. The *participatory* dimension of the framework embodies the imperative of capturing community interest and perspectives on a range of issues whether directly or indirectly linked to current or potential impacts of climate change.

SydneySmith and Matthews work within a number of frameworks including the so-called “vulnerability approach” (cf Smit and Wandel 2006) and “new institutional analysis” (cf Matthews and SydneySmith forthcoming). Elements of resilience and adaptive capacity frameworks will also contribute to how this work is approached but these details are still being worked out at the time of writing. The articulation of specific research instruments will be finalized in conjunction with confirmation of specific research sites in the early part of Year Two of the project, but are likely to include a combination of interviews, focus groups, and participant observation.

Statement of Research Ethics

The project team will abide by the following tenets, especially with respect to work with Aboriginal communities. SydneySmith and Matthews must also adhere to a code of research ethics and require a certificate from the UBC Behavioural Research Ethics Board prior to going in to the field for interviews:

- Communicate with and gain approval from the leadership of the community for the project;
- Engage the wider community in the project through presentations and open houses;
- Abide by any local laws, regulations or protocols that may be in place in the regions that we work;
- Respect the language, traditions, standards, and existing protocols of participating Aboriginal communities;
- Ensure any Indigenous Knowledge shared by community members in the project will remain under the ownership of those individuals;

- Obtain informed consent from community members prior to the start of any research; the consent forms will outline the purpose of the project, the funders, use of the information collected, the potential beneficial and harmful effects of the research on individuals or on the community and/or on the environment, confidentiality wishes of the individual, and their right to withdraw from the project at any time;
- Obtain consent to use information from the community for the project-specific publications and seek additional consent for any future uses of the data;
- Obtain consent to use photos of identifiable individuals within this and/or future related work;
- Offer confidentiality and anonymity to anyone involved in the project that requests it;
- Ensure all raw data collected from the project will be left on file in the community from which it was gathered, along with descriptions of the methods used; the project team will retain a backup copy;
- Ensure that project results will be shared with individual participants, community, and other affiliations. Research summaries and reports will be made available to interested communities;
- Ensure that, subject to requirements for confidentiality, publications will be given appropriate credit to everyone who contributes to the research;
- Seek to enhance local benefits and minimize any potential harm to community members when engaging in a project.

5 CONCLUSION

At the request of INAC, researchers from CIER and the Department of Sociology at UBC have partnered to develop a project to consider the current and future implications of climate change for Aboriginal communities south of 60°. The foregoing report details the outcomes of the first year of project design, implementation and research. The exposure and sensitivity of Aboriginal communities south of 60° to the impacts of climate change and the capacity of communities to respond and cope with attendant risks and hazards is not well understood. This project seeks

to fill some of those gaps in knowledge and present a foundation from which practical adaptations and capacity-building steps may be developed.

The first year of the project has sought to frame an approach to investigating the vulnerability and adaptive capacity of Aboriginal communities south of 60°. Highlights and key messages from this first year of work include:

- There are already impacts observed in Canada south of 60°, including: increased temperatures, decreased water availability and increases in temperature-regulated pests such as the mountain pine beetle;
- Aboriginal communities in Canada face existing challenges such as low annual income, low formal education, poor housing and poor water quality, which will be exacerbated by climate change impacts;
- The project will be guided by a framework embodying key elements of various analytical approaches built to operationalize concepts of adaptive capacity and vulnerability at the community level, and suggest approaches to better equip both INAC and the communities in question with avenues for building adaptive capacity and resilience to climate change and other risks and hazards;
- The aim of the project is not to develop quantitative measures or indicators of vulnerability or adaptive capacity. Rather the goal is to investigate the various dimensions of adaptive capacity at the community level and the factors or conditions that contribute to specific vulnerabilities;
- The project team will be investigating case study regions and employing participatory methods to gather information on the dimensions of vulnerability, adaptive capacity and resilience at the community level. An informal network of researches is being developed to broaden the reach of the project and leverage the number of case studies that we are able to undertake through a two-tiered system of case studies;
- The role of institutions, both locally and in a broader regional or national context, is a critical linking and enabling aspect of the adaptation process. The reduction of vulnerability and/or the enhancement or building of adaptive capacity and resilience

depends heavily on the effectiveness of existing institutions. Institutional capacity in its many forms is therefore, a central issue under investigation in this project.

The impacts of climate change will be wide ranging and vary from community to community as will abilities to cope, and the specific adaptations different communities will be compelled to make. As mentioned, actions to adapt will have to “compete” with other priorities and needs. Given that, efforts to “mainstream” climate change adaptation may help to make communities more resilient. If communities choose to incorporate their adaptation process into the context of everyday business-as-usual, the transition is likely to integrate more smoothly with current operations rather than trying to task one person in the community to take the lead on climate change adaptation.

We want to first understand the dimensions that most contribute to the vulnerability/adaptive capacity of a community. Change will always happen at the community level, therefore there is a need to create a situation where a community can adapt to change (incremental and/or transformational). Ultimately we aim to assist communities in seeking out win-win-win-win solutions – those that contribute to CC mitigation, adaptation, adaptive capacity, and community sustainability.

6 REFERENCES

- Adger, W. Neil (2006) Vulnerability. *Global Environmental Change* 16. pp. 268-281.
- Adger, W. Neil., Brooks, Nick, Bentham, Graham, Agnew, Maureen, and Siri Eriksen. 2004. New Indicators of Vulnerability and Adaptive Capacity. Technical Report 7. Tyndall Centre for Climate Change Research. University of East Anglia Norwich.
- Adger, W. Neil (2003) Social Aspects of Adaptive Capacity. In Smith, Joel B. Richard Klein and Saleemul Huq eds. (2003) Climate Change, Adaptive Capacity and Development. Imperial College Press. London.
- Agrawal, A. 2008. The Role of Local Institutions in Adaptation to Climate Change. IFRI Working Paper W081-3. Prepared for the Social Dimensions of Climate Change, Social Development Department. Washington, DC, International Forestry Resources and Institutions Program, IFRI Working Paper W081-3, School of Natural Resources and Environment. Ann Arbor, MI: University of Michigan.
- Alberini, Anna, Chiabai, Aline, and Lucija Muehlebachs. 2006. Using Expert Judgement to Assess Adaptive Capacity to Climate Change: Evidence from a Conjoint Choice Survey. *Global Environmental Change* 16: 123-144.
- Berkes, Fikret, and Dyanna Jolly. 2001. Adapting to Climate Change: Social-Ecological Resilience in a Canadian Western Arctic Community. *Conservation Ecology* 5(2): 18.
- Brooks, Nick, and W. Niel Adger. 2004. Assessing and Enhancing Adaptive Capacity. Technical Paper 7 in Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Lim, Bo, and Erika Spanger-Siegfried (ed). United Nations Development Program. Cambridge University Press.
- Brooks, Nick, Adger, W. Neil, and P. Mick Kelly. 2005. The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation. *Global Environmental Change* 15: 151-163.

Canada. 1996. Royal Commission on Aboriginal Peoples. People to people, nation to nation: Highlights from the report of the Royal Commission on Aboriginal Peoples. Minister of Supply and Services Canada.

Cutter, Susan L, Barnes, Lindsey, Berry, Melissa, Burton, Christopher, Evans, Elijah, Tate, Eric, and Jennifer Webb. 2008. A place-based model for understanding community resilience to natural disasters. *Global Environmental Change*, 18: 598-606.

Dolan, A. H., and I. J Walker. 2004. Understanding Vulnerability of Coastal Communities to Climate Change Related Risks. *Journal of Coastal Research*, Special Issue 39: (no pages).

Downing, Thomas E. and Anand Patwardhan. 2004. Assessing Vulnerability for Climate Adaptation. Technical Paper 3 in Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures. Lim, Bo, and Erika Spanger-Siegfried (ed). United Nations Development Program. Cambridge University Press.

Eakin, Hallie and Luis A. Bojorquez-Tapia. 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*. 18: 112-127

Ermine, Willie, Sauchyn, Dave, and Jeremy Pittman. 2008. Nikan Oti: Future – Understanding Adaptation and Adaptive Capacity in two First Nations. Final Research Project Report to the Prairie Adaptation Research Collaborative (PARC).

Folke, Carl (2006) Resilience: the emergence o fa perspective for social-ecological systems analyses. *Global Environmental Change* 16. pp. 253-267.

Folke, Carl, Steve Carpenter, Thomas Elmqvist, Lance Gunderson, CS Holling, Brian Walker, Jan Bengtsson, Fikret Berkes, Johan Colding, Kjell Danell, Malin Falkenmark, Line Gordon, Roger Kasperson, Nils Kautsky, Ann Kinzig, Simon Levin, Karl-Göran Mäler, Fredrik Moberg, Leif Ohlsson, Per Olsson, Elinor Ostrom, Walter Reid, Johan Rockström, Hubert Savenije and Uno Svedin (2002) Resilience and Sustainable Development: Building Adaptive Capacity in a World of Transformations Scientific Background Paper on Resilience for the process of The World Summit on Sustainable Development on behalf of The Environmental Advisory Council to the Swedish Government.

Ford, James, Pearce, Tristan, Smit, Barry, Wandel, Johanna, Allurut, Mishak, Shappa, Kik, Ittusujurat, Harry and Kevin Qrunnut. 2006. Reducing Vulnerability to Climate Change in the Arctic: The Case of Nunavut, Canada. *Arctic*, 60(2): 150-166.

Ford, James D, Smit, Barry, and Johanna Wandel. 2006. Vulnerability to Climate Change in the Arctic: A Case Study from Arctic Bay, Canada. *Global Environmental Change* 16: 145-160.

Füssel, Hans-Martin (2006) Vulnerability: A generally applicable conceptual framework for climate change research. *Global Environmental Change* 16. pp. 155-167

Füssel, Hans-Martin and Richard Klein (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic Change* 75: 301-329.

Frankenberger, Timothy R., Luther, Kristina, Becht, James and M. Katherine McCaston. 2002. Household Livelihood Security Assessments: A Toolkit for Practitioners. CARE USA, Atlanta, Georgia.

Gallopín, Gilberto, C. (2006) Linkages between vulnerability, resilience, and adaptive capacity. *Global Environmental Change* 16. pp. 293-303

Grothmann, Torsten, and Anthony Patt. 2005. Adaptive Capacity and Human Cognition: The Process of Individual Adaptation to Climate Change. *Global Environmental Change* 15: 199-213.

Haddad, Brent M. 2005. Ranking the Adaptive Capacity of Nations to Climate Change when Socio-political Goals are Explicit. *Global Environmental Change* 15: 165-176.

Keohane, R. 1988. International Institutions: Two Approaches. *International Studies Quarterly* 32, 379-396.

Keskitalo, E. Carina H. 2008. Vulnerability and Adaptive Capacity in Forestry in Northern Europe: A Swedish Case Study. *Climatic Change*, 87: 219-234.

Hahn, Micah B., Riederer, Anne M. and Stanley O. Foster. 2009. The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change – A case study from Mozambique. 2009. *Global Environmental Change*, 19: 74-88.

C. Helin. 2008. Dances with Dependency: Out of Poverty Through Self-Reliance. Cubbie Blue Publishing.

INAC. 2008. Plan of Action for Drinking Water in First Nations Communities. Progress Report January 17, 2008.

IPCC. 2007. Climate Change 2007: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report. Cambridge, UK.

Lebel, Louis, Anderies, John, M., Campbell, Bruce, Folke, Carl, Hatfield-Dodds, Steve, Hughes, Terry P. and James Wilson. 2006. Governance and the Capacity to Manage Resilience in Regional Social-Ecological Systems. *Ecology and Society* 11(1); 19. [online]

Lemmen, D.S. Warren, F.J., Lacroix, J., and Bush, E., editors. 2008. From Impacts to Adaptation: Canada in a Changing Climate 2007; Government of Canada, Ottawa, ON, 448p.

Leurs, Amy L. 2005. The surface of vulnerability: An analytical framework for examining environmental Change. *Global Environmental Change*, 15: 214-223.

Luers, Amy L., Lobell, David B., Sklar, Leonard S., Addams, C. Lee, and Pamela A. Matson. 2003. A method for quantifying vulnerability, applied to the agricultural system of the Yaqui Valley, Mexico.

Magzul, Lorenzo. Report on the Blood Tribe (Kainai Nation): Community Vulnerabilities. Draft. IACC Project, Unit 1 A: An assessment of vulnerabilities of rural communities and households to water related climate conditions (Chile Canada).

Matthews, Ralph and Robin Sydneysmith (forthcoming) Understanding Adaptive Capacity as a Dynamic Institutional Process: Conceptual Approaches and their Application in the Whitehorse Case Study. In Derek Armitage and Ryan Plummer (Editors), Adaptive Capacity: Building Environmental Governance in an Age of Uncertainty. Springer Publishing Company. New York, NY

McLaughlin, Paul and Thomas Dietz. 2008. Structure, agency and environment: Toward an integrated perspective on vulnerability. *Global Environmental Change*, 18: 99-111.

Mignone, Javier. 2003. Social Capital in First Nations Communities: Conceptual Development and Instrument Validation. PhD Thesis, Department of Community Health Sciences, University of Manitoba, Winnipeg, Manitoba.

Naess, Lars Otto, Norland, Ingrid Thorsen, Lafferty, William, and Carlo Aall. 2006. Data and processes linking vulnerability assessment to adaptation decision-making on climate change in Norway. *Global Environmental Change*, 16: 221-233.

Norris, Fran H., Stevens, Susan P., Pfefferbaum, Betty, Wyche, Karen F., and Rose L. Pfefferbaum. 2008. Community Resilience as a Metaphor, Theory, Set of Capacities, and Strategy for Disaster Readiness. *American Journal of Community Psychology*, 41: 127-150.

O'Brien, Karen, Siri Eriksen, Ane Schjolden, and Lynn Nygaard (2004) What's in a word? Conflicting interpretations of vulnerability in climate change research. CICERO Working Paper 2004:04

O'Brien K., Leichenko R., Kelkar U., Venema H., Aandahl G., Tompkins H., Javed A., Bhadwal S., Barg S., Nygaard L., West J. (2004). Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change*, 14, 303–313.

Parkins, John R., and Norah A. MacKendrick. 2007. Assessing community vulnerability: A study of the mountain pine beetle outbreak in British Columbia, Canada. *Global Environmental Change*, 17: 460-471.

C. Peterson, S. Maier, M. Seligman. 1995 Learned Helplessness: A Theory for the Age of Personal Control. Oxford University Press.

Robinson, John (2004) Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics*. 48 (2004) pp 369-384.

Smit, Barry and Johanna Wandel, (2006) Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16. pp. 282-292.

Smit, B., Pilifosova, O., Burton I., Challenger B., Huq S., Klein R.J.T. and Yohe, G. 2001. Adaptation to climate change in the context of sustainable development and equity Climate Change 2001: Impacts, Adaptation and Vulnerability, (ed.) J.J. McCarthy, O.F

- Canziani, N.A. Contribution of Working Group III to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change.
- Smith, Joel B. Richard Klein and Saleemul Huq eds. (2003) Climate Change, Adaptive Capacity and Development. Imperial College Press. London.
- Statistics Canada. 2008. Aboriginal Peoples in Canada in 2006: Inuit, Métis and First Nations, 2006 Census. Statistics Canada Catalogue no. 97-558-XIE. Ottawa. July 29.
- Stone, Wendy and Jody Hughes. 2002. Understanding community strengths. Family Matters No. 61 Australian Institute of Family Studies.
- Swanson, D.A., J.C. Hiley and H. Venema. 2007. Indicators of Adaptive Capacity to Climate Change for Agriculture in the Prairie Region of Canada: An Analysis based on Statistics Canada's Census of Agriculture. Working Paper for the Prairie Climate Resilience Project, Winnipeg: International Institute for Sustainable Development.
- Tol, Richard S.J., and Gary W. Yohe. 2007. The weakest link hypothesis for adaptive capacity: An empirical test. *Global Environmental Change*, 17: 218-227.
- Vincent, Katharine. 2004. Creating an index of Social Vulnerability to Climate Change for Africa. Tyndall Centre for Climate Change Research. Working Paper 56.
- Vincent, Katharine (2007) Uncertainty in adaptive capacity and the importance of scale. *Global Environmental Change* 17. pp. 12-24
- Wall, Ellen, and Katia Marzall. 2006. Adaptive Capacity for Climate Change in Canadian Rural Communities. *Local Environment*, 11(4): 373-397.
- Wall, E. and K. Marzall. 2004. Climate change and adaptive capacity in Tweed: Profiling resources. Presentation for the Annual conference of the Canadian Rural Revitalization Foundation, Tweed, Ontario, October. Found in Swanson et al. 2007.
- Yohe, G & Tol, RSJ (2002). Indicators for social and economic coping capacity – moving toward a working definition of adaptive capacity. *Global Environmental Change*, 12, 25-40.

Yohe, G., Strzepek, K., Pau, T., Yohe, C. 2003. Assessing Vulnerability in the context of changing socioeconomic conditions: a study of Egypt. In: Smith, J.B., Klein, R.J.T., Huq, S. (Eds.), Climate Change, Adaptive Capacity and Development. Imperial College Press, London.

7 APPENDIX 1 – IMPACTS OF CLIMATE CHANGE TO ABORIGINAL PEOPLES IN CANADA

Atlantic Canada (Vasseur and Catto 2008)

Aboriginal communities in the Atlantic Provinces include Innu, Inuit, Mi'kmaq and other populations. Gosselin (2004) reports that Aboriginal communities have observed environmental changes due to climate change. Coastal communities are at risk of land loss. Being settled in modern communities increases this risk over traditional Aboriginal ways of seasonal migrations. Secondly, the continued reliance on traditional foods of seal, salmon, caribou, rabbit, partridge, ducks, berries and others is at risk due to climate change and changes in habitat. Traditional foods play an important role in the cultural existence of Aboriginal peoples and changes in the availability of these foods could endanger Aboriginal cultures. Elsipogtog First Nation has undertaken work to understand how sea level rise may affect salt marshes containing traditional foods and medicines in the future. Even in the best case scenarios flooding is predicted to flood the sensitive marsh areas. As a result Elsipogtog is planning to adapt to climate change. A key challenge lies in the geography of the First Nation – a thin strip of land along the coast – making relocating critical infrastructure inland difficult. Their only option may be to acquire additional lands. Elsipogtotg has also thought of other several approaches they may choose to take to maintain traditional foods and medicines found in the marshes.

Quebec (Lemmen et al. 2008)

Warming in northern Quebec has been sudden and drastic with a rise of 2° C since 1993. Infrastructure such as roads and airstrips built on continuous or discontinuous permafrost may be at risk of buckling with climate change. Permafrost thawing has already caused slumping, cracking and other signs of deterioration on airstrips and the roads that lead to them in the north (Beaulac and Doré 2005). Travel by boat in the summer, snowmobile in the winter and ice roads in the winter is also affected by climate change. Traditional activities like hunting, fishing, berry gathering, egg gathering, trapping, visiting family and friends are all being affected by climate change in northern Quebec. Climate impacts like unpredictable weather forecasts, later ice formation and earlier ice break up have made travel in the north more hazardous. This has had socio-economic and cultural consequences that put Aboriginal cultures at risk. No other specific

impacts to Aboriginal communities were identified in the other regions of Quebec. However, some climate impacts reported for the rest of Quebec that may affect Aboriginal communities living in these areas include: coastal erosion along the maritime subregion along the banks of the St. Lawrence river; increase in growing degree days by 4 – 20 % between 1960 and 2003 in western and central parts of southern Quebec (Yagouti et al.); and increases in precipitation and temperatures while groundwater recharge remained stable in recent decades in Quebec and the Maritimes (Rivard et al. 2003). Many other potential impacts were discussed however no direct observations were reported.

Ontario (Chiotti and Lavender 2008)

In 2001, the Aboriginal population made up 1.7% of the Ontario population (70% First Nations, 1% Inuit and 26% Métis). Aboriginal communities are found throughout the 3 Ontario subregions: the south, the central and the north (Figure 3) and therefore it is assumed that impacts affecting each of the subregions will also affect Aboriginal communities.

Figure 3. The three subregions of Ontario used in *From Impacts to Adaptation: Canada in a Changing Climate 2007* (Lemmen et al. 2008 - modified from Natural Resources Canada, 2002).



Climate change provides struggles for Ontario's ecology, society and economy. It is already affecting natural and human systems in parts of the province. For example, impacts include decreases in ice cover on lakes; climate extreme increases; and changes in aquatic and terrestrial ecosystems. Current social and economic impacts reported include: shorter winter road seasons, increased risk of forest fires, lower water levels in the Great Lakes, interference with winter tourism, increased smog alerts, and increased extreme heat episodes. While the scale and timing of events will vary across Ontario, nearly every economic area will be affected by climate change (Table 2).

Table 2. Major negative impacts of climate change and onset of 'problems' by subregion in Ontario in From Impacts to Adaptation: Canada in a Changing Climate 2007 (Lemmen et al. 2008)

Cumulative stresses/region	Subregion		
	North	Central	South
Ecosystems			
Fish	Present to 20 years	Present to 20 years	Present to 20 years
Fauna	Present to 20 years	No information on timing	Present to 20 years
Flora	Present to 20 years	No information on timing	No information on timing
Water			
Quality	50 to 80 years	20 to 50 years	Present to 20 years
Quantity (shortages)	No significant impact expected	No significant impact expected	Present to 20 years
Flooding	Present to 20 years	Present to 20 years	Present to 20 years
Health			
Heat	No significant impact expected	20 to 50 years	Present to 20 years
Insect/vector disease	50 to 80 years	20 to 50 years	Present to 20 years
Water quality	50 to 80 years	20 to 50 years	Present to 20 years
Air quality	No significant impact expected	20 to 50 years	Present to 20 years

Agriculture			
Drought	No significant impact expected	No significant impact expected	Present to 20 years
Energy			
Increased demand	No significant impact expected	No significant impact expected	Present to 20 years
Lower production	No significant impact expected	No significant impact expected	20 to 50 years
Forestry			
Fire	Present to 20 years	Present to 20 years	No significant impact expected
Pests and disease	20 to 50 years	20 to 50 years	No significant impact expected
Transportation			
Winter roads	Present to 20 years	No significant impact expected	No significant impact expected
Paved surfaces	No significant impact expected	No significant impact expected	20 to 50 years
Navigation	No significant impact expected	20 to 50 years	20 to 50 years
Tourism and Recreation			
Cold season	No significant impact expected	Present to 20 years	Present to 20 years

Ontario south subregion

Warming temperatures are affecting aquatic ecosystems. They have delayed ice formation on lakes in the winter and contributed to earlier ice break up in the spring. In the last 100 to 150 years the ice season on the Great Lakes has been reduced by 1 to 2 months. Similarly the ice season in the Bay of Quinte on Lake Ontario has reduced substantially since the late 1970's. Since the 1920's, rising near-shore water temperatures have been reported in many locations around the Great Lakes. Warming waters have contributed to increased algal blooms and invasions of non-native species of fleas, mussels and fish. The increases in algae and mussels have led to encrusted water intake pipes prompting coastal communities to address these issues with increase maintenance and in some cases upgrade water treatment plants. Ice fishing has been affected as a result of a shorter ice season and increased risk due to unsafe ice conditions.

Fluctuating lake levels have also affected docks and boating. A majority of 2001 survey respondents reported 'major' and 'devastating' impacts due to fluctuating water levels between 1995 and 2000. The federal government responded to low water levels on Lake Huron with the creation of a \$15 million dollar marina aid program.

Flooding has become a problem in this subregion. Between 1992 and 2003 most of the floods resulted from rain-on-snow conditions and happened between the months of January and May. Flooding due to heavy rainfall events has also increased. For example, there have been 8 heavy rainfall events in the past 20 years in the Toronto region that have caused significant flooding. In June 2002 a series of rain events resulted in 220 and 401 mm of rain in the central subregion of Ontario. Damages due to flooding totalled \$31 million in Ontario, an estimated \$7 million in Manitoba and approximately \$70 million (US) in Minnesota and North Dakota and disrupted rail and road access.

Water borne diseases, such as *Escherichia coli* (*E. coli*) and *Salmonella* are sensitive to climatic conditions, in particular heavy rainfall and high temperatures. Water-borne gastrointestinal diseases affect the young, elderly and people with impaired immune systems. Many Aboriginal communities have high populations of young people and people with impaired immune systems. Other factors not related to climate, such as poorly maintained water treatment plants, nearby

agricultural operations and water system failures have also been linked to drinking water infections. Protecting source waters will reduce risks related to water borne diseases.

Increased freeze-thaw cycles have been reported in the southern subregion. This hastens road wear and tear especially in wet regions with fine-grained deposits for a subgrade.

Ontario central subregion

The forests of the central subregion are affected by climate change impacts. Since 1963, the fire season has increased by as much as 8 days in the boreal forest region of Ontario. A continued combination of drought and high temperatures might produce a ‘tipping point’ that makes fire suppression unfeasible (Flannigan et al. 2005). The current most damaging insect to Ontario forests is spruce budworm. Repeated infestations since the late 80’s has resulted in huge forest dieback leaving fuel for fires.

Forestry operations, a key economic driver for some Aboriginal communities, have suffered from both climatic and non-climatic impacts. Natural Resources Canada (2006) reported that exports from forestry and related industries in Ontario were valued at \$8.4 billion, employing 84 500 people in 2005. In Ontario, more than 50% of employment income in the forestry-dependent communities in the central subregion comes from the forestry sector. Rising winter temperatures have affected the construction of winter roads that are necessary for harvesting and hauling activities. Additionally, winter melts and extended spring conditions have made it necessary to cease hauling on some all-season roads due to damage from heavy loads.

Climate impacts have affected lakes and rivers in the central subregion and these declines may affect drinking water supplies. Decreased precipitation and increased evaporation between the 1970’s and 1990’s have lead to significant decreases in stream flow in the northwestern area of the subregion. Changes associated with this include: increased water renewal times, higher water temperatures, lengthened ice-free times and altered water chemistry in the lakes (Schindler et al. 1996). Between 1992 and 2003, 23 of the 46 flood emergencies reported in Ontario occurred in the central subregion (Wianecki and Gazendam 2004). In the past most floods coincided with the spring melt yet between 1990 and 2003 merely 34% of the floods occurred in between the months of March and April. Flood events occurring in the other seasons resulted from heavy rain events, rain-on-snow and ice jamming. If water quantity and

quality continue to be negatively affected, increased treatment costs may be necessary in Aboriginal communities with water treatment system already under stress.

Highway transportation is a vital link in this subregion and extreme precipitation has resulted in road closures. Major and secondary highways were shut down for more than a week by unprecedented heavy rains in June 2002. Associated flooding damaged bridges, culverts, railways, homes, commercial properties and agricultural industries (Cummie et al. 2004).

Ontario north subregion

There is less information on climate change impacts, climate-related vulnerability, and adaptation research in the north subregion of Ontario than other regions (Smith et al. 1998). Due to its northern latitude the primary concerns are similar to issues in the northern parts of bordering provinces and the Northwest Territories. Potential challenges related to decreased water quality, traditional food supplies, increased risk due to forest fires and effects on infrastructure, like winter roads, were identified in a recent risk management workshop related to climate change impacts on Aboriginal communities (Indian and Northern Affairs Canada 2007).

Climate change impacts to the aquatic and terrestrial ecosystems have been reported, such as decreased ice cover (e.g Evans Strait) and earlier ice melt (e.g. Eastern and south western Hudson Bay and James Bay) in some areas. (Gagnon and Gough 2005; (Stirling et al. 1999, Gough et al. 2004; Stirling et al. 1999). Between 1964 and 2000, reduced water flows have been reported on the Severn, Winisk, Ekwan, Attawapiskat, Albany and Moose rivers (Déry et al. 2005). Reduced flows and increasing temperatures will impact drinking water systems already under stress. This will further tax these systems capacities to provide acceptable drinking water. Waterborne disease outbreaks are of a primary health concern for northern communities and these are expected to get worse with climate change impacts and extreme weather events. O'Connor (2002) and the Commissioner for the Environment and Sustainable Development (2005) identified several First Nations as having vulnerable water treatment systems. In 2006, Kingfisher and Muskrat Dam Lake were listed as two of 21 First Nations with high-risk water systems in Canada (Indian and Northern Affairs Canada 2006).

Floods are also affecting the northern region of Ontario. Spring flooding and ice jams are an issue for communities with sensitive infrastructure situated on floodplains. The community of Winisk suffered two deaths and 129 people were evacuated when spring flooding was triple the

historic normal in 1986 (Public Safety Canada 2006). Spring floods caused Attawapiskat to be evacuated in 1989, 1992, 2002 and 2004 (Environment Canada 2005b, Public Safety Canada 2006) and Kashechewan to evacuate 200 people in 2005 and 2006.

Transportation has also been negatively impacted by climate change. Several sections of winter roads, especially lake and river crossings were delayed for up to 10 days in 2005 and 2006 (Wawatay News 2005a,b). Diesel fuel supplies also rely on the winter road network.

Approximately 70% of a communities energy needs is attributed to space heating in the north subregion. It is reported in 2000 that 31 First Nations in this subregion were off grid with 13 of these relying on diesel generators. It is estimated that approximately 18 000 people living in more than 4000 homes are serviced with electricity generated by diesel systems (Zulak et al. 2000).

The remoteness of northern communities presents challenges for health care services such as limited access. Climate change is adding to these challenges. Access to traditional foods, a healthier and cost efficient alternative to store bought foods, is threatened by changes to the ice, snow and water quality. Access to traditional medicines is also compromised. Traditional foods continue to provide a nutritious and significant portion of many northern diets. A food study conducted in 2002 in Fort Severn, reported that 40% of households relied on hunting and fishing to supplement their diets (Lawn and Harvey 2004).

The Prairies (Sauchyn and Kulshreshtha 2008)

Water ecosystems and resources are affected by climate change. Surface waters are experiencing substantial impacts due to changes in winter precipitation, temperature and duration. The trend of declining stream flows is in part due to decreases in winter snowfall in the last half of the twentieth century and snowmelt runoff that takes place above frozen soil supplies water to small rivers (Byrne 1989). Of 50 unregulated rivers of western Canada monitored in the late 40's - early 50's and in 1993, spring runoff is significantly earlier in 30% of them. Measurable decreases in summer and fall runoff are the result of extensive glacial retreat in the past century, which reduces river flows during the time when water demands are greatest (Demuth and Pietroniron 2003). Higher temperatures in the summer correlate with large algal bloom size in Lake Winnipeg (McCullough et al. 2006).

Twenty-one percent of Manitobans, 23% of Alberta's population and 43% of Saskatchewan residents rely on groundwater for potable water (Environment Canada 2004 b). Higher rates of evapotranspiration will lead to drier soils and effect groundwater discharge resulting in a slow and steady decline of water tables in several regions. Water supply and quality are negatively affected when water tables decline as a result of decreased recharge, sustained drought or over pumping. This was the situation that occurred in the record setting 2001-2003 drought in central Alberta which lasted longer and was more intense than any in their recorded history (Kienzle, 2006). Groundwater near Winnipeg could become increasingly salty as the saline-freshwater boundary could move eastward as a result of climate change (Chen et al. 2002).

Decreased soil moisture in boreal and taiga regions due to more frequent droughts, including prolonged droughts (Sauchyn et al. 2003), will result in the increased size and frequency of forest fires. In one instance, dry organic soils, resulting from recent extreme droughts, burned along with nearly all vegetation. Consequently all water storage capacity was locally lost. Instantaneous runoff results in flash flooding under these circumstances.

Droughts will be intensified by rising annual and seasonal temperatures (Laprise et al. 2003) and extreme precipitation events are also more probable with increased temperatures (Groisman et al. 2005). Conditions similar to these often result in local or regional flooding and as was the case in the South Saskatchewan River basin in 1995 and 2004.

Droughts in 2001 and 2002 were among the first recorded coast-to-coast droughts and affected areas inexperienced with dealing with water shortfalls. These major droughts had negative impacts on the economy, environment, human health and society such as:

- Approximately \$3.6 billion was lost in agricultural production;
- An estimated \$5.8 billion was lost in gross domestic product;
- More than 41 000 jobs were lost;
- Excessive soil erosion due to wind occurred;
- In some areas water shortages were experienced requiring supplemental water at costs to communities and resulting in livestock and crop losses;

- Extensive aspen dieback occurred in the most drought affected areas of Western Canada; and
- Documented negative multi-sector impacts to transportation, hydro production, health, tourism, recreation, water supplies, and agricultural production occurred.

Examples of other flood and drought events that will stress water resource management and are expected to increase in frequency include:

- Edmonton, already saturated by earlier rain events, experienced a thunderstorm that released 150 mm of rain in an hour. Damages of \$175 million were estimated (Environment Canada 2004a).
- The multi-year drought of 2000-2003 had the most severe soil moisture and ground water effects in recorded history. Records during this time period indicate less precipitation than recorded in the mid-30's (Kienzle 2006).
- 2002 was termed "the worst ever for farmers in Western Canada" by Environment Canada (2004a).
- The St. Mary River Irrigation Project in southern Alberta were only able to meet 60% of the need in 2001.

Biological events are recognized as functions of season and weather by Aboriginal people and were used to indicate planting times and predict planting success, fishing and hunting activities (Lantz and Turner 2004). The flowering dates and rates of widely distributed plants are used as dependable indicators of weather and climate and are easily monitored. Beaubien and Freeland (2000) reported a 26-day shift in spring flowering in the past century, which could have an impact on harvesting of traditional plant foods and medicines.

The breeding grounds for 50 – 80% of Canadian duck populations are found in the prairies. The prairie pothole region lying in central North America is the most productive waterfowl habitat in the world (Clair et al. 1998). Waterfowl populations decline in response to drought and habitat destruction (Bethke and Nudds 1995). Decreasing water levels in the prairies will likely have negative impacts on waterfowl (Poiani and Johnson 1993). Most of the variation in growth rates in mallards and other duck populations is attributable to weather fluctuations during the breeding

period (Hoekman et al. 2002). For instance, higher temperatures and earlier snow melt resulted in earlier nesting activity and hatching of geese in northern regions (LaRoe and Rusch 1995). Changes to wildlife migration patterns and population sizes have been linked to a changing climate and more changes are anticipated (Inkley et al. 2004). Traditional ways of life such as hunting and fishing that rely on vertebrate biodiversity will be affected. Higher temperatures and decreasing water levels will also stress aquatic species at risk (James et al. 2001). Small changes in temperature, turbidity, salinity or oxygen levels (all of these are potentially climate change impacts) can affect many species of sensitive fish.

In combination with extreme weather, devastating and dangerous geological processes commonly occur on steep slopes of the Canadian Cordillera. A debris flow in Banff National Park at Five-Mile Creek blocked the Trans-Canada for several days in August 1999, the height of the tourist season (Evans 2002). Extreme rainfall or runoff from rapidly melting snow or ice is often the trigger of such incidents. Due to present and future hydrological and climatic trends (increased precipitation mainly in winter; increased glacial melt and rapid snowmelt) the probability of more frequent landslides, debris flows, rock avalanches and flash floods will also increase (Evans and Clague 1994, 1997). Public safety and infrastructure operations and maintenance costs will be affected particularly due to rising residential development and recreational activities in the Rockies.

Prairie soils are underlain with loose sediments and are vulnerable to wind, water and slumping on river valley sides and where natural vegetation is limited by soil moisture or agriculture. River valleys and dune complexes are the most dynamic landscapes (Lemmen et al. 1998) and they are most sensitive to variations and extremes in climate and hydrology (Lemmen and Vance 1999). Where vegetation endures extended drought conditions (due to less frequent and more intense precipitation events) erosion and shallow slope failures will occur more frequently on slopes and stream channels (Sauchyn 1998, Ashmore and Church 2001).

Many Aboriginal communities have forestry operations or are dependent on them for employment and income generation. Forestry operations, management and access are also affected by climatic events over the short-term. Flooding or severe erosion due to extreme rain events can lead to loss of roads, culverts and bridges. This can decrease or eradicate opportunities for the restoration of temporary logging roads (Van Rees and Jackson 2002). Road washouts also affect water quality and fish habitat by increasing sediment loads, although effects are often minor except in extreme events (Steedman 2000). High winter temperatures

can affect access in winter due to ground thaw and winter road construction and maintenance. All these can prevent forestry operations (Archibald et al. 1997). Deep soil rutting by equipment operation in wet areas and at times of heavy rain can negatively affect soil productivity, tree regeneration and can increase soil erosion (Archibald et al. 1997, Grigal 2000).

Large scale disturbances, such as forest fire, insect outbreaks and blowdowns are strongly influenced by climatic factors (Weber and Flannigan 1997, Voney and Fleming 2000). These disturbances affect forest productivity and species composition across the landscape. Between 1975 and 2003 an average of 3.1 million hectares of prairie forests were affected by insect outbreaks with a maximum of 10 – 12 million hectares reached in the mid 70's (National Forestry Database Program 2005). During the period 1975 to 2005, nearly 1 million hectares on average burned in forest fires with a maximum of 3 – 4 million hectares burned during some years in the 1980's (National Forestry Database Program 2005). The southern extent of the boreal forest is presently vulnerable to drought conditions and it is expected to become increasingly vulnerable in the future (Hogg and Bernier 2005). The frequency and severity of insect outbreaks is also anticipated to increase (Volney and Fleming 2000). It is not surprising then that the frequency of forest fires is expected to increase (Bergeron et al. 2004) as is the fire intensity (Parisien et al. 2004) and the spatial scale (Flannigan et al. 2005). The magnitude of these changes is a challenge to predict.

There is a widespread and diverse transportation network across the Prairies, consisting of 540 000 km of two-lane public roads – 52% of the national total (Transport Canada 2005). Approximately 20% of the roads are paved and thousands of kilometres are public winter (ice) roads. Some 2 300 km of winter roads service remote communities in Manitoba that do not have permanent road access (Manitoba Transportation and Government Services 2006). Rail service and 51 airports (in 2004) also make up the transportation network in this region (Statistics Canada 2004).

The transportation network is a vital link to nearly all economic and social activities and is vulnerable to extreme weather (Andrey and Mills 2003). Warm periods during winter are resulting in more rain and freezing rain events. An increase in extreme precipitation events (Kharin and Zwiers 2000) and an increase in inter-annual climate variability is expected to cause more damage to road, railways and other infrastructure due to flooding, erosion and landslides. Weather-related vehicle and airplane risks and costs, to transport people and goods, will be affected and perhaps the cost of insurance. Conversely, fewer accidents, injuries and fatalities

related to weather may occur (Mills and Andrey 2002) as fewer blizzards are occurring in the Prairies (Lawson 2003). During the winter of 2005-2006, less snow clearing and de-icing chemicals were used in Manitoba as only 42% of the budgeted \$80 million road maintenance allowance was spent (Manitoba Transportation and Government Services 2006).

Northern roads and rail lines underlain with frozen substrates in the winter or permafrost may be compromised with increasing temperatures. It is likely that the railway servicing the port of Churchill in northern Manitoba will require frequent service and repair, if not replacement, due to melting permafrost (Nelson et al. 2002). In 1997 – 1998, an estimated \$15-17 million were spent transporting goods to remote communities in Manitoba and Ontario (Paul and Saunders 2002, Kuryk 2003). In Manitoba, winter roads service 28 communities and more than 25 000 people (Centre for Indigenous Environmental Resources 2006). These economic, social and cultural lifelines allow the most cost-effective means to deliver essential goods like, food, fuel, medical and building supplies (Kuryk 2003, Centre for Indigenous Environmental Resources 2006). Decreased ice thickness, poor ice texture and density, delayed construction, muskeg problems and decreased load limits have been reported by Manitoba Transportation and Government Services. In some cases, equipment has been damaged beyond repair from a single trip on the winter road. Safety of winter roads is also sensitive to climate change. In 2002, during winter road construction a member of Wasagamack First Nation drowned when his grader fell through the ice. Increased financial pressures and social isolation are another health related concern connected to a shortening winter road season.

Frozen water, winter trails and roads play an important function socially, recreationally and culturally. Recently, winter festivities and fishing derbies were cancelled due to unsuitable weather conditions. Furthermore, people reported feeling more disconnected with friends and families from nearby communities due to shorter and less reliable winter roads. Thinner ice and poor winter road conditions have impacted economic activities like commercial ice fishing and the export of fish and furs to larger centres. Additional income generation also comes from winter road construction and maintenance through contracts with Manitoba Transportation and Government Services. Therefore, the timing and length of the winter road season has the ability to affect economic development, housing, capital works, special projects and equipment maintenance.

Few rural communities have the same level of access to disaster assistance, like emergency response teams or health care facilities, as larger centres. The small number of transportation

routes is a limiting factor for evacuations and transport of material and supplies during emergency situations in remote northern communities. A larger economic dependency on natural resources and limited opportunities for economic diversification also makes rural communities more vulnerable to climate change impacts than larger centres. In the Prairies, agriculture supports 78% of the resource related jobs and forestry accounts for 2% of the jobs (Stedman et al. 2005). Many Aboriginal communities depend on these agricultural and forest sector employment opportunities. Climatic stresses, like the 2001 – 2002 drought and non-climatic stresses, like the outbreak of bovine spongiform encephalopathy (BSE) and softwood lumber trade disputes, may combine thereby reducing coping abilities and the chances of proactive planning to reduce vulnerability and risk. Coping ranges are reduced by multiple stressors as community, regional and household finances become limited and the social capital (support networks) become fatigued. Climate change planning opportunities are reduced as they become less salient than more immediate stresses. Of particular concern is the ability of remote communities to respond to extreme weather events, forest fires and other health risks.

Forestry based operations are often located in remote areas with limited transportation routes. There is a high risk to these operations if extreme weather or forest fires compromise these transportation routes. Communities that depend on mining and energy for economic opportunities are also sensitive to climate change because they are often highly dependent on water resources. Water shortages have been experienced and are expected to happen again in the future. Other vulnerabilities are related to power outages and disruptions to transportation networks to remote communities.

Throughout the Prairies, the highest rates of poverty and unemployment are found in Aboriginal communities. While it is estimated that half of the Aboriginal population lives in urban areas, the rest continue to reside in or near their traditional territories throughout all parts of the Prairies. Subsistence activities based on local food supplies is far greater in many Aboriginal communities than in the non-Aboriginal population. Climate change will likely have negative effects on the plants and animals that Aboriginal people rely on including changes like declining numbers and increased annual uncertainty in availability for many traditional foods such as, moose, caribou, fish and wild rice. It is expected that these declines will necessitate an increased dependence on expensive and less nutritious imported market foods. Concerns related to difficulties in accessing traditional and reserve lands in the winter and therefore participating in traditional activities have been expressed. Unsuitable winter conditions impair

people's abilities to travel to trap lines, hunting and fishing areas. Concerns regarding personal safety have been cited as the reason for decreased participation in traditional activities.

The Prince Albert Grand Council (PAGC) hosted an Elder's forum in February 2004 entitled: First Nations' Traditional Ways of Life and Climate Change (Ermine et al. 2005). Elders' observations for the most part, confirmed scientific observations of climate change. Inter-annual variability was recognized by the Elders as a normal part of nature and several concerning trends were identified, such as:

- Increased frequency of extreme weather events like tornadoes and hailstorms,
- Seasonal shifts like summer and fall extending into the winter,
- Dryer summer seasons,
- Abnormal wildlife behaviour like shifting migration patterns and changes in animal distributions,
- Presence of new species like previously unseen birds,
- Expansion of natural ranges of animals such as cougars and white-tail deer,
- Increasing summer temperatures affecting children and Elders,
- Unpredictable weather affecting preparedness for outdoor activities,
- Drought related changes to trees and shrubs so that useful products produced from these are less abundant, and
- Thinning winter coats of fur bearing animals affecting the economic desirability related to a trapping economy.

There is a direct link between weather, climate and human health and wellbeing. Changes in air pollution, food-borne pathogens, heat stress, mental stress, particulate matter, water pathogens and vector borne diseases may negatively affect human health with a changing climate (Séguin in press). Aboriginal people, children, the elderly, the homeless, those living in or in near poverty and those with underlying health concerns are the most at risk of negative health

consequences. Flooding, drought, ecosystem changes and increased temperatures will directly and indirectly affect human health.

The concentration of pathogens and toxins is increased in surface waters under drought conditions (Charron et al. 2003, World Health Organization 2003). Drought also contributes to an increase in dust from open sources, such as unpaved roads, forest fires, tilled fields that accounts for 94% of particulates in Canada (Smoyer-Tomic et al. 2004). Airway inflammation, in the form of asthma, allergic rhinitis, bronchitis, hypersensitivity pneumonitis or organic dust toxic syndrome, is exacerbated by dust inhalation (do Pico 1986, Rylander 1986, do Pico 1992, Lang 1996, Simpson et al. 1998). The financial distress to farming families associated with drought has been well documented (Olson and Schellenberg 1986, Walker et al. 1986, May 1990, Ehlers et al. 1993, Deary and McGregor 1997). Wildfires increase with drought (Smoyer-Tomic et al. 2004) and this is connected with increased respiratory conditions, visits to the hospital and deaths (Bowman and Johnston, 2005). Mental stress can be attributed to evacuations and dislocation due to forest fires (Soskolne et al. 2004). Transportation of medical emergencies and supplies were impaired when the only access road to Fort McMurray was cut off during a May 1995 forest fire (Soskolne et al. 2004).

British Columbia (Walker and Sydneysmith 2008)

Rural BC is comprised of Aboriginal communities and small towns dispersed on the coast and in the interior. Weather related events, including extreme weather are the climate risks most directly affecting the population within British Columbia. An increased frequency of extreme weather has been well documented throughout the world (Easterling et al. 2000, Milly et al. 2002, Palmer and Rälsänen 2002, Schumacher and Johnson 2005). The severity and frequency of forest fires in western North America is also on the rise (Gedalof et al. 2005, Westerlin et al. 2006) and predictions are this trend will continue (Gillett et al. 2004, Flannigan et al. 2005). BC's Provincial Emergency Program (BC-PEP) records personal and economic loss due to infrastructure damage related to extreme weather. BC-PEP reported dramatic increases in the occurrence, severity and costs of extreme events attributed to forest fires, storm surges, drought, and heavy precipitation resulting in landslides and flooding. Economic losses were also suffered from ice jams, freezing rain and rain-on-snow events associated with warmer winters. Between 2003 and 2005, disaster relief payments cost BC citizens on average \$86 million per year, as compared with an average of \$10 million per year for the period of 1999 – 2002 (Whyte 2006). The Canadian Disaster Database corroborates an increase in weather related

vulnerability for BC citizens (McBean and Henstra 2003, Public Safety and Emergency Preparedness Canada 2006b).

Reduced snow pack is resulting from increasing temperatures (Mote 2003a & b, Stewart et al. 2004). Stream flow volumes and timing have been changed by reduced snow pack and ice cover on several lakes and rivers is also decreasing (BC Ministry of Water, Land and Air Protection 2002). Many BC rivers also break up earlier in the spring (Bonsal et al. 2001, Zhang et al. 2001a).

Glacial melt is a key source of fresh water for western Canada contributing to many river levels and regulating temperatures within these (Fleming 2005, Fleming and Clark 2005, Moore 2006). Glaciers contribute 10 – 20% of the water flow to the Columbia River basin annually and 50% during the summer months (Brugman et al. 1996). BC's glaciers are retreating at unprecedented rates compared to the past 8 000 years (Lowell 2000) and over the next 100 years, many will vanish completely.

Groundwater systems are also sensitive to climate change impacts, especially shallow aquifer systems (Rivera et al. 2004). Minor alterations in temperature and precipitation can affect water table levels and rates of groundwater recharge (Changnon et al. 1988, Zektser and Loaiciga 1993). Decreases in stream flow will reduce ground water recharge and discharge (Scibek and Allen 2006).

Over the past century, the mean eustatic sea level has risen 10 – 20 cm (Intergovernmental Panel on Climate Change 2007). In this same time period levels are up 4 cm in Vancouver, 8 cm in Victoria, 12 cm in Prince Rupert and are down 13 cm in Tofino (BC Ministry of Water, Land and Air Protection 2002). This is an important issue given sea-level impacts to coastal infrastructure, such as roads, sewer structures, shipping ports and airports could be devastating. Rising sea levels also threaten several Aboriginal cultural sites and remote coastal communities, as they are sensitive to an associated increase in erosion and storm surge. Sea-level rise also makes freshwater aquifers more vulnerable to saltwater intrusion that could affect water quality and quantities available for irrigation and drinking.

8 APPENDIX 2 - VULNERABILITY AND RISK ASSESSMENT TOOLS

8.1 ASSESSMENT OF TOOLS

Existing tools for vulnerability and risk assessments were compiled and reviewed to determine their relevance for Aboriginal communities in Canada. As identified in the body of the report, CIER and UBC are using a participatory approach to understand vulnerability and adaptive capacity at the level of the Aboriginal community within Canada. The need for, feasibility, and potential elements of a self-assessment tool for Aboriginal communities will be determined through the case study work and network communications. In the event that a self-assessment tool is developed, any existing and relevant vulnerability and adaptive capacity tools will be used as a reference.

The vulnerability and risk assessment guides that were found were mainly focused on environmental hazards and disasters while some were developed specifically for climate change impacts. Many of the guides outlined the broad steps involved in an assessment, such as planning, gather information, analysis, and taking action. The general process involved in carrying out a vulnerability and/or risk assessments is to, gather information about predicted or potential biophysical hazards in a particular area, and then gather information about the level of vulnerability of a population (e.g. community, city) to these hazards. Many of the assessments are intended for practitioners, such as Red Cross or other organizations, who are working in developing countries at the community level. Many of these assessment tools followed a community-based approach in which community members were solicited directly for their input through a number of methods. A few assessment tools were geared towards leaders and decision makers at the municipal or state/provincial level in which the key stakeholders were involved to determine the potential people, property, infrastructure, industry, resources or environments that may be vulnerable to specific predicted climate change impacts (Bruce et al. 2006; Govt BC 2004; Snover et al. (no date)). One guide outlined steps involved in incorporating scenarios in vulnerability and risk assessments at the community level (Malone et al. 2004). Another category of relevant tools were those focused on social capital assessments (Mignone 2003, World Bank (no date)), which provide specific qualitative tools (e.g. mapping, questionnaire, interview questions) in order to assess social capital at the community level.

The tools that were most useful in the context of our project are those that are implemented at the local (community-level) scale and incorporate all components of vulnerability (social, livelihoods, institutions, motivation, infrastructure, biophysical) using participatory approaches. The assessments that provide examples of qualitative and quantitative techniques (e.g. transect walk, social mapping, Venn diagrams, hazard mapping, livelihoods seasonal calendar, and key informant interviews) that can be used to gather information and engage community members can be used as a reference as we develop our approaches to community based work in the case study communities (ActionAid (no date); Albarquez and Murshed 2004; Enarson et al. 2003; Frankenberger et al. 2002; Heljmans and Victoria (no date); Red Cross 1996; Government of Bangladesh 2006). One of the guides is focused on working with women, which can be referenced in our project to ensure we include issues of gender into assessments of vulnerability (Enarson et al. 2003).

8.2 LIST OF TOOLS

Actionaid International. (no date). Participatory Vulnerability Analysis: A step-by-step guide for field staff. London, UK.

Albarquez, Imelda and Zubair Murshed. 2004. Community-Based Disaster Risk Management: Field Practitioners Handbook. African Disaster Preparedness Center (ADPC), Klong Luang, Thailand.

Bruce, James, Egener, I.K. Mark, and David Noble. 2006. Adapting to Climate Change: A Risk-based Guide for Ontario Municipalities. Ontario Ministry of Municipal Affairs and Housing.

Buckle, Philip. 2000. Assessing Resilience and Vulnerability in the Context of Emergencies: Guidelines. Victorian Government Publishing Service, Melbourne.

Buckle, Philip, Marsh, Graham, and Sydney Smale. 2001. Assessing Resilience & Vulnerability: Principles, Strategies & Actions: Guidelines.

Cannon, Terry, Twigg, John and Jennifer Rowell. Social Vulnerability, Sustainable Livelihoods and Disasters. Report to DFID, Conflict and Humanitarian Assistance Department (CHAD) and Sustainable Livelihoods Support Office.

Coburn, A. W., Spence, R.J.S., and A. Pomonis. 1994. Vulnerability and Risk Assessment. Disaster Management Training Programme. Cambridge Architectural Research Limited, UK.

Enarson, Elaine, Meyreles, Lourdes, Gonzalex, Marta, Morrow, Betty Hearn, Mullings, Audry and Judith Soares. 2003. Working with Women at Risk: Practical Guidelines for Assessing Local Disaster Risk. International Hurricane Centre, Florida International University.

Falk, Knud (ed). 2005. Preparing For Disaster: A Community Based Approach. Danish Red Cross.

Frankenberger, Timothy R., Luther, Kristina, Becht, James and M. Katherine McCaston. 2002. Household Livelihood Security Assessments: A Toolkit for Practitioners. CARE USA, Atlanta, Georgia.

Kuban, Ron and Heather MacKenzie-Carey. 2001. Community-Wide Vulnerability and Capacity Assessment (CVCA).Government of Canada, Office of Critical Infrastructure Protection and Emergency Preparedness, Ottawa, ON.

Government of British Columbia. 2004. Hazard, Risk and Vulnerability Analysis Tool Kit. Ministry of Public Safety and Solicitor General Provincial Emergency Program. Victoria BC

Government of The Peoples Republic of Bangladesh. (2006?) A Facilitators Guidebook for Community Risk Assessment and Risk Reduction Action Plan. Directorate of Relief and Rehabilitation, Ministry of Food and Disaster Management. Bangladesh.

Halifax Regional Municipality. 2006. HRM Climate SMART Community Action Guide to Climate Change and Emergency Preparedness. Halifax.

Halifax Regional Municipality. 2007. Climate SMART Climate Change: Developers Risk Management Guide. Halifax.

Heljmans, Annelies, and Lorna P. Victoria. (no date) Citizenry-Based and Development-Oriented Disaster Response: Experiences and Practises in Disaster Management of the Citizens' Disaster Response Network in the Philippines Center for Disaster Preparedness.

IISD. 2007 CRISTAL: Community-based Risk Screening – Adaptation and Livelihoods. Users Manual. A decision support tool for assessing and enhancing project impacts on local adaptive capacity to climate variability and climate change. IISD, IUCN, SEI-US and Intercooperation.

Kohler, Alois, Julich, Sebastian, and Lena Bloemertz. 2004. Guidelines: Risk Analysis – a Basis for Disaster Risk Management. Federal Ministry for Economic Cooperation and Development. Eschborn.

Lu, Xianfu. 2006. Guidance on the Development of Regional Climate Scenarios for Application in Climate Change Vulnerability and Adaptation Assessments within the Framework of National Communications from Parties not Included in Annex I to the United Nations Framework Convention on Climate Change, National Communications Support Programme, UNDP-UNEP-GEF New York, USA

Malone, Elizabeth L, Smith, Joel B., Brenkert, Antoinette L., Hurd, Brian, Moss, Richard H., and Danile Bouille. 2004. Developing Socioeconomic Scenarios for Use in Vulnerability and Adaptation Assessments. UNDP, New York, US.

Mignone, Javier. 2003. Measuring Social Capital: A Guide for First Nations Communities. Canadian Institute for Health Information, Ottawa, Ontario.

Oxfam. 2002. Participatory Capacities and Vulnerabilities Assessment: Finding the Link between Disasters and Development. Oxfam Great Britain – Philippines Programme.

Red Cross. Community Based Disaster Management: (no date) Manual for Facilitators. International Federation of Red Cross and Red Crescent Societies, Sub-regional office, Port of Spain.

Red Cross. 2008. Vulnerability and Capacity Assessment (VCA) Training Guide: Classroom Training and Learning-by-Doing. International Federation of Red Cross and Red Crescent Societies. Geneva, Switzerland.

Red Cross. 1999. Vulnerability and Capacity Assessment: An international Federation Guide. International Federation of Red Cross and Red Crescent Societies. Switzerland.

Red Cross. 1996. Vulnerability and Capacity Assessment Toolbox.

Rudel, Thomas K. (2008) Meta-analyses of case studies: A method for studying regional and global environmental change. *Global Environmental Change* 18 pp.18–25

Snover, A.K., Binder, L. Whitely, Lopez, J., Willmott, E., Kay, J., Howell, D. and J. Simmonds. Preparing for Climate Change: A guidebook for Local, Regional, and State Governments. IN association with and published by ICLEI – Local Governments for Sustainability, Oakland, CA.

SydneySmith, Robin. 2007. Considering Climate Change In Your Community: A Startup Guide for BC Communities. Canadian Climate Impacts and Adaptation Research Network, BC (CCIARN-BC). Natural Resources Canada.

UN. 1998. Guidelines for Community Vulnerability Analysis: An Approach for Pacific Island Countries. The South Pacific Programme Office of the United Nations Department for Economic and Social Affairs.

Venton, Paul and Bob Handsford. 2006. Reducing Risk of Disaster in our Communities. Tearfund, UK.

World Bank. (no date). Instruments of the Social Capital Assessment Tool (SOCAT). Social Capital Thematic Group.

9 APPENDIX 3: INDICATORS OF VULNERABILITY AND ADAPTIVY CAPACITY

Vulnerability Indicators

Theme	Dimension	Indicators
Economic/Resources (Equity, Livelihoods, Entitlement, Resources, poverty,)	Economic Well-being National wealth Economic coping capacity Inequality Economic autonomy Economic assets Capital resources Financial means Poverty Food sensitivity Dependence on agriculture Agricultural self-sufficiency Availability of and access to resources Equity (equally distributed access to resources)	GDP per capita ^{1, 3, 4} Gini Index/coefficient ^{1, 3, 4} Debt repayments [as a percentage of GDP] ^{1, 3} GNI ³ Agricultural employees (% of total population) ^{1, 3, 8} Rural population (% of total) ^{1, 3} Agricultural employees (male and female) ³ Percentage of landless labourers in agricultural workforce ⁸ Agricultural exports (% of GDP) ¹ Agricultural production index ³ Cereals production per capita ⁴ Animal protein consumption per capita ⁴ Roads, km, scaled by inhabited land area ¹ Population without access to sanitation (%) ¹ Rural population without access to safe water (%) ¹

Theme	Dimension	Indicators
Natural/ Ecosystem (water, land, biodiversity)	Natural resources and ecosystems Environmental Stress Sustainability of water resources Environmental coping capacity Biophysical Geographical and demographic factors Coastal Risk Resource Pressure Ecosystems sensitivity Settlements sensitivity	Protected land area ^{1, 3} Per cent forest cover ^{1, 3} Forest change rate (% per year) ^{1, 3} Water resources per capita ^{1, 3} Groundwater recharge per capita ^{1, 3} Ground water availability ⁸ Unpopulated land area (%) ^{1, 3} SO2 emissions per area ⁴ Land unmanaged, % ⁴ Land managed, % ⁴ Fertiliser consumption ⁴ Soil conditions (quality and depth) ⁸ Km or coastline (scaled by land area) ^{1, 3} Population within 100 km of coastline (%) / Flood prone population ^{1, 3, 4} Population density ^{1, 3, 4}
Human (Health, Education, Demographics)	Health and Nutrition (HN) State support for health Burden of ill health General health Healthcare available Removal of economically active population Nutritional status General food availability Access to Nutrition Human resources coping capacity Education (EDU) Educational commitment Entitlement to information	Health expenditure per capita (USD PPP or % of GDP) ^{1, 3} Public health expenditure ³ Disability adjusted life expectancy (DALE) ^{1, 3} Calorie intake per capita ^{1, 3} Life expectancy at birth ^{3, 4} Maternal mortality per 100,000 ³ Completed Fertility ⁴ Dependency ratio ⁴ AIDS/HIV infection (% of adults) ^{1, 3} Food production index ³ Food price index ³ Education expenditure (% government expenditure or % of GNP) ^{1, 3} Literacy rate (% of population over 15) ^{1, 3, 4, 8} Literacy rate (15-24 year olds) ³ Literacy ratio (female to male) ³

Theme	Dimension	Indicators
Technology (capacity, skills Information, resources, Infrastructure)	Technical capacity Commitment to and resources for research Capacity to undertake research and understand issues Physical infrastructure Isolation of rural communities Commitment to rural communities Quality of basic infrastructure	R&D investment (% GNP) ^{1, 3} Scientists and engineers in R&D per million population ^{1, 3} Tertiary enrolment ¹ Km of roads ¹ Rural population without access to clean water and sanitation ^{1, 4} Availability of irrigation ⁸ Quality of infrastructure ⁸
Institutions (Political, governance) Social	Institutions, governance, conflict and “social capital” Conflict Effectiveness of policies Ability to deliver services Willingness to invest in adaptation Barriers to Adaptation Participatory decision making Influence on political process Social capital	Internal refugees (% of population) ^{1, 3} Control of corruption, ^{1, 3} Government effectiveness ^{1, 3} Political stability ^{1, 3} Regulatory quality ^{1, 3} Rule of law ^{1, 3} Voice and accountability ^{1, 3} Civil liberties ³ Political rights ³ Degree of gender equity ⁸

Adaptive Capacity Indicators

Themes	Dimension	Indicators
Economic/Resources (Equity, Livelihoods, Entitlement, Resources, poverty)	<p>Income Financial Economic criteria Economic Resources</p> <p>Sociological criteria (Equity) Employment opportunities Opportunity to access health and social services Distribution of income – general population Distribution of income – agricultural producers</p> <p>Income generation relative to capital investment Income generation relative to summary expense Diversity of employment opportunities Agricultural dependency Vulnerability of agricultural workforce Financial institutional resources Diversity</p>	<p>Sovereign debt rating⁷ Low-to-middle income⁷ Purchasing power parity-adjusted per capita GDP⁷ Per capita income² GINI Index (measure of equity in individual income)² Inequality in the distribution of income (low, high)²</p> <p>Savings⁶ Credit use^{5, 6} Remittances⁶ Pensions⁶</p> <p>Job diversity¹¹ Employment rates/ Unemployment rate^{10, 11} Income level¹¹ Home ownership¹¹ Local business ownership¹¹ Land use diversity⁵ Income diversity⁵</p> <p>Government transfers⁵ Crop insurance⁵ Crop diversity⁵</p> <p>Percentage of district workers employed in agriculture¹² Percentage of landless labourers in agricultural workforce¹² Ratio of gross farm receipts to total capital investment¹⁰ Ratio of income to expenses¹⁰ Off-farm earnings as a percent of total family income¹⁰ Ratio of off-farm contribution of time to on-farm contribution of time¹⁰ Ratio of labour force in health and social service occupation¹⁰ Ratio of farms reporting sales in excess of 250k to all other farms¹⁰</p>

Themes	Dimension	Indicators
Natural/ Ecosystem (water, land, biodiversity)	Natural Soil quality Physical/natural resources Groundwater availability	Biodiversity ⁶ Environmental resources ⁶ Land ⁶ Land area ⁵ Water ⁶ Frequency of water contamination ¹¹ Frequency of water shortage ¹¹ Quality/quantity assessment of surface water ¹¹ Replenishable groundwater available for future use, in million cubic meters ² Wildlife ⁶ Animal units ⁵ Depth of soil cover ¹² Soil degradation severity ¹² Additional land rented ⁵
Human (Health, Education, Demographics)	Population Human (Labour, education, Training health) Health Human capital Female disadvantage/Female literacy and child survival chances Human Resources (Skills, Knowledge 6, Good health, Ability to labour)6	Percentage of population older than 65 years ² Age ⁵ Dependency ratio ¹¹ Adult labour force ⁵ Life expectancy at birth ² Physicians per 100,000 ² Heath care system coverage (private, universal) ² Adult literacy rate (>7 years) ¹² School availability measure ¹¹ Years of schooling completed ¹¹ Education levels ⁵ Female literacy rate ¹² “Missing girls” i.e., less than 48.5% girls in 0-6 population ¹²

Themes	Dimension	Indicators
Technology (skills Information, resources, infrastructure)	Flexibility of infrastructure Physical Level of technology Ability to develop technologies Openness to development and use of technology Information and Skills (knowledge about available adaptation options, the capacity to assess them) Infrastructure development Vulnerability to rainfall variability (Infrastructure) Soil resources Surface water resources Groundwater resources Transportation network (Technology) Water access technology Computer technology Technological flexibility Technological exposure (Information, skills and Management) Enterprise information management Sustainable soil resource management practices Sustainable environmental management practises Human resource management	Access to information via newspaper, television, radio, internet ² Transport ⁹ Shelter ⁹ Energy ⁹ Communications ⁹ Water systems ⁹ Composite index of infrastructure development ¹² Irrigation rate ¹² Irrigation access ⁵ Tractor ownership and tenure ⁵ Annual water resources between 1000-1700 cubic meters per person ⁷ Percentage of land in a shared water basin ⁷ Proportion of area in dependable agricultural land ¹⁰ Ratio of surface water area to total land area ¹⁰ Number and/or yield of wells ¹⁰ Ratio of high capacity to low capacity roads ¹⁰ Ratio of value of irrigation equipment to value of all other farm equipment ¹⁰ Ratio of farms reporting use of computer to all other farms ¹⁰ Ratio of value in tractors under 100hp to total value of all other tractors ¹⁰ Ratio of technologically-demanding to demanding farm types ¹⁰ Ratio of Farms reporting computer livestock and crop record keeping to all other farms ¹⁰ Ratio of area of no-till or zero till seeding to tilled area ¹⁰ Ratio of farms reporting windbreaks and shelter belts to all other farms ¹⁰ Ratio of total farms reporting paid ag labour to all other farms ¹⁰

Themes	Dimension	Indicators
Institutions (Political, governance)	Well-developed social institutions Political	Relationships of power ⁶ Access to political system and processes ⁶ Influence on political system and processes ⁶
Social	Social Political criteria (Institutions and Networks) Informal operating arrangements Email use Internet access Opportunity to access agricultural education institutions Institutional resources Social resources Information and social capital	Low civil freedom ⁷ Moderate civil freedom ⁷ High civil freedom ⁷ Ratio of total farms reporting formal agreements to total number of farms reporting sole proprietorships and partnerships without written agreement minus miscellaneous category ¹⁰ Ratio of total farms reporting email use to all other farms ¹⁰ Distance between centroids of each Census Division and the nearest regionally significant Ag institution ¹⁰ Elected representation ¹¹ Age and condition of utilities ¹¹ Number of emergency programs available ¹¹ Community health and services measure ¹¹ Radio/TV ¹¹ Quantity and quality (amount of trust and shared norms) of networks ⁶ Membership in groups ⁶ Social relations ⁶ Access to wider institutions in society ⁶ Community attachment ¹¹ Voluntary involvement ¹¹ Number of community events ¹¹ Access to climate information ⁵ Connections to sources of technical support ⁵ Participation in farm organizations ⁵

- (1) Adger, W. Neil., Brooks, Nick, Bentham, Graham, Agnew, Maureen, and Siri Eriksen. 2004. New Indicators of Vulnerability and Adaptive Capacity. Technical Report 7. Tyndall Centre for Climate Change Research. University of East Anglia Norwich.
- (2) Alberini, Anna, Chiabai, Aline, and Lucija Muehlebachs. 2006. Using Expert Judgement to Assess Adaptive Capacity to Climate Change: Evidence from a Conjoint Choice Survey. *Global Environmental Change* 16: 123-144.
- (3) Brooks, Nick, Adger, W. Neil, and P. Mick Kelly. 2005. The Determinants of Vulnerability and Adaptive Capacity at the National Level and the Implications for Adaptation. *Global Environmental Change* 15: 151-163. (see table on Pg 155 for detailed info)
- (4) Downing, Thomas E. and Anand Patwardhan 2004. Assessing Vulnerability for Climate Adaptation. Technical Paper 3 in *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures*. Lim, Bo, and Erika Spanger-Siegfried (ed). United Nations Development Program. Cambridge University Pres
- (5) Eakin, Hallie and Luis A. Bojorquez-Tapia. 2008. Insights into the composition of household vulnerability from multicriteria decision analysis. *Global Environmental Change*. 18: 112-127.
- (6) Frankenberger, Timothy R., Luther, Kristina, Becht, James and M. Katherine McCaston. 2002. Household Livelihood Security Assessments: A Toolkit for Practitioners. CARE USA, Atlanta, Georgia
- (7) Haddad, Brent M. 2005. Ranking the Adaptive Capacity of Nations to Climate Change when Socio-political Goals are Explicit. *Global Environmental Change* 15: 165-176.
- (8) O'Brien K., Leichenko R., Kelkar U., Venema H., Aandahl G., Tompkins H., Javed A., Bhadwal S., Barg S., Nygaard L., West J. (2004). Mapping vulnerability to multiple stressors: climate change and globalization in India. *Global Environmental Change*, 14, 303–313.
- (9) Smit, B., Pilifosova, O., Burton I., Challenger B., Huq S., Klein R.J.T. and Yohe, G. 2001. Chapter 18. Adaptation to climate change in the context of sustainable development and equity *Climate Change 2001: Impacts, Adaptation and Vulnerability*, (ed.) J.J. McCarthy, O.F Canziani, N.A. Contribution of Working Group III to the 3rd Assessment Report of the Intergovernmental Panel on Climate Change.
- (10) Swanson, D.A., J.C. to Hiley and H. Venema. 2007. Indicators of Adaptive Capacity Climate Change for Agriculture in the Prairie Region of Canada: An Analysis based on Statistics Canada's Census of Agriculture. Working Paper for the Prairie Climate Resilience Project, Winnipeg: International Institute for Sustainable Development.
- (11) Wall, E. and K. Marzall. 2004. Climate change and adaptive capacity in Tweed: Profiling resources. Presentation for the Annual conference of the Canadian Rural Revitalization Foundation, Tweed, Ontario, October. Found in Swanson et al. 2007