Fostering Adaptive Capacity and Resilience to Environmental Change in Sub-Arctic First Nations: The Use of Collaborative Geomatics, an Interactive, Web-based Informatics Tool

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners. I understand that my thesis may be made electronically available to the public.

Abstract

The Western James Bay region of northern Ontario (the Mushkegowuk Territory) is home to some of Canada's largest wetlands and most pristine ecosystems. This region is also home to approximately 10,000 Omushekgo Cree who inhabit four First Nation communities. Environmental change due to climate change and major resource development are a reality to the people of this sub-arctic region. Furthermore, it is predicted that climate change will have amplified impacts in northern climates. Climate change has and will continue to have impacts on the distribution of species in arctic and sub-arctic ecosystems. To date, it is not clear to what extent these distributional changes in species due to climate change will have on First Nations' place-based relationship with the land and what measures the Cree will take to adapt to these changes.

The University of Waterloo's Computer Systems Group has developed an approach and toolkit for the development of web-based, spatial data and information management systems referred to as collaborative geomatics. This system allows for place-based information, environmental and traditional environmental knowledge (TEK) storage and sharing between First Nation communities. And allows for the development of adaptive strategies and plans for future land use activities in the face of further resource development. This collaborative geomatic system has been designed with First Nation input and has been demonstrated to Chiefs and Councils of the Mushkegowuk Territory. Collaborative geomatics is an interactive, web-based, informatics tool that has been designed to store data, in a secure and culturally-appropriate framework on high-resolution satellite imagery. High-resolution imagery will become the backdrop to placed-based and TEK data. Community members will have the ability to input locations (e.g., significant sites, such as, seasonal camps and hunting locations) on the map in addition to uploading tabular and media data. This allows for the generation of dynamic and robust spatially-relevant information and knowledge-base.

Beginning in August of 2009, formal and informal meetings were held with personnel from the Lands and Resources unit of Mushkegowuk Council, First Nations Chiefs and Councils (the elected local government), and other community members of MooseCree First Nation, Fort Albany First Nation, Kashechewan First Nation, Attawapiskat First Nation, and Weenusk First Nation to gather their assessment (i.e., viability) of the Mushkegowuk collaborative geomatics tool. Together with this formative assessment process, 16 semi-directive interviews (from October 2010 to February 2011) were conducted with community members of Fort Albany First Nations. Interview participants were purposively sampled and included: Chief & Council members, First Nation office personnel, education personnel, health services personnel, elders (≥60 years of age), and young adults. Each interview was audio recorded and transcribed verbatim. Following an adapted grounded theory methodological approach, the transcripts of each interview were coded and categorized according to themes.

Throughout the assessment process, the research team received constructive feedback on the system. Each participant noted the utility of the tool to be used in the education of younger generations. Furthermore, participants felt that they would be able to use the tool to store TEK and help monitor environmental change. The greatest strength of the system was seen to be the visualization of information in numerous media forms (pictures and videos), while the greatest perceived weakness of the system was the security of the information. However, once user accessibility (usernames and passwords) was explained the concern over security of information was greatly reduced. This collaborative geomatic system has the potential to enhance the Mushkegowuk First Nations' adaptive capacity to address environmental change by allowing them to make informed decisions, utilizing the knowledge stored in the collaborative geomatics tool.

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Dedication

This is for my parents.

If they had not pushed me to excel in school from a young age I would not be where I am today.

Table of Contents

Author's Declaration ii
Abstract iii
Acknowledgements v
Dedication vi
Table of Contents vii
List of Tables viii
Chapter 1: Sense of Place and Environmental Change 1
1.1 Place and Sense of Place 1
1.2 Place, Sense of Place and First Nations 3
1.3 Environmental Change in the Arctic and Sub-arctic 4
1.4 Changes in Species Distributions 5
1.5 Social Impacts of Environmental Change and Invasive Species 7
1.6 Research Focus 8
Chapter 2: Collaborative Geomatics Tool 9
2.1 Introduction 9
2.2 Methodology 11
2.2.1 Study Area 11
2.2.2 The Collaborative Geomatics Tool 12
2.2.3 The Formative Assessment Proceess 13
2.2.4 Semi-Directive Interviews 14
2.3 Results and Discussion 15
2.3.1 Potential Uses of the Collaborative Geomatics System 16
2.3.2 Percieved Strengths and Weaknesses of the System 27
2.4 Conclusion and Future Direction 30
Chapter 3: Final Comments and Future Research 33
References 35
Appendix 43

List of Tables

Table 1. Summary of the Collaborative Geomatics Assessment Process 43
Table 2. The Uses of the Collaborative Geomatics Tool 27
Table 3. The Perceived Strengths and Weaknesses of the Collaborative Geomatics System 29

Chapter 1
Sense of Place and Environmental Change

1.1 Place and Sense of Place

The concept of place can be traced back to antiquity. Historical writings by Greek visionaries, such as, Aristotle, Eudoxus and Herodotus, Roman philosophers and romantic literaries discussed the "genius loci" (spirit of place) (Buttimer, 1980; Windsor and McVey, 2005). Dating to pre-Christian times this idea of place related to the belief that local gods controlled and protected peoples' places (Windsor and McVey, 2005). Early Europeans in North America missing their native homeland landscapes, brought with them plants and animals to remind them of their distant homes and to help develop their place (Lockwood et al. 2007). For example, today New Zealand biologically resembles the United Kingdom, since founding groups decided to release plants and animals native to England (Lockwood et al. 2007). It was not until half way through the 20th century that the concept and understanding of place and sense of place was once again revived. The 1970s and 1980s saw a surge of place-based interest especially in the fields of human geography as park managers began to look into the relationships people developed with nature (Tuan, 1975; Buttimer, 1980; Windsor and McVey, 2005).

The study of place is a broad, overarching idea often centralized around how places are socially constructed and the emotional relationships developed with them (Farnum et al. 2005). More simply put, place is a term used to describe meaningful connection(s) that people have to a geographic location. Historically, the study of place has fallen under the field of human geography (Buttimer, 1980). Recently, environmental managers, environmental psychologists, conservationists, urban planners, landscape designers and architects have begun to focus on the notion of place within their fields of work (Kaltenborn, 1998; Farnum et al. 2005; Williams and Stewart, 1998).

Place attachment involves many aspects of "related ideas and phenomena, including place dependence and functional aspects, identity formation, roots and embededness, satisfaction and experiences" (Kaltenborn, 1998: 172). Hess et al. (2008) gives a simplified understanding of place as being the emotional experience(s) and relationship(s) that people and communities develop with a location.

Within the idea of place, lies the notion of sense of place. Unlike place, “sense of place is more of an idea than a well defined construct” (Kaltenborn, 1998:172). This area of place research involves the more complex emotional and spiritual side of place and is grouped under the more holistic term of sense of place. Sense of place includes other place ideas, such as, place attachment, place meanings, place identity and place dependence (Farnum et al. 2005). This field of research deals with the ideas around environmental meaning and the more complex relationships that humans develop with their environment. Unlike place research that involves the physical dimensions of a geographic location, sense of place embodies the “complexity” and “interconnectedness” of environmental relationships (Relph, 1976, Kaltenborn, 1998; Tuan, 1975). In essence, sense of place can be described as the thread that draws people to their environment. The literature on sense of place is widely spread between human geography and psychology fields and there is little consensus between them on an acceptable definition of sense of place. This observation can be mainly attributed to the different approaches that qualitative and quantitative research takes towards the understanding of sense of place (Farnum et al. 2005).

How sense of place develops is still a contested topic within the literature and one that is far from a consensus. However, it seems that the development of sense of place falls within the four categories “biological propensities, environmental features, psychological developments, and sociocultural processes” (Farnum et al. 2005: 6). Therefore, sense of place development has been attributed to the relatedness between an individual’s interaction with their environment and the complex interactions of these four systems (Altman and Low, 1992; Farnum et al. 2005). There are many other theories on how sense of place develops, the overall consensus in the research is that sense of place develops through interconnected and complex relationships that develop from competing internal and external factors from society and the environment (Galliano and Loeffler, 1999; Farnum et al. 2005).

1.2 Place, Sense of Place and First Nations

The importance of place and sense of place to First Nations is just beginning to be recognized. Compared to non-indigenous people, First Nation people have a unique sense of place due to the intimacy, closeness and bonds that form between them and the land. These relationships with the land develop through experiences with the environment and are influenced by many factors, such as, social dynamics, culture, history and Traditional Environmental Knowledge (TEK) (Botts et al. 2003). Traditional environmental knowledge is a type of knowledge developed through experiences and oral tradition and holds information on the classification and empirical observations of the surrounding environment.

Unlike Western cultures, Indigenous cultures believe that there is an interconnected relationship between the landscape and human society (Sejersen, 2004). This sense of place has been shown to be vital to the overall health and wellness of First Nation people and their culture (Wilson, 2003; IPCCb, 2007). Sejersen (2004) argues that indigenous people use "experience and expectations in such a way that the landscape is simultaneously constituted as a memoryscape and visionscape" (Sejersen, 2004: 72). The act of place naming by First Nation people gives us a better understanding of how important place is. Place names often reflect a deeper understanding of nature, history, culture, cosmology and beliefs. Furthermore, place names help develop a sense of belonging and history with the land for many First Nations. Place names often make reference to animals hunted in the area, cultural and ancestral links, historical occupation, physical features and First Nations' perception of the place itself (Sejersen, 2004). Furthermore, place names have been shown to be an important component of memoryscapes (Sejersen, 2004).

Memoryscapes fall into the category of sense-of-selves-in-place (Nuttall, 1991), which itself falls under the overarching idea of sense of place. Memoryscapes develop through memories and visions that are linked to geographic places. To First Nations these memoryscapes become "alive, meaningful, and personal and embeds persons, places, and activities" (Sejersen, 2004:

74). Such memoryscapes are embedded into place names. Through oral traditions, the meaning of place names and the sense of place with the land are often told in narratives by elders to children. This oral history helps First Nation children to develop a sense of place with their environment from a very young age. This sense of place with the land and the memories and connections to place are responsible for guiding future societal activities, land uses, oral history and cultural transmissions of TEK.

1.3 Environmental Change in the Arctic and Sub-arctic

Climate change is expected to affect every corner of the globe; however, northern latitudes, above the 30^{o} North latitude, are predicted to experience climate change earlier and to a greater extent (Berkes and Jolly, 2001; IPCCa, 2007). Global surface temperatures have increased $0.74^{o}C \pm 0.18\ ^{o}C$ over the last 100 years (IPCCa, 2007). Even more disturbing is the fact that the rate of temperature increase for Arctic regions is nearly double that of the global average (IPCCa, 2007). Precipitation trends are also indicating that there will be a significant increase in rainfall in Arctic regions, unlike the Tropics which are predicted to see increased drought (IPCCa, 2007; Gough et al. 2004; Stirling and Parkinson, 2006).

With increased summer rainfall, winters in northern latitudes will see less snowfall resulting in altered ecosystem dynamics (IPCCa, 2007). As temperatures increase, freeze-up dates for water bodies have occurred on average at a rate of 5.8 ± 1.6 days per century later than before (IPCCa, 2007; Gough et al. 2004; Stirling and Parkinson, 2006). Alongside later freeze-up, ice-break up has begun earlier than ever before, causing significant impacts to sea life and sensitive arctic ecosystems. Glaciers and ice caps are also experiencing an increasing rate of melting, leading to sea level rise at a rate of approximately 0.8mm per year and changes in water chemistry (IPCCa, 2007). Aquatic systems are not the only ecosystems experiencing change due to global warming. The traditionally stable states of global terrestrial systems are shifting and changing.

There are two main types of terrestrial impacts that will be seen in northern latitudes, changes in vegetation composition and structure, along with changes in belowground structure and processes. Nutrient poor, but environmentally important, bog systems found in the arctic and sub-arctic regions are predicted to be the most impacted terrestrial ecosystem (Alm et al. 1999). Due to their low rate of decomposition and anoxic conditions, bog systems act as carbon sinks, a natural reservoir for carbon dioxide gas. However, changes to albedo due to decreased snowfall and decreased water availability in summer months may turn these ecosystems from carbon sinks to carbon sources (Alm et al. 1999; IPCCa, 2007).

Climatic models are also predicting that there will be a northward movement of tundra vegetation followed behind by northward movement of boreal tree species (IPCCa, 2007; IPCCb 2007). Such vegetative reshuffling will have significant impacts on species' distributions in these regions. In some cases, species will follow the advancement of vegetation; however, it is more likely that regional species will be left behind resulting in population and potentially species wide declines.

1.4 Changes in Species Distributions

Such dramatic environmental changes are likely to result in an increase in biological invasions (Rahel and Olden, 2008). There is a complex web of terminology used to describe species that act in similar ways marring the field of invasion ecology research. For example, the terms non-native, alien, non-indigenous, weedy, exotic and invasive have been used interchangeably to describe a species that is not normally located in a certain area. There is considerable discussion within invasion literature of when and where each term should be used and the ambiguous meaning behind them. Often such terms as weedy, noxious, exotic and alien are criticized as containing anthropocentric meanings and implying human impact, and therefore, according to some, should be avoided (Lockwood et al. 2007; Simberloff et al. 2003; Colautti and MacIsaac, 2004). In order to address this discourse, many researchers have opted to use terms that are considered by most to be "neutral terms", such as, non-native and non-indigenous (Lockwood et al. 2007; Simberloff et al. 2003; Colautti and MacIsaac, 2004). However, this neutrality is only in comparison to human perception of impact. Lockwood et al. (2007) and others use these neutral terms to describe species that have spread outside their natural geographical range, regardless of their perceived impacts. However, other researchers within the field use the term "invasive" to describe a species that has expanded its geographical range and population size (Richardson et al. 2000; Colautti and MacIsaac, 2004; Lockwood et al. 2007). Therefore, throughout this research project I will use the term "invasive species" to refer to any species that has expanded or is expanding its range beyond what is normal. However, global warming is changing what was once normal.

Nitrogen and phosphorus are often the limiting resources in ecosystems. However, the predicted rise in atmospheric N_2 levels will increase the availability of nitrogen to vegetation (Dukes, 2000; IPCCa, 2007). This increase in nutrients, along with changes in stoichiometry and warming temperatures will increase an ecosystem's invasibility (Dukes, 2000). With the alteration of plant communities, animal and fungal communities are also altered (Lockwood et al. 2007). New invasive species of microbes, fungi, plants and animals have already been spotted in the Antarctic indicating that climate change impacts are already at work (Frenot et al. 2005).

Other abiotic factors, such as, ice cover, water temperatures and river flow help to further safeguard against invasions. Global warming will alter these controls opening arctic ecosystems to invasions (Rahel and Olden, 2008). Normally, ice cover generates hypoxic conditions; however, with climate change the extent of ice cover is predicted to decline, opening lakes to large piscivorous fish. Furthermore, terrestrial ecosystems will likely be threatened by invasive species.

As arctic temperatures increase, invasions by parasites are likely to occur (Dobson et al. 2003). Cool temperatures and short summers previously restricted the diversity and development of parasites in arctic regions. However, as temperatures increase it is predicted that new parasites will enter the ecosystem and likely affect terrestrial organisms such as the already at risk woodland caribou (*Rangifer tarandus*). This is likely to become a culturally significant impact due to the cultural importance of caribou to Canadian indigenous cultures. Norway has already experienced diseased reindeer populations due to an invasive parasite as a result of global warming (Dobson et al. 2003).

Globally, ecosystems have been severely impacted by invasive species. Examples such as the brown tree snake (*Bioga irregularis*) in Guam (Lockwood et al. 2007) and the cane toad (*Bufo marinus*) in Australia have shown the devastation that invasive species can have on ecosystems and their functioning. Canada has also seen its own devastation from invasive species. The emerald ash borer (*Agrilus planipennis*) has been responsible for the destruction of almost every ash tree (*Fraxinus* spp.) in southern Ontario and threatens to impact every ash tree in North America (Mackenzie and Larson, 2010). Previously cold winters would have effectively destroyed this insect; however, with warmer, milder winters the pest is able to continue its plunder. It is clear that invasive species contribute to many ecological impacts; however, what is still unclear is the social impact.

1.5 Social Impacts of Environmental Change and Invasive Species

Historically, invasive species have played a defining role in indigenous culture. Since the beginning of European exploration of the New World, North American indigenous groups have been positively and negatively impacted by invasive species. Invasive wild horse species (*Equus ferus*) brought over on Spanish ships played a pivotal role in North American indigenous culture. However, invasive species such as smallpox (*Variola*) also nearly decimated indigenous populations who held no immunity to the newly introduced pathogen. Despite these historical accounts, indigenous populations throughout the world have been largely ignored when it comes to invasive species research and management. More unsettling is that even less research has focused on social perceptions of invasive species in Arctic and Sub-arctic regions.

Invasive species are expected to become one of the greatest threats to global biodiversity with amplified impacts seen in the arctic and sub-arctic (Sala et al. 2006). Their ecological effects are sobering in terms of their significant biological impacts on native species, biodiversity and ecosystem functioning (Mack et al., 2000; Pimentel, 2009). Ecosystem resilience (the ability of a system to withstand external impact and maintain functionality) is maintained through diversity and functional redundancy (Walker and Salt, 2006). Similarly, cultural systems are maintained by relying on diversity, especially biodiversity within ecosystems (Pfeiffer and Voeks, 2008). However, as invasive species decrease local diversity, ecosystems become more susceptible to environmental shocks, such as extreme weather patterns and increased resource exploitation, resulting in a less diverse ecosystem (Walker and Salt, 2006). The end result is a less resilient cultural and ecological system. Furthermore, it is expected that invasive species and climate change will directly impact culturally important species, such as ones used in religious ceremonies, cultural practices and traditional medicine, therefore affecting First Nation sense of place (Pfeiffer and Voeks, 2008).

1.6 Research Focus

As the global temperatures continue to increase and environmental changes mount, there will be direct and indirect social impacts; however, there has been little research on what these impacts will be. Due to pre-existing inequalities in First Nations, such as, poverty, previous resource development, geographic location and remoteness, the social impacts of environmental change will be amplified. Furthermore, First Nations' sense of place with their environment will place them even further in the crosshairs of environmental change. It is clear that altered environemntal conditions will cause direct health impacts, such as new parasites, pathogens, disease, injury and death (IPCCb, 2007). However, indirect social and cultural impacts will likely become more significant and more difficult to detect and mitigate. Therefore, research must focus on understanding and monitoring these indirect impacts now before societal and cultural losses are seen. It is these issues that are the focus of this paper.

Chapter 2

Fostering Adaptive Capacity and Resilience to Environmental Change in Sub-Arctic First Nations: The Use of Collaborative Geomatics, an Interactive, Web-based Informatics Tool

2.1 Introduction

Globally, indigenous groups represent some of the most vulnerable populations. Specifically, First Nation groups have historically suffered from social, cultural and economic marginalization leading to health issues (Macmillan et al. 1996). In the Mushkegowuk Territory of the western James Bay and southwestern Hudson Bay region, sub-arctic Ontario, Canada, environmental change, both anthropogenic (e.g., climate change, Gough et al. 2004; resource development, McEachren et al. 2011) and natural (e.g., post-glacial isostatic adjustment, Tsuji et al. 2009) are impacting the Omushkego Cree traditional lifestyle (McDonald et al. 1997). Although the global-average surface temperatures have risen by 0.6 ± 0.2 °C over the past century – the arctic and subarctic regions have experienced a general warming of up to 5 °C – the most rapid rates of increasing temperatures among the world's regions during the last century (Anisimov et al. 2007). Thus, sub-arctic Ontario has been affected disproportionately (Gagnon and Gough, 2005). Indeed, statistically significant increases in the length of the ice-free season for the southwestern Hudson Bay and northwestern James Bay regions (1971-2003) have been reported (Gough et al. 2004). The trends in river-ice break-up dates in this region are not as consistent, but the average temperatures in spring and winter have increased in the region (Ho et al. 2005). In addition, climate projection models (an ensemble approach) have revealed that air temperatures will continue to increase for all seasons in the western James Bay region (Hori, 2010). However, glacial isostatic adjustment is also occurring in the western James Bay region and numerical models of the glacial isostatic adjustment process (taking into account sea-level rise due to global warming for different scenarios) have revealed that many of the smaller and larger islands of James Bay will become part of mainland Ontario due to the emergence of land (Tsuji et al. 2009). As the last ice sheets covering the northern regions melted ~5,000 years before the present, the earth’s crust did not completely adjust to the removal of the ice load. Simplistically, think of how the depressions your fingers make in a sponge ball when squeezed tightly, rebounds to its original form after you stop squeezing the ball. Similarly, the present upward adjustment of the earth’s crust is called glacial isostatic adjustment (Tsuji et al. 2009). To date, it is not clear to what extent environmental change has impacted the First Nations’ place-based relationship with the land - or in other words their way of life - and what potential measures the Mushkegowuk Territory First Nations have taken or could take to adapt to these changes.

Internationally, there is an increasing awareness of the need to incorporate indigenous knowledge in the management of the environment (The Brundtland Report, The “Earth Summit”, The Convention on Biological Diversity). The Canadian government has acknowledged that First Nation groups have a unique relationship with the environment and have developed an extensive understanding of the environment (CEAA, 2010). This knowledge of the environment, called Traditional Environmental Knowledge (TEK), was historically, intergenerational and transmitted orally. Although TEK is oral in nature, for approximately 35 years, First Nation communities throughout Canada have been using indigenous mapping to archive and transmit TEK in a written format (e.g., Milton Freeman Research Limited, 1976 a,b,c). Since the 1990s, indigenous mapping has evolved with the Geographical Information System (GIS) whereby First Nations have strengthened their capacity to participate in natural resource management (Chapin et al. 2005; Eades and Sieber, 2011). However, GIS mapping is highly technical, and expensive to implement and maintain (McCarthy et al. 2011). Due to the aforementioned issues and other access, and ownership concerns, First Nation groups are turning towards geospatial web (geo-web) tools to help collect, collate, archive, and analyze their information (Schuurman, 2004; Eades and Sieber, 2011). One such innovative geo-web tool is collaborative geomatics.

Geomatics is a method used to link geospatial data (e.g., cities, regions, countries) and attribute data (e.g., social, economic, ecological and cultural data) (Cusimano et al. 2007). Collaborative geomatics is a mapping tool based on geo-web technology where participants can collaborate, discuss and communicate on community-based cultural asset maps and databases (Cowan et al.

2010). Collaborative geomatics enables communities, in the present case remote First Nation communities, to collect, display, share and analyze information, as well as collaborate with other communities, relevant agencies and private corporations. These features represent a substantial advancement in current practices, as the collaborative geomatics tool is relatively inexpensive to apply and deploy, and user friendly to minimize the need for technical expertise and programming (once the system is in place). Collaborative geomatics can also foster collaboration with and between government, private sector and communities, in this case remote First Nation communities in policy development, application and tracking, and critical needs assessment to address existing and emerging societal, economic and environmental challenges. In the present initiative, common mapping data are deployed, along with supporting web-informatics frameworks, as a background technology that supports geo-spatial transactions and reporting using customized applications. The use of the collaborative geomatics tool by First Nation groups has the potential to build capacity in the communities through the complementary archiving of western science and TEK; while, using the collaborative real-time function to plan and deal with the complex and dynamic nature of environmental change within sub-arctic ecosystems. In this paper, I assessed through a formative process that included both formal and informal meetings, the potential use of the collaborative geomatics tool to build capacity and resilience in Mushkegowuk Territory First Nations to environmental change (Walker and Salt, 2006; Armitage, 2005; Gundersonand and Holling, 2002). In addition, the feasibility and usability of the collaborative geomatics tool was assessed through formal semi-directive interviews in Fort Albany First Nation of the Mushkegowuk Territory.

2.2 Methodology

2.2.1 Study Area

The Mushkegowuk Territory is located in the western James Bay and southwestern Hudson Bay region. The coastal communities of the Mushkegowuk Territory include the following First Nations: MooseCree (located on Moose Factory Island), Fort Albany, Kashechewan, Attawapiskat, and Weenusk (the community of Peawanuck;). Approximately 10,000 First Nation Cree live within the Mushkegowuk Territory, which is represented regionally (except for Weenusk First Nation) by the Mushkegowuk Tribal Council. Fort Albany is located along the south shore of the Albany River (52°15'N, 81°35'W) being a remote fly-in community with a population of approximately 850 people. Year-round access to the village is by aircraft only, with ice-road access in the winter. The western James Bay region is home to one of the world's largest wetland area (Abraham and Keedy, 2005).

2.2.2 The Collaborative Geomatics Tool

The term collaborative geomatics is defined by McCarthy et al. (2011:17) as "a participatory approach to both the development and use of online, distributed-authority, geomatics applications". Similar to neogeography, collaborative geomatics builds upon the concept of Public Participation GIS and Collaborative GIS (CGIS) (McCarthy et al. 2011). The term neogeography is used to describe customized maps created by people considered non-experts in the field (Haklay et al. 2008). Public Participation GIS refers to a GIS system that is used to "broaden public involvement in policymaking as well as to the value of GIS to promote the goals of nongovernmental organizations, grassroots groups, and community-based organizations" (Sieber, 2006:491). Within the literature there are many definitions for Collaborative GIS; however, I will be using the definition by Balram and Dragicevic (2003:8) who define Collaborative GIS as a system that is "centered on the designs, processes, and methods that integrate people, spatial data, exploratory tools, and structured discussions for planning, problem solving, and decision-making."

The collaborative geomatics tool is based on the declarative application engine termed WIDE (Web Informatics Development Environment). The WIDE software toolkit was developed by The Computer Systems Group of the University of Waterloo and the Centre for Community Mapping (COMAP) a non-for-profit corporation. The toolkit was developed to construct, design, deploy and maintain complex web-based systems (Cowan et al. 2006). The uniqueness of collaborative geomatics tool is related to the WIDE software toolkit. The WIDE software toolkit allows for a forms-based approach to system construction and therefore, has resulted in a program that supports the rapid development and modification of systems, not usually found in any other Public Participation GIS system. Therefore, the WIDE toolkit allows for greater community engagement by allowing for the customization of each collaborative geomatics tool in a relatively short period of time.

The collaborative geomatics tool supports a common reference map, based on high-resolution imagery. Some of the basic features of the collaborative geomatics tool includes: the zoom in/out function; and the entry of real-time geospatial information (oral, written, auditory and visual [photographic, video]) that is securely housed within the system through accessibility safeguards. Once the collaborative geomatics tool has been fully community-tested and modified accordingly to meet the community's needs, the collaborative geomatic program will be given to the community, as a stand-alone system.

2.2.3 The Formative Assessment Process

Beginning in August of 2009, formal and informal meetings were held with personnel from the Lands and Resources unit of Mushkegowuk Council, First Nations Chiefs & Councils (the elected local government), and other community members of MooseCree First Nation, Fort Albany First Nation, Kashechewan First Nation, Attawapiskat First Nation, and Weenusk First Nation to gather their assessment (i.e., viability) of the Mushkegwouk collaborative geomatics tool developed specifically for the region (Table 1 [See Appendix]). Formal meetings included workshop presentations or presentations to Chiefs and Councils; while, informal meetings were "kitchen table" gatherings where hands-on use of the collaborative geomatics tool was employed. Convenience sampling was employed. Initially, the software program Camtasia™ was used to record the facial expressions and mouse movements of the participants while using the collaborative geomatics tool. However, some participants were uncomfortable being recorded and the technology was deemed culturally inappropriate, and its use was stopped. Thus, the formative assessment process was used to roughly gauge the potential use of the collaborative geomatics tool to build capacity and resilience in Mushkegowuk Territory First Nations towards environmental change, that is, whether the collaborative geomatics tool should be modified or discarded (Walker and Salt, 2006; Armitage, 2005; Gundersonand and Holling, 2002).

2.2.4 Semi-Directive Interviews

Running parallel to the formative assessment process (from October 2010 to February 2011), semi-directive interviews (Tsuji 1996; Huntington 1998) were conducted with community members of Fort Albany First Nation, as the Chief and Council were particularly interested in the technology. The semi-directive interviews allowed for interviewees to bring out issues (Bryman et al. 2008) that are of particular importance when adapting the collaborative geomatics tool to the needs of the community.

Sampling was purposive, being appropriate for this type of research, as this method has been widely used in exploratory research (Denis, 2004). Purposive sampling was also appropriate as input from specific sectors of Fort Albany First Nation (i.e., Chief & Council, First Nation office personnel, Mundo Peetabeck Education personnel, Mundo Peetabeck Health Services personnel, elders [≥60 years of age], young adults, males/females) was desired. I wanted to understand the usability of the collaborative geomatic tool from the perspective of different groups in the community. Before each interview, oral consent, which is culturally appropriate, was given by each participant after a brief overview on the purpose of the interview.

Sixteen semi-directive interviews were conducted. Each interview was audio-recorded. As with the formative assessment process, Camtasia™ was originally employed to record facial and keyboard actions, but was stopped. In addition to the audio-recordings, notes from the interviews were taken by a secondary team member. Each interview began with a detailed introduction of the collaborative geomatics system. Once the system was explained, the collaborative geomatics tool was demonstrated to illustrate the steps required when imputing information into the tool.

Hands-on activities followed whereby participants added data points, and explored the other functions of the system. Lastly, we progressed to broader questions of environmental change and the utility of the collaborative geomatics tool to the community.

Once the interview concluded, I re-read the notes taken during the interview. Based on the principles of grounded theory, the audio recordings were then transcribed verbatim into digital files by the primary researcher. The transcriptions were then compared to the notes taken during the interview to validate key points. The transcripts were then coded, which entailed giving labels to similar concepts of information that appeared to be of importance (Bryman et al. 2008). Open coding was used on each transcript (Bryman et al. 2008) and can be described as the process where data is broken down, examined, compared and categorized. This "process stays very close to the data and yields the concepts later grouped and turned into categories" (Bryman et al. 2008:253). Each transcript was read several times and then coded and re-coded (Patton, 2002). Through the use of open coding, concepts were labeled within each transcript. Finally, these concepts were then grouped together based on relatedness into themes, or more general categories. This coding process occurred until saturation was reached (Boyatzis, 1998; Lemelin, 2010).

2.3 Results and Discussion

Constructive feedback during the formative assessment phase with the Mushkegowuk First Nations and Mushkegowuk Council clearly indicated the potential utility of the collaborative geomatics tool. Meanwhile, data collected through semi-directive interviews resulted in the coding of 90 concepts, under one of five themes (general uses [of the collaborative geomatics tool], uses concerning environmental change, uses concerning resource development, perceived strengths of system and perceived weaknesses of the system). These five themes were divided into two categories: potential uses of the collaborative geomatics tool (Table 2) and perceived strengths and weaknesses of the collaborative geomatics tool (Table 3).

2.3.1 Potential Uses of the Collaborative Geomatics Tool

Each interviewee presented a novel use for the collaborative geomatic tool in the community. The largest theme of uses mentioned was General Uses (Table 2). Within this theme there was a major sub-theme of Educational Purposes. The majority of participants felt that this geomatic tool could play a large role in the education of their children.

> "*Beats a textbook for sure*" (Participant #6).

> "*It…would benefit a lot if it was programmed in the school, like for the kids to learn…it would encourage them to go out…*" (Participant #5).

> "*I can see this being used by the students of the school…where things are, and where your grandfather is and family relationships…[students] love taking pictures…[Students could record] the break up dates…. the amount of snowfall, mean temperatures or daily temperatures…it's a good project for students…It is what the elders used to do anyway, keep track of everything…transferring everything into, the [collaborative geomatics] library and that's where we find all this stuff. Animal names, vegetation names…where certain types of animal are…to be aware of the land looks like*" (Participant #10).

> "*It would be good, for the new generation that's coming up. They'll know what's going on, and it would be handy like, be good for the schools kids too for the schools. So they will know their ancestors and their culture, fishing, trapping, the land, everything. It would be great…they are into this, all Internet thing. This is good, really good…they would know more about their land…the history…*" (Participant #7)

> "*[Elders] have such knowledge about family, family values. So those kinds of things [codes of conduct] would be helpful to record and have them done with the curriculum in*

the schools. Yeah, part of the teachings, and it's very important…our elders talk about how knowledge was passed on by word of mouth you had to learn from hearing and actually they never wrote anything. It was just passed on, by word of mouth, but we're in, we're into the age now where we can work with these things" (Participant #1).

Clearly, participants acknowledged that there is a need for children to learn about their culture and community in an interactive format, as barriers have arisen whereby the intergenerational transmission of TEK has been disrupted (Tsuji 1996). The residential school system where the children were forbidden from speaking their language and practicing their culture disrupted the transmission of TEK (Tsuji and Nieboer 1999). In addition, technological changes, such as, the use of snow machines, four wheelers and motorized boats have made day-harvesting trips common in the Mushkegowuk Territory resulting in the family unit having less contact time together; thus, less time for the transmission of TEK (Tsuji and Nieboer, 1999).

The collaborative geomatics tool can build capacity in the community to deal with environmental change, by acting as a reservoir for both TEK (including codes of conduct) and western science for the younger generation to utilize.

"*History of our land, I know I have a lot of ideas. I don't go out in the bush a lot [now], but I think this will [help preserve our] …history…what we went through when we were young…for the kids now. It's very different from way back. I find there's a lot of changes and it's good for a system like [the collaborative geomatics tool]…to be in place…or even getting the elders to teach you how to do this sort of stuff. I mean how to trap beavers [and you could video tape that] and then put it on there*" (Participant #9).

"*So that they could keep…[the] history of the community right there [collaborative geomatics tool] and have somebody always inputting data…community archives kind of thing…I think it's good for the community archives…Aboriginal people in this community…need to know their history…something like this documented. Whereas* *we…had our Elders to tell us, to educate us, about this [but many students do not have this opportunity], so… I think looking at the future and technology for…future students, I think it's really helpful. Culturally too…know your community and how it evolved. The data is right there [on the collaborative geomatics tool] if they need to do any studying or research like that…I think it…is pretty easy enough*" (Participant #13).

However, the collaborative geomatics tool must also be accessible to the elders. Indeed, the elders interviewed saw the potential in the collaborative geomatics tool not only for themselves, but also for the younger generation.

"*Yeah it's simple enough. Like I would have to adapt to it like, like anything. You try something new, you have to get used to it first, before you can use it*" (Participant #1).

"*First time you're mesmerized by the buttons, by the squares by the lingo that you use...the poly line, for me I don't know what a poly line is. Until you click it…then I see you can understand what a poly line is, terminology, we'll get used to that*" (Participant #10).

"*You need younger people…They're more into talking and the young people are more technically orientated. They are the ones that will…know what a polyline is. They will start doing that, they won't even question. They will just click on these things and start doing stuff… [But] you still have to bring them on the land*" (Participant #10).

The last quotation brings to light an important point. The collaborative geomatics tool must be viewed as an adjunctive tool for education, as some things can only be learnt/experienced in the outdoor forum. Tafoya (1995) describes how learning and the transfer of TEK is context dependent. He explains that you can learn about berry picking in the classroom, but you need to be outdoors to truly experience berry picking, as the other senses, such as, smell are stimulated, not only of the berries but also all other parts of the environment specific to that time of year. Indeed, this point was mentioned by one of the interviewees:

> "*When [I was young]…me and [my sister]…[would] see….my mom, tanning the hide and all that…we seen a lot of what she did...when you take off the fur, after its frozen, it has a smell…*" (Participant #9).

Experiential learning, including hands-on activity, has been consistently identified in the literature as an important teaching strategy for First Nation people.

Within the General Uses theme, major sub-themes included the utility of the collaborative geomatics tool to be used for various monitoring activities. Indeed, every participant mentioned that the collaborative geomatics tool showed potential to act as some type of monitoring system (Table 2). In particular, the use of the collaborative geomatics tool to make bush travel safer in a changing environment was stressed as being important.

> "*The water is getting shallow…It would give them warning to when you take the boat, cause I know some rivers were just ridiculously shallow in the summer time. Normally it was about 6 feet high back in the day…I can just walk across [now]…. it wouldn't be up to my knees*" (Participant #6).

> "*So they are going to do the elevation things…like following the channel, because…usually you are only to go a certain way but that changes every year though, with the sand bars*" (Participant #8).

> "*So they can click on that and say…there's a rock here. That's our measuring device…and just look at that rock and say, it's too shallow. If it's shallow then…you know where the channels are…common knowledge. Unless it's a first time user, then they are trying to figure out how it would be useful, for first time person. They can see the*

river…and the dark areas where the deeper spots, they can see that and I would tell them those are the deep areas…Teach them about how to use the land, how to find the lake, the routes that you use for winter travel and summer travel" (Participant #10).

"*There's channels on the river where its deep…that would also benefit for the new people, the new ones that go on the river. Cause like just last year, just [the] past fall…a guy went up along for the first time driving [on the river] on his own…he was on the river before, but without driving, you know what I mean? And then…he didn't go far…when he hit his motor, so it broke. So he had to come back and he was alone*" (Participant #5).

Glacial isostatic adjustment would be one of the natural processes impacting the water level of the rivers, along with geomorphological phenomena (e.g., ice rafting; Martini, 1981). This type of information would be entered onto the collaborative geomatics tool, along with the associated TEK. For example, anthropogenic processes are also known to affect water levels in the river.

"*The other thing that's concerning too…the hydro projects that are going be put into effect, about damming of the rivers. You know…you can see the fluctuations of the water level because of the already existing dams up, up river…it affects the water downstream. Sometimes it's high water because they have to release some water…*" (Participant #1).

Safer bush travel in the other seasons was also identified as being very important.

"*Alright, see there's our ski doo trails [on the collaborative geomatics tool]…like maybe mark here this ski doo trail goes to, little box that says this is where this leads to*" (Participant #5).

"*Well most of them [his elders] know…depending on the ice what kind of winter it would be…depending on the color, even the color of ice, it'd be blue or brown…they know too when to not go there, when it's not safe to go on top of that ice...*" (Participant #1).

"*Say spring-time, spring-time right there's spots that there that are not safe. That would be really useful…ask people to take pictures where it's not safe or early winter when it starts to freeze up. There's some spots that don't freeze up right away, and those pictures…would be helpful to put them on there and people go on there. Or people that come and visit the community from out of town…didn't know, didn't know their way around, like to go out on the ski doo trails or anything like that. Trail Markings, yah so along the trail there's an "X" so be careful right? Yeah like a red X and a picture pops up saying it's not safe to [ride here]….make a detour on that spot during this year only*" (Participant #5).

As the collaborative geomatics tool has real-time capability, the posting of unusual weather processes was also seen as a potential function:

" *When it comes to climate itself, when you go down south…when you have these weather advisories, they are specific to [relatively small areas]…but when you come up to the North here, it's just a big area that they give it at, Attawapiskat to Moosenee. It's not really accurate, so I think it would help in that sense to track storms…because we need to notice stuff and that would be the same thing here, cause we need to keep track where these thunderstorms form. So I always look at the thunder clouds forming and…you never see them to the north, but I always see them from Albany to in between Moosenee… You can see more, lightening, and more intense thundering*" (Participant #12).

Evidently, the collaborative geomatics tool was seen by the participants as an important real-time system that could improve the safety of bush travel, especially with young people, in a rapidly changing environment.

The ability of the collaborative geomatics tool to store climate change data was also positively received. The majority of participants had personal stories of climate change and their changing environment, and believed the system would be useful to monitor these changes long-term:

> "*Every year it's getting different. Like in October it's getting warmer. And even in the winter time, it's not the same as before…Yeah, so it's kind of strange*" (Participant #16)

> "*It would be nice if you could do that…Record…I know that the weather has changed lots in the last ten years, 20 years. Cause the winters used to be colder before…last year the coldest was -30°C maybe one, two days and before that -14, -13, -17, 18, that's how it was here all year… The temperatures I take temperature, everyday…the elders say it's different now, that its changed lots…elders that's about 70 years old or even 80 years old, they're going to say like, like 40 years ago it was colder, colder winters, you had more snow…It would be helpful for the whole community, not just one person, other people want to see too. They are going to ask questions and say…whats going on. They want to get in there too. It would be helpful for people, for the whole community to get in there*" (Participant #15).

By storing environmental change information, participants believed that this would allow the community to be better prepared for future changes. In addition, the storing of information related to catastrophic events, such as, flooding from the Albany River break-up, may help the people be better prepared mentally for flooding, as it would not be an unknown. Present day flooding from spring river break-up is less predictable than in the past.

> "*Weather wise…it's a very good idea to track…the ice breakups, the projections of where it breaks up or where the…jams are, and where its building up down the river*" (Participant #6).

"*And there was a lot of snow last year too. And there's more snow again this year…It's strange like last year; it wasn't like that much water, but a year before…the town almost flooded and there wasn't hardly any snow that year you know what I mean? …Like It's …weird*" (Participant #5).

"*Short video…my nephew has a small footage of when it flooded… they should have a page for like flooding…Like compared to now, things are different…I asked her [a friend] what does your father-in-law think of the break up, is there going to be a flood and I guess her father-in-law said its unpredictable now-a-days…there's too much change*" (Participant #9).

Flooding concerns were also related to global warming, as Fort Albany First Nation is a salt-water coastal community.

"*The flooding level of the coast…I don't know, there must be some information somewhere that they actually know what's happening, and what levels of water it's going to be 10 year, 20 years down the road…scientists…know how to calculate the volume of water that's in the oceans and how it's going to affect all the coastal communities…that kind of information would also be helpful to determine how we make plans in our communities…we would have to really lobby the government, to do something instead of waiting for the last minute to move, until there's a catastrophe*" (Participant #1).

The collaborative geomatics tool would be very helpful in this case, as this information already exists (Tsuji et al. 2009) and could be stored on the collaborative geomatics tool, where it could be easily accessed at the user's convenience. It should be mentioned that even when a community presentation and/or presentation to Chief and Council are made in these remote First Nations, as in this case, if a person is not in town during that time period, the person may not be aware. Thus, the utility of the collaborative geomatics tool as a planning tool is clearly illustrated in this example.

The monitoring of invasive species (defined as novel species or species that have extended their distributional range) was identified by every participant as being important with the potential utility of the collaborative geomatics tool being noted. Many participants noted that community members are already taking pictures of different species and putting them up on Facebook™ and believed that this system would be a good idea to use to upload pictures of new species and link them to satellite imagery, allowing for a historical account of distributional changes. Many of the participants had already noticed invasive species in their area.

> "*Mostly birds…Lot of birds [pelicans] that are weird*" (Participant #2).

> "*I am pretty sure a lot of people can put pictures to certain points…I know my brother has a pictures of the pelicans that were here a couple of years ago*" (Participant #9).

> "*We're starting to get the new…species…a couple of weeks ago, there was somebody that shot a raccoon and raccoons are not usually [here]*" (Participant #13).

> "*I think once in a while we get raccoons, long time ago here too. Yeah, my dad talks about it. Time to time they'll see a raccoon, but not all the time*" (Participant #2).

> "*It was around in June…we went out on the [James] bay just for a drive…and then just walking around…just checking…I see these really tiny, like a hair strand, they look like hair strands they were just swimming around. First time I [have] seen those kinds of things. So I took one, like this just moving around, just like a hair, it's like a hair thing. I don't know what it was. They were on the land and water, where there's little water you can see them, like, that was the first time I'd ever seen those. You can see it just moving around fast, I was thinking, I wondering if these things get into the birds you know what I mean?*" (Participant #5)

It was not just invasive species that were noted, but also native species that were observed, temporally displaced.

> "*There's…black flies you call them, there, a couple of days ago…October, there shouldn't be flies at all. Usually it's in August, maybe early September, but it's October what, 26th today and there's still flies*" (Participant #15).

Further, certain species have extended their home range or have become more abundant:

> "*What about tracking polar bears? I know there's more polar bears…reported East of Moosenee now…about maybe 20 miles…they're not normally there*" (Participant #15).

> "*You know the bald eagle...20 years ago…there would be one, one bald eagle…but now there's more and the geese are getting scared of them…the bald eagle…go after the geese*" (Participant #15)

> "*Yeah monitoring purposes, so we can…just point and click and see, write down what happened that day…trying to find out what's going on with this species and making sure that we do try to …find…new species, why they are here, try to determine all this stuff. I'm not too sure how far the bass are supposed to go, but back in the early 80s, there was a guy that had a gill net and in the fall and he caught a bass in there [Moose River]. And nobody believed him. But he said it was a bass, fat and big and he put it back in. And then another guy went up to Moose Head last year and found a, something this big I think, white, and it looked like a fish. Its white, this big, had little fins on its side, and it was swimming along, trying to go under water…gave it to MNR to look at it and they said it's not supposed to be this far north*" (Participant #12).

It is apparent that the polar bears are of concern, since they have been coming ashore during the spring goose harvesting season or summer months. This is a relatively new occurrence and the polar bears have attacked subsistence hunters in the region, who have had to kill the polar bears in order to protect themselves. The bald eagle concern is related to the fact that the eagles either kill the geese or scare the geese away during the waterfowl harvesting season, impacting the amount of traditional food that can be harvested. The northward migration of the smallmouth bass is an important issue, as this species of fish will have a negative impact on indigenous game fish (Jackson and Mandrak 2002, Chiotti and Lavender 2008) that the Cree harvest.

Resource development was also viewed as a major environmental concern. Mining development, roads, power lines and dam development have already negatively impacted animals in the regions (Tsuji et al. 2010). Overall, many people felt that this system would allow for the collection and storage of baseline environmental information that could be used to monitor environmental and cultural impacts of resource development and for use in cross-referencing data collected by mining companies.

> "*Are they going to do one [collaborative geomatics tool] for the mine too or how it's affecting each community too? Yeah. We should look into the impacts before the mine comes, we got to start getting samples of fishes too. Monitoring the fishes because you never know [about the] Albany River, and chemicals. It's better to start monitoring*" (Participant #14).

> "*It's just DeBeers [diamond company] that's collecting information [TEK] from community members but they don't want to share that information to the public…they don't want to give the community members the information*" (Participant #14).

Table 2. The potential uses of the collaborative geomatics system grouped into three themes mentioned by participants during the interview process. Hierarchical order represented within the table shows the most supported uses by the participants.

General Uses	Educational Purposes
	Monitoring of Transportation Routes
	Monitoring Culturally Important Species
	Monitoring Vegetation
	Monitoring Endangered Species
	Protection of Migration Routes
	Cultural History Archives
	Protection of Culturally Important Lands
	Mapping Land-use Activities
Uses Concerning Environmental Change	Monitoring Climate Change
	Monitoring of Flood Conditions
	Monitoring Invasive Species
	Future Preparedness
	Monitoring Ice-break up
	Storing Weather Trends
	Recording of Temperatures
	Ability to See Time-lapsed Change
Uses Concerning Resource Development	Preparedness for Future Development
	Development of Baseline Data
	Collection of Data for Cross-referencing
	Monitoring Development Impacts on Fish Populations
	Monitoring Dam Impacts

2.3.2 Perceived Strengths and Weaknesses of the System

The greatest strength of the system was the visual aspect of the collaborative geomatics tool and being able to upload media files (pictures, videos, audio). The visual aspect of the learning process has been identified as being culturally important for First Nation people. Being able to see their land and the community on the high-resolution satellite imagery was a very important part of the system, making the addition of information to the system easier. Every participant found the imagery recognizable and easy to navigate through. It became apparent from the interviews that the greatest strength of the collaborative geomatic system was the use of geospatial and visualization aspects. According to one participant:

> "*There's not (many) people that go out on the land that know how to work with these things (computers), but they do take pictures, they do take pictures and they ask their, whose ever, on the computer all the time, upload these*" (Participant #5).

The participant continued to explain how pictures were already important stating:

> "*When I go up river every fall, I take pictures, like everywhere*" (Participant #5).

Another participant stated that:

> "*They (community members) love taking pictures, they love taking pictures*" (Participant #10).

Participants also noted that the majority of people carried cameras while out on the land and were already taking pictures of different species and posting them on Facebook™. However, these Facebook™ postings were scattered and the collaborative geomatics tool would allow all these pictures to be stored on one system that is secure, customized, and owned by the community.

Relatively few system weaknesses were noted during the interviews. The majority of perceived weaknesses revolved around system security. Since the information contained within the system is likely to be culturally important, there was concern expressed that outsiders would have access to this. However, once the security features of the system were explained (username and password), each participant felt that the system was in fact secure enough to hold important cultural information. One specific concern was over the security of uploaded pictures. Participant #9 was concerned that another user would be able to download her pictures. I showed the participants that this was not possible and the participants were satisfied with the security. Another weakness of the system was seen to be the outdated nature of some of the satellite imagery, but 2010 high-resolution satellite images are in the process of being uploaded onto the collaborative geomatics tool.

Table 3. The perceived strengths and weaknesses of the collaborative geomatics system that were mentioned by participants during the interview process. Hierarchical order represented within the table shows the most supported benefits and weaknesses of the system by the participants.

Perceived Strengths of System	Visualization of Information
	Use of Pictures
	Use of Videos
	Visualization of the Community
	Mirrors How Elders Used to Teach
	Allows for Community Preparedness
	Sharing of Information
	Ability to Join Communities
	Shows Escalating Ecosystem Concerns
	Generates Community Awareness
	Increased Community Involvement
	Use of Maps to Display Information
	Similarities to Facebook™
	Information Made Accessible
	Shows Traffic on Land
	Shows Evolution of Community
	Potential of Layering Land-use Activities
	Tool for Elders to Use
	Collaborative Shared Screen Function
Perceived Weaknesses of System	Confidentiality of Information
	Ownership of Information
	Exposing Resource Information to Outsiders
	There is a Learning Period Required for the System
	Some People May be Computer Illiterate
	Security of Pictures Uploaded
	Old Satellite Imagery
	Terrorist Concerns
	Terminology Issues

2.4 Conclusion and Future Direction

It is clear that there was a very positive reception to the collaborative geomatics tool. Each participant found the system easy to use, even those who did not consider themselves to be computer savvy. Participants commented that the program was "*powerful*" (Participant #3), a "*good tool*" (Participant #12) and would be "*really good for [the] people*" (Participant #7). In order to increase program success, many participants felt that it would be important to hold community meetings to further explain the system and introduce it to the rest of the community, especially the elders and youth. There are research projects that incorporate TEK in the study of animal migration, ice break-ups, vegetation patterns, and species distributional changes (e.g., Couzin, 2007), but none use a similar collaborative geomatics tool.

Historically, First Nation communities have shown the ability to be resilient and adaptable to external influences whether societal, cultural and/or environmental (McDonald et al. 1997). Their TEK has allowed First Nations to learn from their environment and its variability, and adapt appropriately, while passing this knowledge from generation to generation. First Nation people of the Mushkegowuk Territory have experienced climatic warming before and have been able to adapt to such events (Woodland Heritage Services, 2004). However, societal changes and the current accelerated rate of environmental changes have reduced First Nations' ability to adapt (Ford et al. 2006). Young people are no longer going out on the land and are turning to a more southern lifestyle. Throughout the interviews many participants commented on the lack of connection that the youth have with the land. It is this disconnect with the environment between the youth and older generations that threatens the adaptive capacity of the First Nation culture. However, many believe that this collaborative geomatics system held a key to influencing the youth to become more aware of their land. According to participants, the system shows potential to teach youth about taking responsibility for their land, to learn about their heritage and community. The collaborative geomatics tool offers a way to connect today's youth with elders, allowing for knowledge transfer and increased adaptive capacity.

Another way in which the system can allow for increased adaptive capacity is by helping the community to prepare for future events. Many participants felt that this system would help the community gather their own information on environmental change. By collecting and storing their own data, the community would have information to compare with data collected by the government and resource developers, allowing for the community to become more knowledgeable and proactive.

It is clear that this system has the potential to empower the community to take charge of their land, knowledge and future, thereby leading to the increased ability to adapt to future environmental impacts.

> "*A tool like this can help…especially planning, something they lack around here*" (Participant #6).

> "*They're [funding agencies] always wanting supportive documentation about proposals that we submit to them for funding…that you know there's certain things we want done and here's our database*" (Participant #1).

Some technological issues with the collaborative geomatics tool noted during this study, such as, the icon bar being too small and not properly labeled, making it difficult to navigate through, have already been addressed. Meanwhile, the direct zoom feature will be addressed in the near future, as it was cumbersome to manually zoom to an area. There should be a legend which has key landmarks and locations that when clicked will take you directly to the location. In addition, funding has been secured to introduce the collaborative geomatics tool to more youth of the community and to schoolchildren, as adaptive capacity needs to be intergenerational.

In closing, as the Chief of Fort Albany First Nation has stated:

> "*We want to get to that security, where we feel really comfortable when we get the information…and all this data collection stays in the community…Yeah. Some place to store that information, as long as it's secure. The other thing is that I think we have to learn how to really progress with the times…making sure that we are very knowledgeable*".

Chapter 3
Final Comments and Future Research

It is now clear from numerous scientific studies that global temperatures are rising at a rate never experienced before. This elevation in temperatures is having impacts on Earth's ecosystems, resulting in changes in snowfall, rainfall, ocean levels and species distributions. Such environmental changes have been well documented, however, there has been little research into the impacts of climate change on social systems. As the global population continues to rise and the divide between the rich and poor widens, it is expected that climate change effects will disproportionately impact already marginalized populations. Furthermore, experts predict that northern latitudes will experience the greatest impacts of environmental change due to global warming. First Nation communities in Canada have a history of marginalization and social inequalities especially in communities located in northern regions of the country. Despite these differences there has been little done to mitigate the impacts of environmental change. It is clear that arctic and sub-arctic First Nation communities have already experienced environmental changes such as new species and pathogens, along with changes in extreme climatic events. However, there has been little research on how these changes will, or have, impacted First Nation sense of place with the land. This study set out to examine a potential tool that could be used by First Nations of the Mushkegowuk Territory, to help monitor and manage environmental change and its impacts. It is clear from this research that the collaborative geomatics tool developed by the University of Waterloo's Computer Systems Groups has the potential to allow for the community to monitor environmental change and store TEK. Furthermore, this system shows promise in being used as an educational tool. Each of these potential uses will help to foster adaptive capacity within the community. Increased adaptive capacity will lead to increased resilience (Walker and Salt, 2006), allowing for the community to better withstand the shocks and stresses that global environmental change will bring. Furthermore, since the collaborative geomatics tool has the ability to store TEK and aid in knowledge transfer, this will support a further increase in adaptive capacity and resilience (Walker and Salt, 2006; Armitage, 2005; Gundersonand and Holling, 2002).

The utility of this collaborative geomatic tool has been made clear. Taking into account the study in Fort Albany First Nation the next step will be to address the technological issues that developed as a result of this research. The goal is to start using the system during the summer of 2011. Once implemented, follow-up interviews and workshops will be conducted to address further technological issues and to monitor the uptake of the system within the community. Following this, I am hoping to continue to work with the community to use the system to collect and store environmental change information along with TEK. This will involve collecting and collating environmental data such as rainfall, snowfall, temperature and species distributional information. Traditional environmental knowledge will be collected and stored with the help of community members, along with information on sense of place. New species will also be monitored along side the environmental information and TEK within the system. Once data is collated and stored within the system, it will be easier to understand, predict and manage environmental change and its impacts. Only then, can we get a better understanding of the true cost of global environmental change.

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Appendix

Table 1. Summary of Collaborative Geomatics Assessment Process

Date	Location	Type of Meeting	Participants
6 August 2009	Fort Albany First Nation (Community Hall), Ontario, Canada	Formal presentations included background and rationale for the collaborative geomatics tool, including information on the proposed Bill 191 (now Ontario's Far North Act).	Fort Albany First Nation Chief & Council Kashechewan First Nation Chief and Council
9 August 2009	Timmins, Ontario	Informal presentation of background and rationale for the collaborative geomatics tool, including information on the proposed Bill 191 (now Ontario's Far North Act).	Members of Attawapiskat First Nation Chief & Council, and Attawapiskat Health Services
11 August, 2009	Timmins, Ontario	Informal presentation and discussion of the collaborative tool.	Lands and Resources, Mushkegowuk [Tribal] Council
6-12 December 2009	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members
15-24 February 2010	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members
25 May – 3 June, 2010	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members
10 August 2010	Peawanuck, Ontario	Informal meetings with respect to the collaborative geomatics tool.	Weenusk First Nation community members.
11 August 2010	Peawanuck, Ontario	Formal presentations included background and rationale for the collaborative geomatics tool, including information on the proposed Bill 191 (now Ontario's Far North Act).	Weenusk First Nation Chief and Council
8-10 September 2010	Timmins, Ontario	Mushkegowuk Council Land-Use Planning Workshop. Formal presentations included background and rationale for the collaborative geomatics tool	Chiefs and Councils and/or their representatives (Taykwa Tagamou First Nation, Chapleau Cree First Nation, Missanabie Cree First Nation,

			MooseCree First Nation, Fort Albany First Nation, Kashechewan First Nation, Attawapiskat First Nation, Weenusk First Nation)
6-15 December 2010	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members
21-28 February, 2011	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members
3-10 April 2011	Fort Albany First Nation	Informal meetings with respect to the collaborative geomatics tool.	Fort Albany First Nation community members