COMMUNITY ADAPTATION PROJECT



WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

SEPTEMBER 2010
DRAFT 1

Northern Climate ExChange

independent information, shared understanding, action on climate change

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TAKING ACTION ON CLIMATE CHANGE

Canada Northern Strategy Trust

Yukon College

UBC

Yukon Government

Prepared by the Whitehorse Adaptation Project Team
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Executive Summary

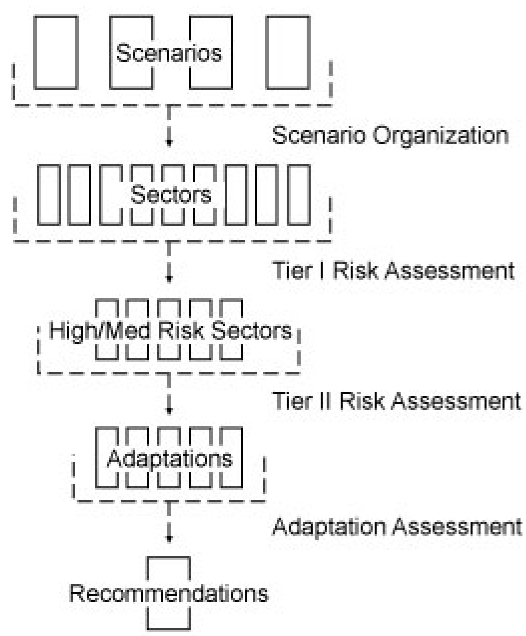
About This Plan

Climate has been changing in Whitehorse. It is clear from meteorological data going back to the 1940's that temperature has been warming, especially in winters. Break up has also been arriving earlier, freeze up later and growing degree days have been increasing. The Whitehorse Community Adaptation Project, or WhiteCAP, was funded by the Northern Strategy Trust to begin the process of ensuring that Whitehorse residents are prepared for climate change. WhiteCAP consists of two distinct phases: planning and implementation.

The WhiteCAP plan is intended to assess how climate change may positively or negatively affect the community over the next forty years, to 2050. The plan uses a modified form of scenario planning and risk assessment. The first half of the planning process, which focused on exploring multiple scenarios of how the community may change by 2050, is presented in the companion document for this plan: *Future Histories of Whitehorse: Scenarios of Change.* The WhiteCAP plan reports on the risk assessment portion of the Whitehorse adaptation planning process. Portions of the plan will be implemented in the second year of the project.

The scenario planning portion of the WhtieCAP process is based on an evaluation of community vulnerability. To assess vulnerability we developed four scenarios describing how climate change may affect the community of Whitehorse based on an increase in regional mean annual temperature of 2°C to 4°C and a population growth of 12,000 to 24,000 people by 2050. Based on these scenarios the community identified 237 impacts and proposed 245 adaptations to address climate change.

Figure 1: Risk Assessment Process



Two levels of risk assessment were conducted to establish where community vulnerability was greatest (Figure 1). The first level of risk assessment, or tier one, examined the nine sectors identified in discussions of vulnerability with the community. Risk was determined based on the severity of anticipated impacts, the likelihood of the impact occurring, and the adaptive capacity of the community to respond to that impact. Five priority sectors were determined to be of risk to the community: natural hazards, infrastructure, environment, food security, and energy security. The second level of risk assessment identified high risk consequences of climate change for the community in each of these sectors. For those impacts that are considered opportunities the assessment process was the same, however we considered the strength of the opportunity rather than the severity of the risk.

WhiteCAP is a community planning process. The broader community was engaged through a series of open houses, beginning with an introductory open house in June 2009 to promote the project. Members of the community were then invited to participate in a workshop or community input session to discuss how climate change may exacerbate vulnerability in the Whitehorse region. A second open house was held shortly after to report on the results of the community input session and provide the broader community the opportunity to contribute to the scenarios. A third open house was held in the fall of 2010 to provide the community the opportunity to comment on the plan (anticipated). A final open house is scheduled for the summer of 2011 to report on the findings of the finalized plan and on community projects completed during the second year of WhiteCAP. In all, four open houses and three workshops will have been held in the community over the two years of the adaptation project, from June 2009 to June 2011.

Climate Change and Whitehorse

Climate change projections show how the Whitehorse region may be altered by shifting temperature and precipitation. Shifts in temperature and precipitation will have spin-off effects that will enhance vulnerabilities or establish opportunities for the community. Projected mean annual temperature and seasonal temperatures for the Whitehorse area were estimated for 2030 and 2050. Projected increases indicate that warming will differ seasonally, and that winter period will experience the most significant warming – increasing 3.3°C to 5.4°C. Mean annual precipitation is anticipated to increase from 585mm to 638 to 657mm by 2050. Seasonal precipitation is expected to increase throughout the year, with the greatest increases occurring in the winter and fall. Winter precipitation is projected to increase between 11.3% and 13.9%, while autumn precipitation is projected to increase between 9.4% and 12.9%. Based on the projected shifts in temperature and precipitation, the growing season for Whitehorse is expected to increase; rising from 150 days to 168-175 days by 2050, an addition of 18-25 days. The growing season was estimated based on projected changes to seasonal freeze-up and thaw dates in the Whitehorse region.

Identifying Adaptations to Climate Change in Whitehorse

Each adaptation was assessed to determine how well it addresses the consequences of climate change identified in Tier II of the risk assessment. A priority response was characterized by fit (how well it benefits the broader community), whether it is win-win, and whether it builds adaptive capacity. Of the 245 adaptations suggested by the community, 49 were determined to leverage community capacity appropriately. These 49 adaptations indicate that a broad range of actions are required across many disciplines to adequately prepare for climate change. These actions can be integrated into existing projects and programs to increase the efficiency of responding to climate change. This is called “mainstreaming”.

Mainstreaming Climate Change in Whitehorse

Ongoing processes into which climate change adaptations can be integrated include land-use/local area planning (e.g. City of Whitehorse Official Community Plan), sustainability planning, emergency response planning and infrastructure planning. A number of adaptations have also been recommended to address the lack of data available to inform future decisions. Adaptations for increased monitoring and data collection have been gathered under the heading of "future research" and should be integrated into the Yukon's research agenda where possible.

Land-use / Local Area Planning

- Forward consequences of climate change to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure
- Create zoning that reflects potential future changes in the landscape
- Identify critical thresholds, responsibilities and partnerships
- Revisit regional planning and all other relevant planning regularly
- Generate standards/best practices for subdivision development for climate change, energy, forest fire, wind breaks, etc.
- Empower greenspaces plan (build resilience to climate change)
- Reassess situation and values over time while planning for change now
- Look into a strategy to enforce the protection of riparian buffers
- Encourage small community plots

Sustainability Planning

- Create a strategy to move forward as demand for waste management constrains flexibility
- Separate untreatable garbage at source to reduce leaching
- Create a strategy to compensate for capacity issues as people and expertise are strained by changing climate conditions
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Create and implement a groundwater management plan
- Look into a strategy to enforce the protection of riparian buffers
- Encourage small community plots
- Investigate new and innovative ways to grow food
- Create an energy plan for Whitehorse (including comprehensive energy management)
- Promote seasonal energy uses: e.g. greenhouses
- Push for super-green construction to reduce heat demands
- Support recycling as a growth industry
- Explore urban gardening and community greenhouse opportunities
- Continue to expand on education opportunities for regional agriculture
- Build processing facilities and cold storage
- Share knowledge of food growth between First Nations and science

Emergency Response Planning

- Integrate climate change risk and impact into emergency planning
- Require a second strategy for community based disaster response (equivalent to a residential fire strategy)
- Continue education around responsible fire safety
- FireSmart vulnerable infrastructure
- Educate and train safety sector on climate change
- Investigate and assess catastrophic flood scenarios

Infrastructure Planning

- Pass consequences of climate change on to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure
- Incorporate climate change and variability into infrastructure development currently in planning stages
- Investigate and assess catastrophic flood scenarios
- Establish a budget for dealing with climate change impacts: for example roads and road clearing
- Separate untreatable garbage at source to reduce leaching
- Assess dependence of Whitehorse to highway and vulnerability of highway to climate change outside city limits
- Generate standards/best practices for subdivision development for climate change, energy, forest fire, wind breaks, etc.
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Build processing facilities and cold storage

Future Research

- Investigate and assess catastrophic flood scenarios
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Retain capacity and expertise on evapotranspiration and groundwater recharge, since they are critical and uncertain
- Monitor water quality and quantity, fish, wildlife and other indicators
- Gather and collect local observations/data conclusions, both scientific and traditional
- Restore weather stations
- Set aside funding to monitor fish, wildlife and the environment
- Train (and pay) local people for monitoring
- Take advantage of digital technologies to gather, store, and share information – this information hub must consider the abilities of the people who need access to it

Implementation

The Northern Strategy Trust Fund has provided $120,000.00 for the implementation of the WhiteCAP plan in the second year of the Whitehorse Adaptation Project. In the fall of 2010, the Whitehorse Local Advisory Committee will select projects for implementation through a proposal uptake. All proposed projects will be interpreted from the recommendations of this plan. Projects will be selected by the local advisory committee under the purview of Yukon College according to established terms of reference. Proponents will be provided with the draft adaptation plan, the project vision, the terms of reference and a submission template in the fall of 2011. Projects will be implemented from October 2010 to June 2011 under the supervision of the Whitehorse Local Adaptation Coordinator. A full implementation report will be provided at the conclusion of the implementation period in the summer of 2011.

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1.0 Introduction

Climate change, and the host of challenges and opportunities it presents to the North, has become an important matter for the Yukon. Over the past fifty years, the Western Arctic region of Canada has experienced a significant increase in temperature of approximately 3ºC (ACIA, 2004, Zhang et al, 2000) and an increase in precipitation of roughly 8% (ACIA, 2004). This change in temperature and precipitation has resulted in subsequent shifts in landscape conditions, which may increase the vulnerability of Yukon communities to environmental stresses associated with variable weather, drought, food and energy security, flooding and forest fire. These environmental stresses in turn carry implications for northern infrastructure, the health of northern residents, and our economy. Given the far reaching implications of climate change, the need to adapt our communities to a changing and uncertain future grows ever more clear.

The *Whitehorse Climate Change Adaptation Plan* has been developed by the Northern Climate ExChange (NCE) Community Climate Change Adaptation Project (CCCAP) and funded by the Yukon Northern Strategy Trust. The mandate of CCCAP is to increase the adaptive capacity of the Yukon to respond to climate change through the development and implementation of adaptation plans in three communities, Dawson, Whitehorse and Mayo.

The Whitehorse Community Adaptation Project, or WhiteCAP, consists of two distinct phases: planning and implementation. The WhiteCAP plan is intended to assess how climate change may positively or negatively affect the community over the next forty years, to 2050. The methodology used in the planning process includes a modified form of scenario planning and risk assessment. The first half of the planning process, which focused on exploring multiple scenarios of how the community may change by 2050, is presented in the companion document for this plan: *Future Histories of Whitehorse: Scenarios of Change.* The WhiteCAP plan reports on the risk assessment portion of the Whitehorse adaptation planning process. Portions of the plan will be implemented in the second year of the project using funding provided by the Northern Strategy Trust.

Figure 1.1: Whitehorse Adaptation Plan Context Map

Whitehorse is the political and commercial hub of Yukon, with a relatively diverse economy and extensive infrastructure. As of December 2009 the community had a population of 25,690 (YBS, 2010); or 75% of the total population of the Territory. This far exceeds the population of any other Yukon community[1]. Whitehorse is located within the traditional territories of two Yukon First Nations; Kwanlin Dün and Ta'an Kwäch'än (Environment Yukon, 2004). Given the size and diversity of the community of Whitehorse and the range of potential issues anticipated to result from climate change in the region, the study area boundary for the adaptation plan was established at the Whitehorse city limits (Figure 1.1). The community of Whitehorse includes all people residing within city limits. Although this precludes nearby unincorporated communities, it is the expectation of the project team that the climate change risks for these communities will be similar to that faced by Whitehorse. The recommendations of this plan will therefore also hold true for neighboring communities.

The WhiteCAP plan first documents the methodology used to assess the vulnerabilities of Whitehorse to climate change. The plan then inventories the current socio-economic and environmental characteristics of the community to provide a basis for discussions of risk later in the planning process. While some climate change impacts may be unprecedented, many represent impacts that are already familiar, but that may occur more frequently or more severely.

The project team has assessed priority based on the likelihood and severity of impacts and also by how prepared the community already is to address the impacts – or their adaptive capacity. Section four discusses climate change in a regional context. The remainder of the plan is devoted to determining priority adaptations for the community of Whitehorse. This report concludes with a discussion of potential community partners, a suggested timeline, mainstreaming recommendations and next steps. Due to the technical nature of some of the language in this report, a glossary of terms has been provided in Appendix A and a list of acronyms has been provided in Appendix B.

1.1 The Whitehorse Climate Change Adaptation Plan Vision

A Whitehorse Local Advisory Committee was established at the outset of the Whitehorse Adaptation project. The mandate of this local advisory committee was primarily to provide guidance and ensure that the planning process sufficiently reflects community concerns and is grounded in community capacity. As a starting point for this process, the Whitehorse Local Advisory Committee was asked to describe their vision of a community that has successfully adapted to climate change. This vision has guided the development of the *Whitehorse Climate Change Adaptation Plan*:

> *The community of Whitehorse is preparing for climate change, including variability and uncertainty, by building capacity, knowledge, resilience and partnerships. Adaptation should be proactive and where practical enhance natural systems, climate change mitigation, and the development and well-being of the community.*

The community vision defined by the Whitehorse Local Advisory Committee identifies a number of priorities which include knowledge provision, partnership identification and capacity development. These priorities have been considered throughout the planning process. Other aspects of the vision, such as climate change mitigation and well-being of the community have been factored into the planning process as special considerations.

1.2 Special Considerations of the Whitehorse Adaptation Plan

Several special considerations emerged consistently throughout the adaptation planning process in Whitehorse. While these considerations were not directly associated with building the adaptive capacity of the community, the frequency with which they were raised does indicate that a relationship exists between them and climate change adaptation. These special considerations include: sustainable development, climate change mitigation, and the special link between the community and the wilderness surrounding Whitehorse.

1.2.1 Sustainable Development

Sustainable development has emerged as a dominant concern in the City of Whitehorse. In 2009 the City of Whitehorse officially adopted *The Whitehorse Strategic Sustainability Plan* which encompasses a wide range of community values, including a sense of community, a high quality of life, nature, leadership, First Nations culture, the arts and local businesses (COW, 2009). These values directly influence climate change adaptation through their contribution to the social capital of the community, and in turn the contribution of social capital to adaptive capacity (Adger, 2003). Other attributes of sustainable development, such as increases in efficiency of resource use and in the flexibility of land use, can also make a significant contribution to the adaptive capacity of the community (Fellows, 2006).

1.2.2 Climate Change Mitigation

Climate change mitigation is a priority for the community of Whitehorse. The mitigation of climate change through the control of greenhouse gas emissions will reduce the severity of the impacts to which the community will have to adapt. As a result, a balance between mitigation and adaptation is the most effective way to respond to climate change vulnerabilities (IPCC, 2007). Often adaptations have a mitigative aspect that can reduce the greenhouse gas emissions of a community while increasing their adaptive capacity. Adaptations that reduce greenhouse gas emissions have the added benefit of reducing the overall risk of the community to climate change, a distinct advantage over adaptations that increase the greenhouse gas emissions of a community.

Several opportunities for reducing the greenhouse gas emissions of Whitehorse were identified through the adaptation process. Many correlate to the Community Action Plan established by the City of Whitehorse in 2004, which suggested a number of educational, operational and policy actions that would reduce the carbon footprint of community buildings, transportation, the land use sector, waste management and the improvement of data compilation and monitoring (COW, 2004). Where possible the recommendations of this plan should compliment the action plan.

1.2.3 Connection Between the Community and Wilderness

The special connection between Whitehorse residents and the wilderness areas surrounding the City were reported at several points in the planning process. This connection was also reported in *The Whitehorse Strategic Sustainability Plan*:

> *The Yukon River runs through Whitehorse and our city is surrounded by mountains. Our residents value the nearby access to the wilderness. Residents value the wildlife, green spaces and trails in our neighbourhoods and the connections to other neighbourhoods. We value clean air and water* (COW, 2009:8).

This connection influences recreation, culture and the sense of well-being in the community[2]

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[1] For example, in December 2009 the community with the second highest population in the Territory was Dawson City (1,873). The majority of Yukon communities host a population of less than 1,000 residents (YBS, 2010).

[2] A special mapping session was held by NCE in November, 2009 with interested participants. Participants were asked to map those special aspects of Whitehorse that they valued.

2.0 Whitehorse Adaptation Planning Process

The Whitehorse adaptation planning process was created to manage the complexity associated with regional climate change. The process was inspired by the *Risk-Constrained Organization* approach to strategic management described by Masch (2004) to achieve a “natural” approach to decision-making. The natural approach “…does not rely on any unwarranted assumptions and incorporates ‘multiple everything’ – strategies, scenarios, and different risk types” (Masch, 2004: 435).

The natural approach was used primarily to manage the uncertainty and variability associated with climate change impacts in northern regions. All climate has variability, and projecting future climate always contains uncertainty. For example there is some uncertainty in forecasting future global climate. Downscaling from global to regional climate adds more uncertainty[3]. Using this regional climate to assess the biophysical and socioeconomic implications of climate change introduces even more uncertainty.

Fortunately we have ways to address this uncertainty within the planning process. In the case of the WhiteCAP plan, uncertainty was addressed using a combination of scenario planning and risk management. Scenario planning allows for a range of likely outcomes of future actions to be determined. While it is difficult to say what the climate will be precisely, we have reasonable confidence that it will fall within the range of scenarios. Risk management is a technique that allows us to make informed decisions in the face of uncertainty.

2.1 Community Engagement

The community of Whitehorse was actively engaged throughout the adaptation planning process, from June 2009 to September 2010 (anticipated). Community engagement occurred at several levels including Whitehorse Local Advisory Committee meetings, open houses, newsletters, technical working sessions, presentations to project partners[4] and workshops with broad community input.

The Whitehorse Local Advisory Committee was organized and led by the Whitehorse Adaptation Coordinator and provided extensive guidance on the development of the adaptation plan at all stages of its development. The advisory committee included representatives of Ta’an Kwäch’än Council, Kwanlin Dün First Nation Government, Yukon Government, City of Whitehorse and the Yukon Conservation Society. The committee primarily ensured

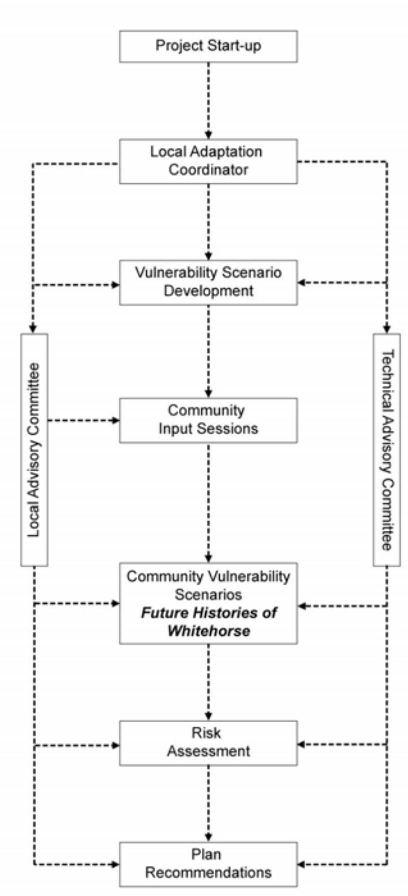

Figure 2.1: Whitehorse Adaptation Planning Process

community priorities were addressed, established transparency in the planning process, and ensured community ownership over the adaptation plan through participation. As illustrated in Figure 2.1, the Whitehorse Local Advisory Committee compliments the Technical Advisory Committee, facilitating the integration of local and scientific knowledge in the planning process. The membership of both committees is documented in Appendix C.

The broader community was engaged through a series of open houses, beginning with an introductory open house in June 2009 to promote the project. Two community workshops were also held in the fall of 2009 to document community values in the regional landscape. As noted above, members of the community were invited to participate in a third workshop or community input session to discuss how climate change may exacerbate vulnerability in the Whitehorse region. A second open house was held shortly after to report on the results of the community input session and provide the broader community the opportunity to contribute to the scenarios. A third open house was held in the fall of 2010 to provide the community the opportunity to comment on the plan (anticipated). A final open house is scheduled for the summer of 2011 to report on the findings of the finalized plan and on community projects completed during the second year of WhiteCAP. In all, four open houses and three workshops will have been held in the community over the two years of the adaptation project, from June 2009 to June 2011.

2.2 Scenario Planning and Risk Management

The Whitehorse adaptation plan is based on an evaluation of community vulnerability. To assess this vulnerability we developed four scenarios describing how climate change may affect the community of Whitehorse based on an increase in regional mean annual temperature of 2°C to 4°C and a population growth of 12,000 to 24,000 people by 2050. The spin off effects of these ranges were first discussed with the Whitehorse Technical Advisory Committee[5] in November, 2009 and then expanded on at a community input session in January 2010. The scenarios revealed a range of issues across ten broad categories / sectors of community-level impacts: general, economic, environment, socio-cultural, infrastructure, energy security, hazards, food security, health and education. The full community climate change scenarios and all proposed adaptations are available in the companion document for this report: *Future Histories of Whitehorse: Scenarios of Change.*

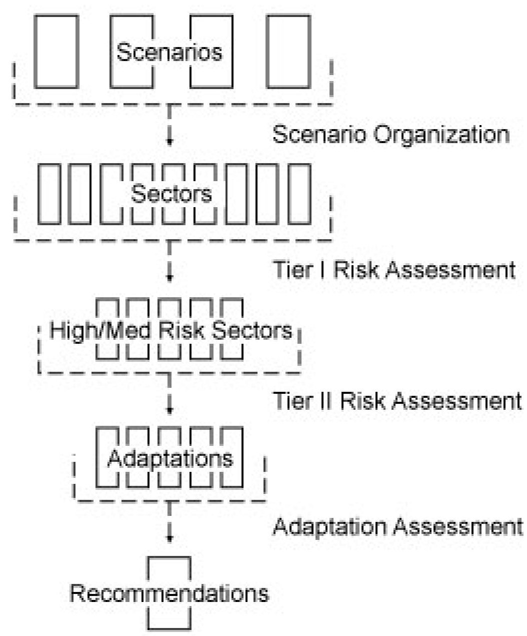

Figure 2.2: Risk Assessment Process

The community identified 237 impacts and proposed 245 adaptations to address climate change. Of these, the project team anticipated only a small proportion would be of priority, therefore two levels of risk assessment were conducted to establish where community vulnerability was greatest (Figure 2.2). The first level of risk assessment, or tier one, was carried out by the Whitehorse Technical and Local Advisory Committees in May and June 2010 respectively. The committees examined the results of the community input session and prioritized the broad sectors that had emerged from that meeting based on the severity of anticipated impacts, the likelihood of the impact occurring, and the adaptive capacity of the community to respond to that impact. The results of each meeting were similar. The five priority sectors were determined to be natural hazards, infrastructure, environment, food security, and energy security.

In the second tier of risk assessment the project team evaluated each specific impact from the priority sectors. The same criteria of likelihood, severity and adaptive capacity were used to assess risk on an impact by impact basis. For those impacts that are considered opportunities the assessment process was the same, however we considered the strength of the opportunity rather than the severity of the risk.

2.3 Limitations of the Whitehorse Adaptation Plan

The Whitehorse adaptation plan makes recommendations to increase the resilience of Whitehorse based on the assessment of climate change vulnerability. The plan was developed through a rigorous process which emphasized local knowledge and its integration with scientific information. However, given the broad nature of the assessment, the plan is necessarily limited by the availability and quality of data, the complexity of the community and our emphasis on qualitative information.

Climate change will have a universal impact on the North, affecting almost every facet of the land and the people who live on it. Assessing this complex system is challenging and uncertainty is a significant component of climate change research (Malone and Brenkert, 2008). Uncertainty arises from a number of sources, especially the lack of readily available regional data to support or reject assumptions. While the Whitehorse adaptation planning process was designed to manage uncertainty to the greatest degree possible, data gaps do exist. Therefore, the Whitehorse adaptation plan should be revisited regularly as new information emerges and the uncertainty associated with adaptation planning is reduced.

The Whitehorse region is also remarkably complex. As will be described in the next section, the area is composed of extensive infrastructure, a number of interrelated governing bodies, and a relatively diverse population and economy. This complexity has been challenging to appraise given the broad nature of the adaptation plan. Extreme or special cases characterized by a high level of uncertainty have been especially challenging to evaluate. Such cases include a population explosion beyond that indicated by current trends (or conversely a population decline), exceptional disaster situations, and/or regime shifts at an unprecedented rate of change. Our recommendations have been developed based on the information that could be gathered and supported by local, professional and academic technical expertise and knowledge. It should also be noted that an increase in community resilience through the timely implementation of adaptation strategies will address some or all of the vulnerabilities associated with unprecedented and/or extreme events.

The use of spatial information in this report has been largely to inform the observations provided to us by the community and by the Local and Technical Advisory Committees. Quantitative information has therefore not played a significant role in the planning process. In part our reliance on qualitative data has arisen due to the emphasis on local and technical knowledge in the plan. Quantitative data has also been challenging to integrate due to the broad nature and suite of issues that this plan addresses. As uncertainty is addressed and additional information becomes available, it is likely that a greater emphasis can be placed quantitative information in the adaptation planning process. It is encouraged that quantitative information should be integrated into future versions of this adaptation plan as opportunity allows.

[3] This uncertainty is compounded when the large resolution and level of error in the model is refined or downscaled to a scale suitable for regional planning. Global Climate Model (GCM) grid cells are typically 1° to 5º latitude and longitude in size. Downscaling introduces error into the climate model by interpolating the implications of climate change a regional scale. It has also been observed that a polar amplification of the influence of greenhouse gas emissions and other variables influencing climate occurs in GCMs. This amplification varies with each GCM and some projections of climate change in northern regions or more robust. The performance of the GCM over the broader north correlates to their performance over Greenland and Alaska. Some level of error is associated with all GCM projections (Walsh et al, 2008).

[4] The Project Team presented at two Council and Senior Management (CASM) sessions in the spring of 2009. The City of Whitehorse (COW) provided official approval for staff participation in the project at an official council meeting in the summer of 2009. [also meeting with Ta'an lands group in summer 2010]

[5] The Whitehorse Technical Advisory Committee is made up of professionals from within and outside the community. The mandate of the Technical Advisory Committee is to provide academic and professional support for the adaptation planning process through the integration of local and scientific knowledge.

3.0 Whitehorse Community Profile

Many factors create the unique characteristics that define the vulnerability and resilience of Whitehorse to climate change. Some of these characteristics are the result of the people (e.g. demographic profile, history of addressing climate and related hazards in the community, etc.), which influence local adaptive capacity. Other characteristics emerge from the landscape (e.g. biophysical profile of the community), which determines the susceptibility of the region to environmental stresses and hazards. The following situation analysis briefly[6] describes the current make-up of the community and creates the context for the evaluation of climate change risk later in the plan.

3.1 Whitehorse Demographic Profile

Many aspects of the Whitehorse community shape its adaptive capacity, including age, tradition, governance, economy, wealth, education profile, and the transience of the population. These variables define the human resources, the institutional capacity and the expertise available for the community to respond to climate change.

As is common in Canadian communities, Whitehorse is characterized by an aging population. Aging populations are those that are growing most rapidly in the 55+ age group (Cameron, 2006). Members of the community over 55 years of age typically have slimmer financial resources and are physically vulnerable to climate related events to a greater extent than younger cohorts (F. Duerden, Ryerson University, pers comm. July, 2010). As of December 2009, 21.4% of the city's population was 55 years of age or more (YBS, 2010). Moreover, in all growth projections for the Yukon, the 50+ age group is anticipated to increase to 35.4% -37.5% by 2018 (YBS, 2008a). The current age distribution of Whitehorse and the projected growth in the 50+ age group has tangible implications for the community's adaptive capacity given that 75% of the Yukon's population resides within city limits.

The economy of Whitehorse is characterized primarily by public sector employment. 26% of the population is employed by government, either Federal, Territorial, Municipal, the Council of Yukon First Nations, Ta'an Kwäch'än Council or Kwanlin Dün First Nation. Private sector employment in Whitehorse is characterized by retail trade (11% of the total labour force), the health and social assistance sector (10%), accommodation and food services (8%), construction (7%) and education (6%), with the remaining proportion constituted by manufacturing, transportation and warehousing, telecommunications, finance and insurance, and other service industries. The dominance of the public sector in the employment profile has a stabilizing effect on the local economy and somewhat moderates the boom-bust influence of the mining industry (COW, 2010). This economic stability is important to community adaptive capacity.

The average income of Whitehorse residents is high when compared to the rest of Yukon and Canada. In addition to being relatively wealthy, the community is well educated. Of the total population 15 years of age and over, 28% have an education diploma below the university level, 20% have a university level education, 21% have a college education, and 11% have a certificate or diploma in trades or an apprenticeship. 20% have no diploma or degree. The major fields of study reported by the community include social sciences and law, business management and public administration, architecture and engineering and health (Stats Canada, 2010).

The population of Whitehorse has become increasingly stable over the past few decades. 78% of individuals registered as permanent residents who had lived in the community for over five years (Kischuk, 2009). The decreased mobility of the community increases its adaptive capacity because permanent residents tend to have a greater investment in their community and are therefore more likely to take action under adverse conditions. In addition, 19% of the Whitehorse population has identified as "aboriginal[7]" (YBS, 2008b). The proportion of indigenous peoples in the community supports a strong sense of place and connection to the region.

3.2 Biophysical Profile of the Whitehorse Region

Climate change vulnerability for the community arises from biophysical characteristics such as topography, hydrology, freeze-thaw activity, and local biodiversity. The City of Whitehorse is located along the Yukon River in relatively mountainous terrain. It is a community squarely within the boreal forest. As illustrated in Figure 3.1, the city is a distributed urban system, characterized by extensive linear infrastructure and relatively secluded subdivisions. Country residential neighbourhoods on the periphery of the community, such as Mary Lake, Wolf Creek and Hidden Valley, are especially isolated. Much of the development within the urban core has occurred on the floodplain, including portions of the downtown, Marwell and Riverdale.

Whitehorse is located in the Yukon Southern Lakes Ecoregion of the Boreal Cordillera Ecozone[8]. This ecoregion is characterized by dissected plateaus and broad valleys occupied by numerous lakes and rivers. The rolling hills of the region create a profile on average of 1,000 to 1,500 metres above sea level, while downtown Whitehorse is at 650m. Wetlands and large lakes cover approximately 5% of the region (Yukon Ecoregions Working Group, 2004). Within Whitehorse, some wetlands have been bisected by infrastructure such as roads, powerlines, etc. These wetlands, such as those around McIntyre Creek may be vulnerable to climate change. Others, such as the wetlands located on the east side of the river remain relatively intact and untouched. The hydrology of the region has also been influenced by the creation of the Whitehorse Dam, which is situated on the Yukon River south of the downtown core. In addition to creating Schwatka Lake, the dam has raised the water table in areas to the south and east, adding to the Hidden Lakes. Wetlands to the south have been and will continue to be influenced by development, including the proposed Whitehorse Copper subdivision (J. Kenyon, Ducks Unlimited, pers comm. July 2010).

Vegetation in the Yukon Southern Lakes ecoregion is a by-product of the rain-shadow and forest fire regime which characterize the region. Open coniferous and mixed woodland dominated by pine dominates the region. White spruce and mixed aspen are also commonly found. Black spruce has a limited distribution (Yukon Ecoregions Working Group, 2004). The region also supports the greatest mammalian diversity in the Yukon. Some 50-60 Yukon species can be found around Whitehorse, including: moose, grizzly bear, wolves, coyotes, red fox, sheep, wolverine, woodland caribou, deer, lynx, beavers, and the occasional cougar (Yukon Ecoregions Working Group, 2004). The Yukon Bird Club reports 264 species that can be seen in the immediate vicinity of the community, of which 129 are confirmed to breed in the region[9]. 11 species found within, near or migrating through Whitehorse city limits have been listed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). These species are listed in

Table 3.1. Elk Thistle (*Cirsium foliosum*) has not been listed by COSEWIC, but is of conservation concern[10].

Table 3.1: Whitehorse Regional Species Listed By COSEWIC		
Common Name	Scientific Name	Status
Grizzly Bear	*Ursus arctos*	Special Concern
Woodland Caribou (Northern Mountain Population)	*Rangifer tarandus caribou*	Special Concern
Olive-sided Flycatcher	*Contopus cooperi*	Threatened
Common Nighthawk	*Chordeiles minor*	Threatened
Rusty Blackbird	*Euphagus carolinus*	Special Concern
Baikal Sedge	*Carex sabulosa*	Threatened
Wood Bison	*Bison bison athabascae*	Threatened
Peregrine Falcon	*Falco peregrinus anatum/tundrus*	Special Concern
Horned Grebe	*Podiceps auritus*	Special Concern
Short-eared Owl	*Asio flammeus*	Special Concern

Invasive species are currently established in the City of Whitehorse. The Yukon Invasive Species Council is providing support to this planning process and will provide a list of species of concern for inclusion in later drafts of this report.

Much of the Whitehorse region is characterized by gravel, clays and silts as the majority of the region was glaciated during the McConnell Glaciation. Permafrost in the region is discontinuous and between 2 or 3m thick where found in Whitehorse. In and around Whitehorse, permafrost is more typically found at higher elevations. Most of the built up area of Whitehorse is along the valley floor and lower elevations where permafrost is rare. East of Whitehorse, less than 8% of the Alaska Highway has been constructed on permafrost. West of Whitehorse to Haines Junction, however, the incidence of permafrost increases and permafrost can be measured beneath 20% of the highway's length (Yukon Ecoregions Working Group, 2004). Regional soils were formed by glacial activity and are classified as Eutric Brunisols (Yukon Ecoregions Working Group, 2004). These soils classified as 5 (of 8) by the Canada Land Inventory and are suitable for forage and cold hardy vegetables[11] (Tarnocai et al, 1988).

3.3 Environmental History of the Whitehorse Community

Historic stresses can be indicative of the impacts of climate change that the community may need to respond to in future and also provide some insight to the strength of the community to address hazards. Assuming that climate change will exacerbate current vulnerabilities, the history of environmental stresses in the City of Whitehorse can be used to measure the adaptive capacity of a community. The frequency of such stresses provides a broad indication that an event can occur and also indicates the experience of the community with responding to challenges as they emerge. Therefore, the adaptive capacity improves with the frequency with which the community has had to respond to an environmental stress. The full environmental history for Whitehorse is provided in Appendix D.

The environmental history of Whitehorse, compiled from local newspapers[12], indicates that the community has experienced stresses from forest fires, flooding, and variable weather. Forest fires are the most important and common environmental stress experienced by Whitehorse. Severe fires occurred in the vicinity of Whitehorse in 1958, 1969, 1978, 1984 and 1991. These fires affected air quality and damaged infrastructure. The cost of responding to forest fires can be expensive. For example, the cost to the City of Whitehorse to respond to the 1984 fire outbreak was $4,600,000 ($8,600,000 in today's economy). Regionally, flooding can occur due to ice jams and precipitation. Localized flooding has occurred throughout the study area, although the areas most common to flooding are the downtown core and Marwell. The City of Whitehorse continues to upgrade the storm drainage system regularly, and the frequency and severity of flooding across the city has decreased over time.

Variable weather is characterized by ice and icy conditions, fluctuating temperatures, and heavy snowfall. Variable weather is a normal part of the regional climate and examples of the damages caused by ice, temperature and snow were observed throughout the historic record. Every year, rapidly fluctuating temperatures can produce fog and melting that freezes creating icy conditions. These conditions in turn create dangerous driving and walking has resulted in injury and / or damage and costs for individual residents. Storms and severe weather events have resulting in localized damage. Heavy snowfall has been problematic within the community, as a result of loading or due to localized flooding from melt. Damage to buildings and linear infrastructure such as powerlines has occurred. In the case of variable weather, residents have coped with the results as they arose.

Over the past 80 years the infrastructure of the City has been modified and upgraded significantly. It is therefore evident that the City of Whitehorse has a proven capacity to adapt and change where necessary. This capacity and the combination of significant public sector presence and professional training in Whitehorse emphasize the influence of institutional experience on the adaptive capacity of the community. Most residents will look to their governments to take action before taking action themselves. This influence was illustrated in the community environmental history, which indicates that community's adaptive capacity is low where behavioural rather than institutional level change is required. The Whitehorse Community Adaptation and Vulnerability In Arctic Regions (CAVIAR) project, funded by the International Polar Year (IPY), has extensively examined the institutional capacity of Whitehorse and its role in climate change adaptation and will provide information to substantiate this link in the Whitehorse adaptation plan when the opportunity arises.

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[6] Whitehorse has been extensively documented elsewhere and therefore only minimal detail is provided in this situation analysis. The 2010 City of Whitehorse Official Community Plan provides and excellent starting point for additional reading.

[7] The Aboriginal identity population is composed of those persons who reported identifying with at least one Aboriginal group, that is North American Indian, Métis or Inuit, and/or those who reported being a Treaty Indian or Registered Indian, as defined by the Indian Act of Canada, and/or those who reported they were members of an Indian band or First Nation (YBS, 2008).

[8] Both the Yukon Southern Lakes Ecoregion and the Boreal Cordillera Ecozone are described in extensive detail in Ecoregions of the Yukon Territory: Biophysical Properties of Yukon Landscapes.

[9] For a complete list see Checklist of the Birds of Whitehorse, Yukon. Compiled by Cameron Eckert, Helmut Grünberg, Lee Kubica and Pamela Sinclair. Available at the City of Whitehorse.

[10] As determined by the Yukon Conservation Data Centre (R. Mulder, Environment Yukon, pers comm. July 2010).

[11] These class 5 soils are thermally and moisture limited. Even if the present thermal limitation was removed by climate change, it may be replaced by an aridity limitation of equal severity if evapotranspiration rates exceed moisture availability. Removal of moisture limitations through irrigation would increase the soil class from 5 to 2 (Tarnocai et al, 1988).

[12] Evidence of environmental stress in the vicinity of Whitehorse was principally gathered from the archives of the two local newspapers; the *Whitehorse Star*, and the *Yukon News*. About 50 articles from 1930 to 2009 were read to determine the extent, influence and repercussions of historic climate events. Other information was subsequently gathered from relevant Yukon Government or City of Whitehorse departments.

4.0 Climate and Whitehorse

The city of Whitehorse is located in the Upper Yukon-Stikine Basin climate region of Yukon (Whal et al, 1987). This climate region is influenced by the St Elias/Coast Mountain Ranges, which create a rain shadow. This rain shadow influences the amount of precipitation that falls in the region, typically 200 to 325mm per annum (Yukon Ecoregions Working Group, 2004). Mean annual temperature for the region is -1°C to -2°C (Yukon Ecoregions Working Group, 2004). The northwest-southeast orientation of the valley in which Whitehorse has been developed ensures the city is the most consistently windy location in the region (Whal et al, 1987).

This section summarizes the climate of Whitehorse. Past trends in precipitation and temperature are provided. As well, climate projections through to the 2050's are provided. Trends and projections are compared to climate normal from 1961-1990. Projected climate changes to the Whitehorse area were generated by the Scenarios Network for Alaska Planning (SNAP). SNAP is located at the University of Alaska-Fairbanks. The trend analysis was completed by NCE over the winter of 2010.

4.1 Past Climate Trends in the Whitehorse Area

Climate has been changing in Whitehorse. It is clear from meteorological data going back to the 1940's that temperature has been warming, especially in winters. Winter also has the greatest variability in temperature. Break up has been arriving earlier, freeze up later and growing degree days have been increasing. Past climate trends give us a context from which to evaluate local climate and also a sense whether or not the climate has been changing. Trends can be compared against projections of future climate, such as those provided in the next section. Where the trend agrees with projections, our confidence in knowing the future climate increases. Where the trends disagree with projections, our confidence decreases.

Whitehorse is semi-arid. While there has been a small increase in precipitation over recent decades, there is already a great deal of variability in precipitation and therefore, the trend is difficult to discern. Further, some data from recent decades has been lost. Non-parametric trend analysis (thus avoiding biases associated with missing data) show that winter precipitation is trending down. The trends for temperature and precipitation are provided in Table 4.1.

Flow data is available for the Yukon River at Whitehorse. Warming trends and the melting of the glaciers which feed the Upper Yukon Basin have increased lake levels in the system above Whitehorse but have not resulted in appreciable increase in overall annual flow of the Yukon River through Whitehorse. Seasonal variation in flow has changed, but this is most likely to be as a result of hydrological control systems operated by Yukon Energy and not a change in the climate system. Flooding is not typically associated with peak flow in summer, but is instead related to both freeze up (and ice damming) and spring melt (especially in heavy snow years with rapid melt onset).

Standard meteorological data show a decreasing trend for wind at Whitehorse. However, more detailed research using weather balloons show a clear increase in wind. This contradiction is likely explained by changes to the horizon as trees have grown up or been replaced by buildings. Both trees and buildings will break the wind and affect ground measurements of wind. At a range of elevations above sea level (from 1200 m to 2000 m) wind speeds have been increasing at a rate of +0.2 m/s per decade (Pinard 2007). At the same time, days have been getting less cloudy at a rate of 1% / decade but there is a lot of variability with cloudiness from one year to the next.

Generally the trends show good agreement with projections (with the possible exception of winter precipitation). Some of the trends appear to be outside the range of natural fluctuation and thus related to global climate change. However, we need to understand that natural influences are also present, mostly driven by the relationships to large scale ocean circulation patterns.

Table 4.1 Climatic Trends for the Whitehorse Region

Climate Variable	1961-1990	2000-2009	Rate of Change
Annual Temperature (°C)	-1.1 ± 1.2°C	0.0 ± 0.9°C	0.4°C /decade
Winter Temperature (°C)	-15.9 ± 4.5°C	-13.2 ± 2.5°C	0.9°C /decade
Annual Precipitation (mm)	268 ± 44mm	276 ± 46mm	1.6mm/decade
Summer Precipitation (mm)	109 ± 38mm	121 ± 33mm	2.3mm/decade
Annual Average flow (m^3/s)	244 ± 31 m^3/s	239 ± 30 m^3/s	0 m^3/s/decade
Growing Degree Days (5°C base)	991± 87 GDD	1062 ± 120 GDD	24 GDD/decade

4.2 Projected Climate Conditions for the Whitehorse Region (2041-2070)

65 maps were generated by SNAP to assess how climate change may affect the Whitehorse area. The climate projections anticipate a warmer Whitehorse which experiences increased precipitation. Projected climate conditions were based on two time cuts (2030 and 2050) and two standard IPCC scenarios (B1 and A1B)[13]. The B1 scenario projects moderate to low climate change over the next century. The A1B scenario anticipates medium to high climate change by 2100. These two scenarios were selected to provide a reasonable range in possible shifts in temperature and precipitation by 2050. A more detailed explanation for the projections and all 65 maps are provided in Appendix E. Details on the projected extension of the growing season based on changes to the seasonal freeze-up and thaw dates for Whitehorse are presented in the same appendix.

4.2.1 Temperature

Projected mean annual temperature and seasonal temperatures for the Whitehorse area were estimated for 2030 and 2050. Annual and seasonal baseline temperatures are compared to the projected temperatures in Table 4.2. The relative difference between the projected and baseline temperature is provided *in italics*. Projected increases indicate that warming will differ seasonally, and that winter period will experience the most significant warming – increasing 3.3°C to 5.4°C.

Table 4.2: Baseline and Projected Temperatures for the Whitehorse Area (°C)					
Season	Baseline (1961-1990)	Modest climate change		Medium-high climate change	
		2030	2050	2030	2050
Annual	-5.4	-3.3 *(+2.1)*	-2.9 *(+2.5)*	-3.5 *(+1.9)*	-1.7 *(+3.7)*
Spring	-5.1	-2.9 *(+2.2)*	-2.9 *(+2.2)*	-3.4 *(+1.7)*	-1.7 *(+3.4)*
Summer	10.3	11.5 *(+1.2)*	11.8 *(+1.5)*	11.1 *(+0.7)*	12.3 *(+1.9)*
Autumn	-5.9	-3.9 *(+2.0)*	-3.1 *(+2.8)*	-4.0 *(+1.9)*	-2.0 *(+3.9)*
Winter	-20.9	-18.0 *(+2.9)*	-17.6 *(+3.3)*	-17.6 *(+3.2)*	-15.5 *(+5.4)*

4.2.2 Precipitation

Mean annual precipitation was also projected for the Whitehorse area based on the 1961-1990 baseline (Table 4.3). Projected annual mean precipitation in the City of Whitehorse area is anticipated to increase from 585mm to 638 to 657mm by 2050.

Table 4.3: Baseline and Projected Precipitation for the Whitehorse Area (mm)					
Season	Baseline (1961-1990)	Modest climate change		Medium-high climate change	
		2030	2050	2030	2050
Annual	585	620	632	638	657
Spring	89	96	99	100	100
Summer	211	224	224	225	234
Autumn	170	178	183	186	192
Winter	115	121	123	128	131

Seasonal precipitation is expected to increase throughout the year, with the greatest increases occurring in the winter and fall. Winter precipitation is projected to increase between 11.3% and 13.9%, while autumn precipitation is projected to increase between 9.4% and 12.9%. Table 4.4 shows the same projected precipitation, but this time as a change compared to the 1961-1990 climate baseline.

Table 4.4: Projected Changes in Precipitation for the Whitehorse Region								
Season	Modest climate change (Increase from 1961-1990)				Medium-high climate change (Increase from 1961-1990)			
	2030		2050		2030		2050	
	mm	%	mm	%	mm	%	mm	%
Annual	35	5.9	47	8.0	53	9.1	72	12.3
Spring	7	7.9	10	11.2	11	12.4	11	12.4
Summer	13	6.2	13	6.2	14	6.6	23	10.9
Autumn	8	4.7	13	7.6	16	9.4	22	12.9
Winter	6	5.2	8	7.0	13	11.3	16	13.9

4.2.3 Growing Season

Based on the projected shifts in temperature and precipitation, the growing season[14] for Whitehorse is expected to increase in all projections; rising from 150 days to 168-175 days by 2050, an addition of 18-25 days. The growing season was estimated based on projected changes to seasonal freeze-up and thaw dates in the Whitehorse region.

The date of autumn freeze-up is anticipated to occur later in all projections; moving from late September into early/mid October. The freeze-up date in Yukon is therefore anticipated to occur 11-16 days later by 2050. Projected spring thaw dates are expected to occur earlier in the Whitehorse region. The thaw date in Yukon is projected to occur 8-12 days earlier by 2050.

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[13] As described in the IPCC *Special Report on Emissions Scenarios*

[14] The projected growing season provided for Whitehorse corresponds to the number of days between spring thaw and autumn freeze-up. The dates for spring thaw and autumn freeze up are defined by the time at which mean temperatures cross 0°C.

5.0 Climate Induced Vulnerabilities and Opportunities

It is evident that climate change will affect the community of Whitehorse. It is also evident that while some opportunities will emerge from climate change, the majority of the consequences of coming changes will be negative. The four community climate change scenarios developed with the community in the winter of 2009 indicate that even a moderate onset of climate change will influence Whitehorse[15]. In that scenario, climate change negatively affected infrastructure, increased the vulnerability of the community to forest fire and flooding and contributed to the overall decline of the local environment. The implications of this moderate scenario suggest that, regardless of the rate of and severity of climate change, the community must prepare to address – and therefore plan for – coming challenges.

Even in the modest climate change scenario, opportunities are also evident. These opportunities support sustainable development and economic diversification. As with the consequences, the presence of these opportunities indicate that the community of Whitehorse can benefit from climate change with sufficient preparation. However, given the number of consequences associated with climate change it may be challenging to focus on any potential benefits. There is a need to ensure that the community is aware of and prepared to take advantage of these potential benefits through the appropriate prioritization of vulnerabilities and opportunities.

Adaptive capacity is an integral component of an adaptation strategy. The adaptive capacity of a community refers to how prepared the community is to address the emerging consequences of climate change. The adaptive capacity of Whitehorse is made up of the institutional capacity of the community (Burch, 2010), its physical resources (Kelly and Adger, 2000), the availability of skills and education (Smit and Pilifosova, 2003), and its experience in addressing consequences[16] (Grothmann and Patt, 2005). The institutional capacity of the community refers to the ability of the local government, to coordinate responses and distribute resources (Burch, 2010). Where all of these factors are high, the community is resilient to the effects of climate change. Where one or more factors are low, the community is vulnerable to the effects of climate change and the risk to residents' increases.

The Whitehorse Adaptation Plan has prioritized vulnerabilities and opportunities using risk assessment. In order to assess risk, three factors were considered: likelihood, severity and the adaptive capacity of the community. The level of risk increases if the impact is likely to occur, if the severity of the impact is high and if the community does not have the resources or wherewithal to address emerging problems (i.e. the community adaptive capacity is low). To ensure opportunities were properly weighted, consequences that provided some benefit to the community were evaluated using a similar rationale. In the case of opportunities we evaluated the strength of the benefit associated with the consequence rather than its severity. The risk assessment for the WhiteCAP plan was carried out using a two tiered evaluation process.

The first tier drew on the knowledge of the Whitehorse technical and local advisory committees, who identified the priority sectors. In the second tier a more focused evaluation of individual consequences of climate change was completed by the project team. The results of both evaluations are provided in the following sections. Adaptations to high ranking risks are evaluated in Section 6.

5.1 Broad Sector Level Risk: Tier I Risk Assessment Results

Nine broad sectors vulnerable to climate change were apparent in the community based scenarios developed at the Community Input Session held in Whitehorse in January 2010. These sectors were: the local economy, environment, people and cultural resources, infrastructure, energy, natural hazards (especially fire and flood), food security (including agriculture), health and education. The broad risk associated with each sector was evaluated by the Whitehorse Technical and Local Advisory Committees at separate meetings in May and June 2010 respectively. The intention of the first tier risk assessment was to determine where the community was most vulnerable to climate change overall. By providing a relative ranking for likelihood, severity and adaptive capacity to each of the nine sectors identified in the community session, the sectors were prioritized into high, medium and low categories. The Whitehorse Technical and Local Advisory Committees independently produced a similar ranking of the sectors (Table 5.1).

Table 5.1: TAC and LAC Sector Tier I Risk Assessment Ranking

Sector	Sector Weighting			Ranking
	TAC	LAC	TAC + LAC	
Hazards	High	High	High	High
Infrastructure	High	High	High	High
Environment	Medium	High	Medium	Medium
Energy Security	Medium	Medium	Medium	Medium
Food Security	Low	High	Medium	Medium
Economy	Low	Medium	Low	Low
People	Low	Low	Low	Low
Health	Low	Low	Low	Low
Education	Low	Low	Low	Low

Figure 5.1 illustrates the relative ranking of each sector and emphasizes the range of risk associated with climate change.

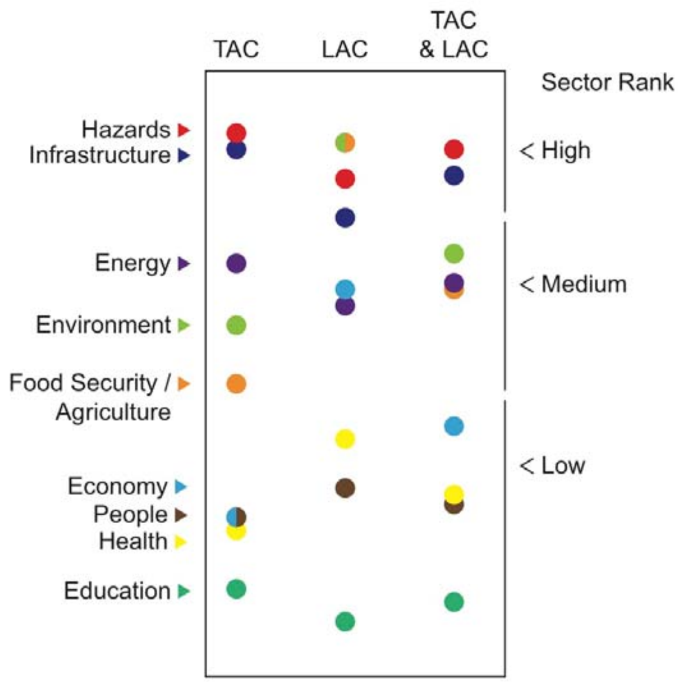

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Figure 5.1: Priority Scale of Tier I Risks

The combined evaluation of the Whitehorse Technical and Local Advisory Committees indicates that the greatest climate change risk for the community of Whitehorse lies with the hazards and infrastructure stress. A more moderate risk was associated by both committees with environmental decline, energy security and food security. A low level of risk was associated with economy, the influence of climate change on people and culture, health and education. These four sectors were therefore removed from consideration in the Tier II assessment due to the low level of risk from climate change. These sectors are reported on in full in the *Future Histories of Whitehorse: Scenarios of Change.* The remaining sectors are evaluated in detail in the following sections.

5.2 Community Based Consequences: Tier II Risk Assessment Results

In the second stage of the vulnerability assessment only the sectors ranked as high and medium were considered by the project team. Again, relative rankings of likelihood, level of impact and adaptive capacity were assessed, but this time on a consequence by consequence basis. Those sectors which were prioritized as high in the first stage tend to have more high ranking impacts. However, in every sector, there are impacts ranging from low to high.

5.2.1 Hazards

Hazards are characterized by climate influenced disturbances at the landscape scale such as landslides, forest fires, floods, etc. Increasing winter temperatures, increased variability in water availability and the more frequent occurrence of extreme weather events all increase the hazard risk for the community of Whitehorse.

Table 5.2.1
Community Consequences of Hazards

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
H.1	Community vulnerability to forest fire increases due to heavy fuel load, lighting, drought, wind, etc.	H	H	L	High
H.2	Increased risk of catastrophic fire	H	M	L	High
H.3	Egress from subdivisions becomes a problem during emergency situations	H	M	L	High
H.4	Possibility of regional beetle infestation leading to more dead stands and increased risk of forest fire	H	L	L	High
H.5	Community continues to not buy into FireSmart program	M	H	M	High
H.6	Heavy increase in rural residential leads to an accompanying increase in vulnerability	M	H	M	High
H.7	Increased risk of catastrophic flood and infrastructure failure (e.g. bridge)	H	L	M	High
H.8	Variable and/or increased snow, ice and wind compromises infrastructure	M	M	M	Medium
H.9	Concerns about freeze-thaw and road icing	L	H	H	Medium
H.10	Frequent fires outside City limits leads to health issues and problems with air quality	L	L	M	Medium
H.11	Slope instability as a result of rain and warming (e.g. escarpment)	M	L	M	Low
H.12	Variable rain and growth lead to issues of leaching and seepage	M	L	H	Low

5.2.2 Infrastructure

Climate change increases the risk to linear and non-linear infrastructure in Whitehorse. Non-linear infrastructure includes buildings, foundations structures while linear infrastructure is the community's powerlines, roadways, storm and sewer systems, etc. Climate induced vulnerability is generated by an increased risk of hazards, as well as increased temperature fluctuations, frost heaves, windthrow, and severe weather.

Table 5.2.2
Community Consequences Associated with Infrastructure

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
I.1	Increased incidence of damage to powerlines from windthrown trees, etc.	H	H	H	High
I.2	Increase in multipliers - roads affect access which affects safety, etc.	H	M	M	High
I.3	Increased rate of leaching from unlined dump - hazardous waste requires special consideration	M	M	L	High
I.4	General strain on infrastructure as the result of age and pressure from growth and climate change	M	H	H	High
I.5	Increased cost to maintain roads due to shifting landscape conditions (erosion)	M	H	M	High
I.6	Integrity of spillways and dams declines	H	L	L	High
I.7	Stormwater requires treatment, levels exceed current capacity	M	M	M	Medium
I.8	Climate change (freeze-thaw, erosion, etc) affects road safety and infrastructure	L	H	M	Medium
I.9	Highway washouts related to increased storms and flooding (threatens food security)	M	L	M	Medium
I.10	Impact of roofs, roads and other linear structures through variable / increasing snow load	M	H	H	Medium
I.11	Sewage lagoon system may be stressed due to population and precipitation increases	M	M	H	Medium
I.12	Growth of green infrastructure not possible	M	L	L	Medium
I.13	Structural strain on bridge abutments as glacial flow increases river levels	H	L	M	Medium
I.14	Changes in energy type and use will likely require new and/or upgraded infrastructure	L	M	M	Medium
I.15	Increased stress on culverts due to precipitation	L	M	H	Low

5.2.3 Environment

Community vulnerability from climate induced environment stresses in the Whitehorse region stems from an increasing presence of damaging invasive species, changes to the quality / productivity of the environment and increasing pressure on local wildlife. The resulting risk to the community is characterized by declining water quality, shifting landscape conditions and a changing community relationship to the environment.

Table 5.2.3
Community Consequences of Environmental Decline

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
EV.1	Evapotranspiration and groundwater recharge are critical and still uncertain	H	H	L	High
EV.2	Introduction of pests/invasive species	M	H	L	High
EV.3	Concern about change to water quality and increasing demand	H	M	M	High
EV.4	Warming water combined with decreased groundwater leads to loss of fish habitat	M	M	L	Medium
EV.5	Wildlife pressures from climate change, fragmentation, hunting and competing land use	M	H	H	Medium
EV.6	Ecosystem stability declines; habitat shift occurs	M	L	L	Medium
EV.7	Watersheds, forests, wetlands will experience change as we grow at the same time	M	M	L	Medium
EV.8	Information cannot be generated/communicated fast enough to keep pace with changes	L	H	M	Medium
EV.9	Increased nutrification of water with warming - affecting water quality - (pressure from agriculture)	L	L	M	Low
EV.10	Increased commodification and increase in the value of water	L	L	H	Low
EV.11	Increased population stresses river and lakes from increased recreation pressure and development	L	M	H	Low
EV.12	Concern about air quality if we increase industry, wood -fires and if inversions should occur	L	L	H	Low

5.2.4 Food Security

Food security refers to a community's access to sufficient, safe and nutritious food to meet their dietary needs and food preference for an active and healthy life (Paci et al, 2004). While food security encompasses economic access, the risks associated with food security in Whitehorse are tied to a reduction in the physical presence of sufficient healthy food within the community due to negative climate-induced impacts.

Table 5.2.4
Community Consequences of Decreased Food Security

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
F.1	Increased incidence of drought places more reliance on groundwater, problems with irrigation arise	H	M	M	High
F.2	Decrease in First Nations ability to harvest traditional foods, leading to loss of culture and health issues	M	M	M	Medium
F.3	The cultivation of food leads to introduction of invasive species and disease	M	M	L	Medium
F.4	Endemic pest and diseases affects food security and health	M	M	H	Medium
F.5	External food supply is diminished as transportation becomes less reliable	H	L	H	Medium
F.6	Conflict emerges over the balance of land use, water use, water availability and soil suitability	L	H	M	Medium
F.7	Contamination increases due to increased use of fertilizers and other pollutants	M	L	H	Low
F.8	Concerns arise of historic land dispositions for agriculture	L	M	H	Low
F.9	Supermarkets compete with local producers as a by-product of scaling issues	L	L	H	Low

5.2.5 Energy Security

Energy security is indicative of the community's access to reliable sources of energy sufficient to meet its needs. The energy security of the Whitehorse community may be negatively affected by climate impacts which reduce the efficiency of existing sources of energy or the feasibility of future (renewable or sustainable) sources of energy.

Table 5.2.5
Community Consequences of Decreased Energy Security

	Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
ES.1	Energy sector increasingly vulnerable to external forces (rising energy costs, expected carbon costs)	M	H	M	High
ES.2	Energy future is uncertain; compounded by the lack of a Whitehorse energy strategy	M	M	H	Medium
ES.3	Land use conflicts arise over future alternative energy projects (e.g. windfarms)	M	L	H	Low
ES.4	Variability in cloudiness may affect consistency of passive and active solar	L	L	H	Low

5.3 Opportunities

Climate related opportunities were evident in many of the sectors evaluated in the Tier II risk assessment. These opportunities were prioritized by evaluating the benefits, the likelihood of the consequence emerging from shifting climate conditions, and how prepared the community is to profit from the consequence. Additional opportunities are evident in the sectors ranked as having a low risk in the Tier I assessment. These opportunities are reported in the *Future Histories of Whitehorse: Scenarios for Change.*

Table 5.3
Community Climate Change Opportunities

	Sector / Consequences	Level of Impact	Likelihood	Adaptive Capacity	Priority
O.1	*Food Security* Longer growing season, likely an opportunity for agriculture	H	M	M	High
O.2	*Infrastructure* Increased need for Whitehorse to serve as a hub - infrastructure expansion	H	M	M	High
O.3	*Food Security* Whitehorse emerges as a hub, supplying food to outlying communities through local agriculture	H	L	L	High
O.4	*Energy Security* Gas pipeline mega-project may bring energy opportunity	H	L	L	High
O.5	*Food Security* Increased yields but concerns about variable precipitation	M	M	M	Medium
O.6	*Energy Security* Warmer winters reduce heating load (e.g. +2°C in winter = 5-10% reduction in heating costs)	L	H	H	Medium

[15] See “Scenario 1: City of Wilderness” in *Future Histories of Whitehorse: Scenarios of Change*

[16] As interpreted within the context of an individual’s perception of the risk associated with the impact.

6.0 Climate Change Adaptation and Whitehorse

The Tier II assessment of climate change risks highlights the broad nature of climate change vulnerability as perceived by the community of Whitehorse. High priority risks exist in all of the evaluated sectors (hazards, infrastructure, environment, food security and energy security) and many of these risks are interconnected. Adapting to climate change in the Whitehorse region will therefore require the community to address sweeping concerns of an interdisciplinary nature with varying capacity to do so.

Climate change adaptations for the community of Whitehorse were first suggested by participants at the community input session in January 2010. The list of adaptations compiled from our consultation with the community is not necessarily exhaustive and additional adaptations exist that have not been noted here. As with the identification of consequences, discussions of adaptations were rooted in local knowledge. All adaptations suggested by the community are provided in the *Future Histories of Whitehorse*. In this section the project team has evaluated those adaptations suggested by the community to respond to higher priority risks. The evaluation was intended to ensure that existing capacity in the community was enhanced.

6.1 Community Adaptations to High Risk Consequences of Climate Change

Leveraging adaptive capacity requires that community resources be applied to those actions that best address identified risks. A summary of the sector risk is provided at the beginning of each subsection. Only those adaptations that address high risk consequences were evaluated. Each adaptation was assessed to determine how well it addresses the impacts (fit), how well it benefits the broader community (win-win) and whether it builds adaptive capacity.

Fit is a measure of how well an adaptation responds to climate change impacts, both in number and priority. To evaluate if an adaptation has a good fit, the project team considered:

- How many impacts does the adaptation improve and what is their priority?
- How well does the adaptation address the range of impacts
- How well does the adaptation integrate with other adaptation strategies?
- Is the cost of the adaptation acceptable?

Win-win actions are those adaptations that provide other benefits to the community in addition to climate change (Snover et al, 2007). To assess if an adaptation was win-win, the project team considered:

- Is the adaptation also mitigative?
- How well does the adaptation integrate with other existing planning processes?
- Will the action decrease the risk of losing unique environmental or cultural resources?
- Will the adaptation increase scientific confidence?

The project team also determined the extent to which the adaptation would develop community adaptive capacity. To ensure that a positive contribution was made to capacity development, we discussed:

- Is the adaptation equitable?

- Does the adaptation enhance the resources (financial, physical, knowledge) available for action?
- Does the adaptation enhance or build partnerships?
- Does the action increase the community's resilience?

6.1.1 Hazards

Hazards are expected to be exacerbated by climate change in the Whitehorse region. Challenges for which the community is currently poorly prepared include increases to local forest fire risk, flood risk and the impact of snow, ice and wind on vulnerable infrastructure. Even a modest increase in forest fire risk is anticipated to negatively affect the community.

Table 6.1.1
Suggested Adaptations for Hazards

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Incorporate fire considerations in all subdivision planning and zoning (such as no dead ends, fire breaks, aspen plantings, access to water and other holistic planning issues)	H.1 - 4 H.6	H	M	M	Medium
Increase densification of City to reduce vulnerability to hazards	H.2	L	M	L	Low
Pass consequences of climate change on to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure	All H's	H	H	H	High
Integrate climate change risk and impact into emergency planning	All H's	H	H	H	High
Allow fire department greater latitude for proactive responses	H.1 - 4	H	L	H	Medium
Incorporate climate into infrastructure development currently in planning stages	H.1 H.2 H.6 - 8	H	M	H	High
Consider fuel abatement and fuel mitigation (produces biomass)	H.1 H.2 H.4	M	M	L	Medium
Require a second strategy for community based disaster response, equates to a residential fire strategy	H.1 - 4 H.6	H	H	H	High
Enhance building codes: Consider biomass heating to maintain air quality and reduce the risk structural fire	H.8	L	H	M	Medium
Continue education around responsible fire safety	H.1	H	M	H	High

Table 6.1.1
Suggested Adaptations for Hazards

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
	H.2 H.5				
Create a strategy for harvesting salvage wood, such as from insect damage, as both an opportunity and a control measure	H.4	L	L	L	Low
Ensure fire safety is incorporated into residential planning: for example, densification can be buffered better than rural residential development	H.1 - 3	L	M	M	Medium
FireSmart vulnerable infrastructure	All H's	H	H	H	High
Create zoning that reflects potential future changes in the landscape	All H's	H	H	H	High
Climate change education and training for safety sector	All H's	H	M	H	High
Ensure critical buildings have back-up power for lighting/heating in case of emergencies	H.2 H.6	M	M	L	Medium
Maintain green spaces and/or strategic agriculture to reduce fire risk	H.1 H.2	L	M	M	Medium
Investigate and assess catastrophic flood scenarios	H.7	M	H	H	High
Encourage/support redundant emergency systems on both sides of the river (to prepare against loss of bridge)	H.7	L	M	H	Medium

6.1.2 Infrastructure

Even a modest onset of climate change is anticipated to negatively affect the linear infrastructure of Whitehorse, such as roads and powerlines. Risks to linear infrastructure stem from variable weather and wind (powerlines and roads) or erosion and landslides (roads). Risks to linear infrastructure from climate change are anticipated to compound existing stresses, exacerbating the cost of maintenance and creating secondary risks for the community as the influence of multipliers increases. Climate change is also anticipated to increase the risk of leaching from the Whitehorse dump. Spillways and dams are also perceived to be at a slightly higher risk from a catastrophic flood.

Table 6.1.2
Suggested Adaptations for Infrastructure

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Establish a budget for dealing with climate change impacts: for example roads and road clearing	I.2 I.4 I.5	H	M	H	High
Use multiyear funding to accommodate climate variability	I.2 I.4 I.5	H	M	H	High
Recommend development densification to allow for greater cost sharing of infrastructure	I.4 I.5	M	H	M	Medium
Educate the public to set a fair expectation for quality of service	All	H	H	M	High
Reduce downtown vehicle traffic and pressure on roads through densification, mixed use zoning and better transit	I.4 I.5	M	H	H	Medium
Need to identify critical thresholds, responsibilities and partnerships	All I's	H	H	H	High
Look into feasibility of micro-hydro	I.6	L	L	M	Low
Increase available warehousing (links to food storage)	I.4	M	M	H	High
Expand active road monitoring stations in problem areas (roads and infrastructure)	I.5	M	M	M	Medium
Explore feasibility of automatic de-icing at problem intersections	I.2	M	L	L	Low
Source-separation of untreatable garbage to reduce leaching	I.3	H	M	H	High
Increase storm water retention within the city – allow for on site-disposal (for example, create porous parking lots)	I.6	L	M	L	Low
Create a hazardous materials transfer station	I.3	H	M	M	Medium

Table 6.1.2
Suggested Adaptations for Infrastructure

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Assess dependence of Whitehorse to highway and vulnerability of highway to climate change outside city limits	I.4	H	H	H	High
Assess storm drainage capacity/capability and design for extreme in future climate change projections when being replaced through maintenance schedules	I.6	L	M	H	Medium
Ensure standards and regulations are “living” so they are changes as we get more information	All I’s	H	H	H	High
Have flexible zoning (beyond the downtown core) to allow for densification increases in areas of the City	I.2 I.4 I.5	H	M	M	Medium
Design neighbourhoods outside the downtown core to have services	I.1	M	L	M	Medium
Regional planning and all relevant planning needs to be revisited regularly	All I’s	H	M	H	High
Redesign buildings if there are problems down the road, such as retrofitting insulation, etc.	I.4	L	M	M	Medium
Use buildings as carbon sinks and/or use waste materials for insulation	I.2 I.4	L	L	M	Low
Incorporate waste/local materials in building design/construction to create more affordable housing	I.2	L	L	M	Low
Generate standards/best practices for subdivision development for climate change	I.1	H	M	H	High
Promote education and training to compensate for increased snow loads	I.4 I.5	M	M	H	Medium
Look at technologies that can help us prepare for changes down the road and implement them now	All I’s	H	H	H	Medium
Create a strategy to move forward as demand for waste management constrains flexibility	I.6	H	H	H	High
Create a strategy to compensate for capacity issues as people and expertise are strained by changing climate conditions	All I’s	H	H	H	High

6.1.3 Environment

Risk to the environment of Whitehorse from climate change is characterized by shifts in the rate of evapotranspiration, the introduction of invasive species and pressure on water quality. Impacts on local water quality due to infrastructure decline were a risk identified by the community. These infrastructure risks do overlap with environmental risks to water quality, the adaptations correlating to these infrastructure risks are reported in section 6.1.2. It is important to note the cross-sector nature of some adaptations.

Table 6.1.3
Suggested Adaptations for Environment

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Give teeth to greenspaces plan (build resilience to climate change)	EV.1	M	H	H	High
Need to reassess situation and values over time while planning for change now	All EV's	H	H	H	High
Evapotranspiration and groundwater recharge are critical and uncertain, therefore we need to retain capacity and expertise in these areas	EV.1	H	H	H	High
Integrate life-cycle management into decisions: for example, water life-cycle includes how water passes through the human built world	EV.3	M	L	M	Medium
Create and implement a groundwater management plan	EV.1 EV.3	H	M	H	High
Monitor water quality and quantity, fish, wildlife and other indicators	All EV's	H	H	H	High
Increase our use of greywater for other purposes (toilets, plants, etc.)	EV.3	L	L	M	Low
Create an education program around water conservation	EV.3	H	M	H	High
Continue to look at water conservation – avoid shipping water out of the Territory	EV.3	L	L	L	Low
Look into a strategy to enforce the protection of riparian buffers	EV.3	H	M	H	High
Make any sale of water taxable so the community benefits	EV.3	M	L	H	Medium
Gather and collect local observations/data conclusions, both scientific and traditional	All EV's	H	M	H	High
Restore weather stations	All EV's	H	H	H	High
Set aside funding to monitor fish, wildlife and the environment	All EV's	H	M	H	High

Table 6.1.3
Suggested Adaptations for Environment

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Divert additional environmental protection funds to Territorial and First Nations governments	All EV's	H	M	H	High
Train (and pay) local people for monitoring	All EV's	H	H	H	High
Take advantage of digital technologies to gather, store, and share information – this information hub must consider the abilities of the people who need access to it	All EV's	H	M	H	High
Look at other areas with similar biophysical characteristics to predict what changes may occur and how to address them	All EV's	M	L	M	Medium
Aquifer monitoring	EV.1	M	M	H	Medium

6.1.4 Food Security

Priority climate change risks to food security were associated with an over reliance on groundwater due to an increased incidence of drought.

Table 6.1.4
Suggested Adaptations for Food Security

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Choose crops that conserve water or are not water intensive	F.1	H	L	H	Medium
Encourage small community plots	F.1	M	M	H	High
Investigate new and innovative ways to grow food	F.1	H	H	H	High
Increase animal husbandry in the region	F.1	L	M	M	Medium
Create policies to encourage the use of greywater for agriculture purposes	F.1	H	L	M	Medium
Increase irrigation infrastructure in region	F.1	M	L	M	Low

6.1.5 Energy Security

The energy sector may be increasingly vulnerable to external forces including rising energy costs and a future cost tied to carbon emissions. These risks may limit the availability of energy to the Whitehorse community over time.

Table 6.1.5
Suggested Adaptations for Energy Security

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Create an energy plan for Whitehorse (including comprehensive energy management)	ES.1	M	H	H	High
Respond to the need for energy storage (even in homes)	ES.1	M	L	M	Low
Promote seasonal energy uses: e.g. greenhouses	ES.1	H	H	H	High
Continue to investigate the feasibility of district heating	ES.1	M	M	H	Medium
Push for super-green construction to reduce heat demands	ES.1	M	H	H	High
Take advantage of benefits if pipeline comes (will not be cost effective at our current economy of scale)	ES.1	L	M	L	Low

6.2 Adaptations to Support Opportunities

Climate change adaptation is also necessary to ensure that the community of Whitehorse is strategically prepared to benefit from climate change opportunities. The following adaptations were suggested by the community to support opportunities as they arise.

Table 6.1.2
Suggested Adaptations to Support Opportunities

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Re-open the railway corridor and repair the old link into the downtown	O.2	L	L	M	Low
Install communication infrastructure to facilitate people working from home	O.2	M	L	H	Medium
Revisit Skagway as a transportation node	O.2	L	L	L	Low
Increase available warehousing (links to food storage)	O.1 O.3	H	M	H	High
Learn from other circumpolar countries	O.2	H	M	H	High
Create a hazardous materials transfer station	O.2	H	M	M	Medium
Support recycling as a growth industry	O.2	H	M	H	High
Create a strategy to capitalize on the potential increased need for Whitehorse to serve as a hub – incorporate trickle down effect to communities (if Whitehorse cannot supply them then others are vulnerable).	O.1 - 3	H	L	M	Medium
Create an energy plan for Whitehorse (including comprehensive energy management)	O.4 O.6	H	H	H	High
Examine the feasibility of any benefits associated with the gas pipeline	O.4	M	M	M	Medium
Push for super-green construction to reduce heating demands	O.6	H	M	H	High
Choose crops that conserve water or are not water intensive	O.5	H	L	H	Medium
Use agriculture to build soil	O.1	M	M	H	Medium
Explore urban gardening and community greenhouse opportunities	O.1 O.3	H	M	H	High

Table 6.1.2
Suggested Adaptations to Support Opportunities

Adaptations	Addresses	Fit	Win-win	Community Capacity	Priority
Continue to expand on education opportunities for regional agriculture	O.1 O.5 O.6	H	M	H	High
Investigate improving efficiency of food transportation	O.3	L	L	H	Medium
Place a moratorium on subdividing agriculture land	O.1	M	L	M	Medium
Investigate new and innovative ways to grow food	O.1	M	H	H	High
Create food security plans that address poverty and the sharing of food	O.1 O.3	H	M	H	High
Increase animal husbandry and the number of fish farms in the region	O.1	L	L	H	Medium
Provide a support structure for community gardens so food can be sold	O.1 O.3	H	M	M	Medium
Make a portable abattoir available in Whitehorse	O.1 O.3	L	L	H	Low
Create policies to encourage the use of greywater for agriculture purposes	O.1	H	M	L	Medium
Create and implement a Whitehorse/Territory-wide food security plan	O.1 O.3	H	M	H	High
Zone more agriculture land	O.1	L	L	M	Low
Build processing facilities and cold storage	O.1 O.3 O.5	H	H	H	High
Share knowledge of food growth between First Nations and science	O.1 O.3	H	M	H	High

7.0 Next Steps

Of the 245 adaptations suggested by the community, 49 are recommended as having a high priority. These adaptations are presented in Table 7.1 along with suggested partners to assist the community with building their adaptive capacity. While partnerships between many levels of governments and institutions will be more effective when implementing adaptations, lead partners have been identified as those best in a position to assist the community. Where community level response is proactive and necessary, the suggested partner has been designated as “community groups” in anticipation of volunteer action or actions by community members. This includes the actions of local businesses and individuals.

It should be noted that the recommended adaptations are based on an evaluation of community capacity only. The capacity of suggested partners has not been evaluated as a component of this study. The capacity of identified partners to implement the adaptation may therefore also be low.

Table 7.1
Recommended Climate Change Adaptations for the Community of Whitehorse

Hazards Adaptations	Lead Partner
Pass consequences of climate change on to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure	Yukon College
Integrate climate change risk and impact into emergency planning	Yukon Government, City of Whitehorse
Incorporate climate into infrastructure development currently in planning stages	City of Whitehorse, Ta’an Kwäch’än Council, Kwanlin Dün First Nation
Require a second strategy for community based disaster response, equates to a residential fire strategy	City of Whitehorse
Continue education around responsible fire safety	City of Whitehorse, Ta’an Kwäch’än Council, Kwanlin Dün First Nation
FireSmart vulnerable infrastructure	City of Whitehorse, Ta’an Kwäch’än Council, Kwanlin Dün First Nation
Create zoning that reflects potential future changes in the landscape	Yukon Land-Use Planning Council
Climate change education and training for safety sector	Yukon Government, City of Whitehorse
Investigate and assess catastrophic flood scenarios	Yukon Government

Table 7.1
Recommended Climate Change Adaptations for the Community of Whitehorse

Infrastructure Adaptations	Lead Partner
Establish a budget for dealing with climate change impacts: for example roads and road clearing	Government of Canada, Yukon Government, City of Whitehorse
Use multiyear funding to accommodate climate variability	Government of Canada, Yukon Government, City of Whitehorse
Educate the public to set a fair expectation for quality of service	Community Groups
Need to identify critical thresholds, responsibilities and partnerships	Yukon Government, City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Increase available warehousing (links to food storage)	Community Groups
Source-separation of untreatable garbage to reduce leaching	Yukon Government, City of Whitehorse
Assess dependence of Whitehorse to highway and vulnerability of highway to climate change outside city limits	Yukon Government
Ensure standards and regulations are "living" so they are changes as we get more information	Government of Canada, Yukon Government, City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Regional planning and all relevant planning needs to be revisited regularly	Yukon Government, City of Whitehorse
Generate standards/best practices for subdivision development for climate change, energy, forest fire, wind breaks, etc.	Yukon Government
Create a strategy to move forward as demand for waste management constrains flexibility	Yukon Government, City of Whitehorse
Create a strategy to compensate for capacity issues as people and expertise are strained by changing climate conditions	Yukon Government
Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships	Yukon Government, City of Whitehorse
Communicate with partners and government departments with regard to concerns and opportunities identified within this exercise to inform their respective planning processes	Yukon Government, Yukon College

Table 7.1
Recommended Climate Change Adaptations for the Community of Whitehorse

Environment Adaptations	Lead Partner
Give teeth to greenspaces plan (build resilience to climate change)	City of Whitehorse
Need to reassess situation and values over time while planning for change now	City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation, Council for Yukon First Nations
Evapotranspiration and groundwater recharge are critical and uncertain, therefore we need to retain capacity and expertise in these areas	Yukon College, City of Whitehorse, Yukon Government
Create and implement a groundwater management plan	City of Whitehorse
Monitor water quality and quantity, fish, wildlife and other indicators	Yukon College, Yukon Government
Create an education program around water conservation	Community Groups, Yukon College
Look into a strategy to enforce the protection of riparian buffers	Government of Canada, Yukon Government, City of Whitehorse
Gather and collect local observations/data conclusions, both scientific and traditional	Community Groups, Yukon College, Council of Yukon First Nations, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Restore weather stations	Government of Canada
Set aside funding to monitor fish, wildlife and the environment	Government of Canada, Yukon Government
Divert additional environmental protection funds to Territorial and First Nations governments	Government of Canada
Train (and pay) local people for monitoring	Government of Canada, Yukon Government
Take advantage of digital technologies to gather, store, and share information – this information hub must consider the abilities of the people who need access to it	Yukon Government, Yukon College, Council of Yukon First Nations

Table 7.1
Recommended Climate Change Adaptations for the Community of Whitehorse

Food Security Adaptations	Lead Partner
Encourage small community plots	City of Whitehorse
Investigate new and innovative ways to grow food	Community Groups, City of Whitehorse, Yukon College
Energy Security Adaptations	
Create an energy plan for Whitehorse (including comprehensive energy management)	City of Whitehorse
Promote seasonal energy uses: e.g. greenhouses	Community Groups
Push for super-green construction to reduce heat demands	Yukon Government, City of Whitehorse
Opportunities	
Learn from other circumpolar countries	Community Groups, Council of Yukon First Nations, Yukon College
Support recycling as a growth industry	Yukon Government, City of Whitehorse
Explore urban gardening and community greenhouse opportunities	Community Groups, City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Continue to expand on education opportunities for regional agriculture	Community Groups
Create food security plans that address poverty and the sharing of food	Community Groups, Government of Canada, Yukon Government, City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Create and implement a Whitehorse /Territory wide food security plan	Yukon Government
Build processing facilities and cold storage	City of Whitehorse, Ta'an Kwäch'än Council, Kwanlin Dün First Nation
Share knowledge of food growth between First Nations and science	Yukon Government, Ta'an Kwäch'än Council, Kwanlin Dün First Nation

A timeline for implementation will be developed with the Whitehorse Local Advisory Committee based on their knowledge of the community and their vision for a community resilient to climate change. That timeline will be presented in subsequent drafts of the plan.

7.1 Mainstreaming

Mainstreaming climate change is the integration of climate change into standard planning practices. Ongoing processes into which adaptations can be integrated include land-use/local area planning (e.g. City of Whitehorse Official Community Plan), sustainability planning, emergency response planning and infrastructure planning. A number of adaptations have also been recommended to address the lack of data available to inform future decisions. Adaptations for increased monitoring and data collection have been gathered under the heading of "future research" and should be integrated into the Yukon's research agenda where possible.

Land-use / Local Area Planning

- Forward consequences of climate change to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure
- Create zoning that reflects potential future changes in the landscape
- Identify critical thresholds, responsibilities and partnerships
- Revisit regional planning and all other relevant planning regularly
- Generate standards/best practices for subdivision development for climate change, energy, forest fire, wind breaks, etc.
- Empower greenspaces plan (build resilience to climate change)
- Reassess situation and values over time while planning for change now
- Look into a strategy to enforce the protection of riparian buffers
- Encourage small community plots

Sustainability Planning

- Create a strategy to move forward as demand for waste management constrains flexibility
- Separate untreatable garbage at source to reduce leaching
- Create a strategy to compensate for capacity issues as people and expertise are strained by changing climate conditions
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Create and implement a groundwater management plan
- Look into a strategy to enforce the protection of riparian buffers
- Encourage small community plots
- Investigate new and innovative ways to grow food
- Create an energy plan for Whitehorse (including comprehensive energy management)
- Promote seasonal energy uses: e.g. greenhouses
- Push for super-green construction to reduce heat demands
- Support recycling as a growth industry
- Explore urban gardening and community greenhouse opportunities
- Continue to expand on education opportunities for regional agriculture
- Build processing facilities and cold storage
- Share knowledge of food growth between First Nations and science

Emergency Response Planning
- Integrate climate change risk and impact into emergency planning
- Require a second strategy for community based disaster response (equivalent to a residential fire strategy)
- Continue education around responsible fire safety
- FireSmart vulnerable infrastructure
- Educate and train safety sector on climate change
- Investigate and assess catastrophic flood scenarios

Infrastructure Planning
- Pass consequences of climate change on to other decision making groups involved in planning, design, engineering and establishing standards for subdivision development, road construction and infrastructure
- Incorporate climate change and variability into infrastructure development currently in planning stages
- Investigate and assess catastrophic flood scenarios
- Establish a budget for dealing with climate change impacts: for example roads and road clearing
- Separate untreatable garbage at source to reduce leaching
- Assess dependence of Whitehorse to highway and vulnerability of highway to climate change outside city limits
- Generate standards/best practices for subdivision development for climate change, energy, forest fire, wind breaks, etc.
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Build processing facilities and cold storage

Future Research
- Investigate and assess catastrophic flood scenarios
- Increase research and monitoring of infrastructure in order to identify critical thresholds, cost benefits, responsibilities and partnerships
- Retain capacity and expertise on evapotranspiration and groundwater recharge, since they are critical and uncertain
- Monitor water quality and quantity, fish, wildlife and other indicators
- Gather and collect local observations/data conclusions, both scientific and traditional
- Restore weather stations
- Set aside funding to monitor fish, wildlife and the environment
- Train (and pay) local people for monitoring
- Take advantage of digital technologies to gather, store, and share information – this information hub must consider the abilities of the people who need access to it

7.2 Implementation

The Northern Strategy Trust Fund has provided $120,000.00 for the implementation of the adaptation plan in the second year of the Whitehorse Adaptation Project. In the fall of 2010, the Whitehorse Local Advisory Committee will select projects for implementation through a proposal uptake. All proposed projects will be interpreted from the recommendations of this plan. Projects will be selected by the Whitehorse Local Advisory Committee under the purview of Yukon College according to established terms of reference.

The terms of reference for implementation projects was established by the Whitehorse Local Advisory Committee in summer 2010. The committee agreed that a number of projects will be funded and that per project funding would range from $10,000 to $50,000. Funding will be awarded to proposals which best meet the necessary requirements. These requirements include priority of consequence addressed, fit with the overall adaptation strategy, the cost effectiveness of the project, and the perceived benefits of the project. Projects will be evaluated by the Whitehorse Local Advisory Committee based on the following criteria:

1. Priority (5 points)
What is the likelihood of the impact(s) that the adaptation will address?
What is the severity of the impact(s) that the adaptation will address?
What level of capacity do we already have to deal with the impact(s)?

2. Fit (5 points)
How many impacts does the adaptation improve?
How well does the adaptation integrate with other adaptation strategies?
How well does the adaptation integrate with other existing planning processes?

3. Cost (5 points)
What is the cost of the adaptation?
What is the likelihood of success (how feasible is the adaptation)?
What are the risks of failure?

4. Benefit (5 points)
Does the adaptation contribute to sustainability (does it also mitigate climate change)?
What are any co-benefits (capacity, knowledge, resilience and / or partnerships)?
How will the project move us forward with adapting to climate change?

Proponents will be provided with the draft adaptation plan, the project vision, the terms of reference and a submission template in the fall of 2011. Projects will be implemented from October 2010 to June 2011 under the supervision of the Whitehorse Local Adaptation Coordinator. A full implementation report will be provided at the conclusion of the implementation period in the summer of 2011.

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WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

APPENDIX A:
GLOSSARY OF TERMS

Glossary of Terms

Adaptation is the ability of a system to adjust to climate change, either to moderate potential damages, to take advantage of opportunities, or to cope with the consequences of climate change (IPCC, 2007a).

Adaptive Capacity is the ability of a system to adjust to climate change, either to moderate potential damages, to take advantage of opportunities, or to cope with consequences (IPCC, 2007a).

Evapotranspiration is the amount of water returned to the atmosphere from the combination of evaporation and transpiration (the passage of moisture through the surface of plant leaves) (SNAP, 2009).

Greenhouse Gases are sources of carbon dioxide emitted by humans that contribute to global warming and include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6), hydrochlorofluorocarbons (HCFCs), chlorofluorocarbons (CFCs), the aerosol precursor and the chemically active gases sulphur dioxide (SO_2), carbon monoxide (CO), nitrous oxides (NO_X) and non-methane volatile organic compounds (NMVOCs) (Nebojša et al, 2000).

Mitigation is an action intended to reduce the onset and severity of climate change and includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks (IPCC, 2007a).

No regrets actions refer to those adaptations that provide benefits to the community in current and future climate conditions, even if no climate change occurs (Snover et al, 2007).

Resilience is the capability of a system to maintain its function and structure in the face of internal and external change and to degrade gracefully when it must (Allenby and Fink, 2005: 1034).

Risk Management is the systematic application of management policies, procedures and practices to the tasks of analyzing, evaluating, controlling and communicating the possibility of injury or loss due to an adverse effect to health, property, the environment or other things of value (CSA, 1997).

Scenarios are an internally consistent view of what the future might turn out to be (Porter, 1985).

Scenario Planning is a strategic planning tool for medium to long-term planning under uncertain conditions involving the assessment of multiple futures (Lindgren and Bandhold, 2003).

Susceptibility is the degree to which a community is exposed to hazards (WHO, 1999).

Win-win actions reduce the impacts of climate change while providing other environmental, social or economic benefits (Snover, et al, 2007).

WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

APPENDIX B: LIST OF ACRONYMS

List of Acronyms

CASM	Council and Senior Management (City of Whitehorse)
CCCAP	Community Climate Change Adaptation Project
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
COW	City of Whitehorse
CYFN	Council of Yukon First Nations
GHG	Greenhouse Gases
GCM	Global Climate Model
IPCC	Intergovernmental Panel on Climate Change
MAT	Mean Annual Temperature
NCE	Northern Climate ExChange
SNAP	Scenarios Network for Alaska Planning
WPYR	White Pass and Yukon Route

WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

APPENDIX C: WHITEHORSE ADAPTATION PROJECT COMMITTEE MEMBERS

Whitehorse Adaptation Project Committee Members

Whitehorse Local Advisory Committee Membership

Members	Affiliation
Shannon Clohosey	Sustainability Office: City of Whitehorse
Clive Sparks	Fire Department: City of Whitehorse
Simon LaPointe	Department of Lands: Ta'an Kwäch'än
John Miekle	Department of Lands and Policy: Kwanlin Dün
Dan Boyd	Consumer Services and Infrastructure Development: Yukon Government
Lewis Rifkind	Yukon Conservation Society
John Streicker	Whitehorse Local Adaptation Coordinator: Northern Climate ExChange

Whitehorse Technical Advisory Committee Membership

Members	Affiliation
Lacia Kinnear	Coordinator, Northern Climate ExChange
Robin Sydneysmith	PhD Sociology, University of British Columbia
Paul Kischuk	Principle, Vector Consulting
Frank Duerden	Professor Emeritus, Department of Geography, Ryerson University
Paul Murchison	Project Engineer, Department of Highways and Public Works, Yukon Government
Ric Janowicz	Manager, Hydrology Section, Department of Environment, Yukon Government
Ralph Matthews	PhD Sociology, University of British Columbia

WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

APPENDIX D:
A HISTORY OF ENVIRONMENTAL STRESSES IN WHITEHORSE: 1930-2009

A History of Environmental Stresses in Whitehorse: 1930-2009

Prepared to Support the
Whitehorse Climate Change Adaptation Project (WhiteCAP)
31 December 2009

Karine Grenier and Meghan Larivee

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1.0 Introduction

The term climate change refers to a significant change in the variability or average state of the climate (IPCC). Adaptive capacity as it relates to climate change is the ability or potential ability of a community to adjust to climate change by addressing and planning for changes, taking advantage of related opportunities, or coping with the consequences of change[1] (modified from IPCC 2007). Current model predictions by the Intergovernmental Panel on Climate Change (IPCC), report the greatest climate warming in the eastern arctic. Yet, certain regions of the North West are also predicted to continue warming at a faster than average rate due to characteristic mountainous terrain and subsequent microclimates. In particular, the Yukon has warmed at an unprecedented rate (IPCC 2007). Of particular interest is the ability of the capital city of Whitehorse to respond adaptively to reoccurring environmental stresses that are likely to increase in severity and frequency due to a warming climate. We define an environmental stress as an extreme, generally short-lived, natural event that tends to impact the immediate landscape. The findings of this report will assist with the evaluation of adaptive capacity during the development of the *Whitehorse Community Climate Change Adaptation Plan*. For this reason, the environmental stresses highlighted in this report are those likely to be affected by climate change. We provide an overview of how environmental stresses affected the community from 1930 to 2009, by: 1) identifying the primary stresses affecting Whitehorse, 2) providing historical examples of related events of how residents and the city responded, and 3) gauging the community's adaptive capacity to respond to potential impacts of climate change related events based on historical responses.

Geographically, Whitehorse is a relatively remote community located in the southern region of the Yukon Territory, at 60°43'N and 135°4'W. Whitehorse is situated in the Upper Yukon Basin, a region characterised by deep river valleys and an elevation grade of 600-1200m. Climate is continental with a highly variable daily and seasonal temperature regime. On average, the region receives 200-300mm of precipitation annually[2]. The regional climate is influenced by teleconnections between the Pacific Decadal Oscillation, the El Nino Southern Oscillation, and the Arctic Oscillation[3]. The community is considered relatively urban by Northern standards. As of 2006[4], the population of Whitehorse was 22,114-23,991 residents – approximately 75% the population of Yukon. Because of its central location along the Alaska Highway and relatively high population density, Whitehorse functions as an economic and service hub for the territory.

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[1] IPCC: Intergovernmental Panel on Climate Change (http://www.ipcc.ch/)

[2] Whal, H.E., Fraser, D.B., Harvey, R.C., and Maxwell, J.B. 1987. *Climate of Yukon.* Environment Canada, Government of Canada , Ottawa, Canada .

[3] Werner, T. and Murdock, T. 2008. *Changes in Past-Hydro-climatology and Projected Future Change for the City of Whitehorse: Summary Report.* Pacific Climate Impacts Consortium, Victoria, Canada.

[4] Yukon Bureau of Statistics. 2007. *Population and Dwelling Counts; Census 2006 Information Sheet #C06-01.* Yukon Government, Whitehorse Yukon. [Online 10 November 2009] http://www.eco.gov.yk.ca/stats/pdf/popdwell.pdf Ric Janowicz 2002

2.0 Methods

Evidence of environmental stress in Whitehorse was principally gathered from the archives of the two local newspapers; the *Whitehorse Star*, and the *Yukon News*. About 50 articles from 1930 to 2009 were examined to determine the extent, influence, and repercussions of historic extreme natural events. Additional information was gathered from relevant Yukon Government and City of Whitehorse departments.

The environmental stresses experienced in Whitehorse are classed into three categories commonly influenced by climate conditions: forest fires, flooding, and weather fluctuations. This last category was further subdivided into ice, weather variability, and snow. Historic environmental stresses are therefore presented in six categories. For each category, the causes, impacts and community responses are reported for each environmental stress. Whenever possible, resulting monetary costs have been adjusted to 2009 Canadian dollar values.

3.0 Whitehorse Environmental Stresses 1930-2009

3.1 Forest Fire

Forest fires are uncontrolled fires occurring in the bush and countryside. They are the most important and common environmental stress experienced by Whitehorse residents. The behaviour and impact of a forest fire depends on a combination of factors such as available fuels, physical setting, and weather.

There are many examples of forest fire incidents during the 1930-2009 period. The most prominent fire occurred in June 1958 and burned a significant portion of the Ibex Valley. Strong winds pushed the blaze towards Whitehorse, forcing an evacuation; in part, caused by insufficient community response capacity. Some residents never returned to the area. The 400 square mile (~103,000 ha) burn was only stopped by precipitation from a timely storm. The potentially catastrophic effects of the fire continue to linger in the memory of the community. Smaller forest fires tend to cause more localized evacuations and damage. For example, in June 1969, Porter Creek and Crestview subdivisions were almost destroyed by a fire. In May 1970, Riverdale was threatened by a fire that burned 650 acres and forced residents to evacuate. Another fire threatened residents living east of Lake Laberge in 1978, burning 1359 acres. The Haeckel Hill blaze in 1991 also occurred within City limits. Another fire in 1991 affected 1500ha, forcing the evacuation of the Echo Valley subdivision.

3.1.1 Causes of Forest Fires

Fires are typically started by one of two sources, those occurring naturally and those stemming from human activity. Most fires in Whitehorse are caused by human negligence (Yukon Wildland Fire Management 2010). Careless campers and hunters, vandalism, and industrial activities are all cited as the main causes of forest fires. In the winter, fires can be caused by electrical shorts in the wiring of houses or by chimney fires. Wood heat is also a potential source of fire, especially during cold weather when large fires are not well supervised (Yukon Wildland Fire Management). In January 1956, sixteen phone calls were made to the fire department due to strained boilers and chimneys catching fire, causing structural damage to several homes.

The primary natural source of fire ignition is lightning, which often ignites fires during warm periods when temperatures may exceed 35°C for many consecutive days. Therefore, hot weather combined with a dry season create a high potential for fire. Such conditions were present in the summer of 1948 when lightening sparked a local forest fire. Fires ignited by lightening strikes are reported annually and generally result in more intense fires (YourYukon, column 233, series 1, June 29, 2001, Sarah Locke).

3.1.2 Impacts of Forest Fires

Forest fire activity may have several consequences. In addition to the physical damage, the related financial costs can have detrimental effects on the community. For example, fire control budgets include the cost of personnel salaries, equipment maintenance, aircraft, and supplies and are based on an annual estimate of fire activity. Thus a high number of forest fires could require the hiring of additional fire fighters and the acquisition of additional equipment. Fire can also devastate vulnerable infrastructure such as roads, power lines and phone lines, adding to the total cost of the fire and leaving residents without communication and power. For example, the city's fire budget became strained in 1984, when a severe forest fire resulted in over-exertion of the fire crew and the need for additional equipment. Four WWII A-26 tankers were used to drop fire retardants, while two bird dog aircraft, two patrol planes, a DC-3 (used by smoke jumpers), 100 employees, and mountain lookouts were ultimately needed to control the fire. The effort cost approximately $4.6M ($8,600,651.47 in 2009)[5], exceeding the fire budget for that year (*Whitehorse Star, May 24th 1984)*. The city ultimately tried to recover some of the cost of fighting the fire on Crown/Commissioners land from the federal and territorial governments.

In addition to the area burned, high winds conditions can create problems by spreading smoke to new areas. In 1998, the smoke from a nearby 3000 ha forest fire (about 1km away from Logan subdivision) drifted over Whitehorse and the surrounding area creating poor air quality for the residents.

Local infrastructure can exacerbate local vulnerability; gravel roads that are irregularly maintained can be especially problematic, creating difficult or even insurmountable problems for fire crews trying to access hinterland areas. In May 1974, a private house burned down because it was located in a slough area that the fire truck could not reach. Residences located long distances from a fire hall increase response times for fire fighters.

Forest fire is a natural process of regeneration and can be a benefit to wildlife. Generally, only small animals such as mice and voles perish in local forest fires. Large animals such as moose and bear can simply evacuate threatened regions. For example, a group of marten escaped the 1991 Haeckel Hill fire unscathed. Snowshoe hare populations generally increase in areas that have recently recovered from forest fires. This benefits lynx, coyotes and avian predators such as goshawks and great horned owls. Recently burned areas can provide improved growing conditions for certain plant species. For example, morel mushrooms grow in large quantities in the moist

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[5] All values have been adjusted for inflation to their value in 2009 using the Bank of Canada inflation calculator [online February 2010] http://www.bankofcanada.ca/en/inflation_calc.html

environment that can develop in burned areas. These mushrooms can be quite valuable if sold to an interested market.

3.1.3 Community Responses to Forest Fires

Only large fires near communities or residences tend to elicit a response from the community. In June 1958, the Red Cross organized a special White Pass train to evacuate residents to the Carcross Residential School. The seriousness of the 1958 forest fire also prompted authorities to upgrade the Robert Service Way to provide an alternative access route into and out of downtown Whitehorse (*2004 Wildland Fire Review, 421.34.y94*). One of the most important recent responses to forest fires in the Whitehorse area was the purchase of a new fire management system designed to detect fire in July 1983. The cost was $82,000 ($159,013.51 adjusted value).

Military firefighters, the city fire department, and the forestry division have historically worked together to control large fires threatening the city. Equipment used to fight fires included bulldozers, aircrafts and helicopters. A large fire in June 1957 required a collaborative response from fire fighters representing a number of organizations. These firemen worked collectively to make a firebreak to trap the blaze. In the past, the city has also been forced to organize head-counts of evacuees, while hotels have offered free rooms during periods of population relocation. The Alaska Highway was also periodically closed during historic fire seasons due to poor driving conditions.

Successful fire management depends on fire prevention, detection, and suppression. In April 2003, the Protective Services Branch of the Department of Community Services became responsible for the Fire Management Program from the federal government. Fire prevention relies both on prevention of natural and human based ignition. Fire ratings are typically assigned to proactively manage fires. Fire bans are often issued during periods where the fire rating is moderate to high. Fire detection is possible through regular surveillance of a particular area and though reports made by members of the public via the forest fire hotline or otherwise. Finally, fire suppression depends on the capacity of fire fighting crews and equipment made available by the Department of Community Services.

3.1.4 Forest Fires: Adaptive capacity and climate change

A dry climate and a close proximity to forested areas make Whitehorse vulnerable to frequent forest fires. The extent of resultant damage is dependent on the intensity, spread of the fire, and on the capacity of firefighting crews to control the blaze. The Yukon's Fire Management Plan provides the structure for implementing an adaptive response plan. However, due to the city's relative isolation, communities remain vulnerable to fires that become difficult to control due to unpredictable or changing weather patterns. A recent fuel management plan was compiled for the western Whitehorse region which highlighted that certain areas of the surrounding forest would burn particularly hot and fast[6].

[6] Yukon News, June 11, 2010, Whitehorse ill prepared for fire, Chris Oak.

Biophysical and climate research suggests that climate change may influence the frequency and intensity of forest fire activity in the northern boreal system[7],[8].The area surrounding Whitehorse is characterized by a relatively arid climate, thus an increase in average temperature and changes in the intensity and frequency of precipitation events could increase the risk of forest fires. Strong communication between the government, the public, and fire managers will strengthen adaptive capacity. Overall, public education campaigns and further monetary investment in fuel management will be important preventative measures that will help to ensure that residents are aware and prepared for potential changes in the forest fire regime due to climactic changes. Effective fuel management is expensive but must be maintained. Although a Firesmart program has instigated the clearing of underbrush (potential ignition fuel) in forest surrounding certain subdivisions, such measures will not undermine the need for quick institutional response should a fire break out. Future forest fires could become bigger and more intense if periods of drought are followed by sudden thunder storms which generate lighting. Given that there are more people living in and around Whitehorse these fires may become harder to fight. For example, there were 7.4% more residents in Whitehorse in 2006 compared to 2001[9]. Large fires in the future may potentially threaten property and infrastructure more than ever before, especially in relatively remote areas on the periphery of the city.

3.2 Flooding

Flooding is an important environmental stress in Whitehorse and can occur year round, regardless of seasonal conditions. Flooding can cause damage to buildings, houses, bridges, roads, and sewage structures. Local vulnerability stems primarily from the Yukon River which traverses the city, one of the biggest rivers in North America. The Yukon River reacts quickly to shifting seasonal conditions because of its directional flow (the flows goes south to north) and its many tributaries. Seasonally, river levels rise in the fall and spring, driven by increased levels of precipitation, and ebb at the end of the summer. Cold weather can cause ice-jamming and flooding as the river does not freeze completely during winter months.

3.2.1 Causes of Flooding

There are numerous natural and anthropogenic reasons for flooding. In the spring, the river ice breaks and moves with the current; potentially creating conditions for an ice-jam, resulting in flooding. Ice jamming can also be problematic in winter when triggered by widely fluctuating seasonal temperatures, such as from very cold to very warm. Flooding can also result from the thawing of permafrost, which adds more water to the river. Permafrost can be melted by forest fires or by a heavy snowfall. Forest fires can melt about 3.6 metres of permafrost. Heavy snowfall can trap heat from the ground, acting as an insulator to melt permafrost, especially if the snowfall occurs early in the season.

[7] Duffy, P.A., Walsh, J.E., Graham, J.M., Mann, D.H. and Rupp, T.S. 2005. Impacts of large-scale atmospheric-ocean on Alaskan fire season severity. Ecological Applications 15:4, 1317-1330.

[8] Westerling, A. L., Hidalgo, H. G., Cayan, D. R., Swetnam, T. W. 2006. Warming and earlier spring increase western US forest wildfire activity. Science 313:5789, 940-943.

[9] 2006 Community Profiles, Statistics Canada

Localized flooding can happen any time through the summer due to heavy precipitation events, such as thunderstorms. According to climatologists, thunderstorms are most likely to occur in the Whitehorse area during June and July. Thunderstorms are caused by the sun heating the earth's surface and causing a large amount of warm air to rise. When the warm air is cooled by mixing with unstable atmospheric conditions at very high altitudes, a relatively sudden burst of precipitation is produced. This burst of precipitation can exceed the natural or engineered drainage capacity of a region, resulting in localized flooding. Thunderstorm activity can continue until the end of July and into August. After August, limited daylight decreases the surface area heated by the sun reducing the likelihood of a storm occurring.

Development along the Yukon River floodplain and through the river corridor has exacerbated the threat of floods. Since the installation of the new hydraulic turbines at the power dams, workers have observed flooding along the riverfront as the river is less frozen in winter[10] .

3.2.2 Impacts of Flooding

Flooding directly impacts residents; damaging infrastructure and property and potentially threatening the lives of residents. Damage from flooding is evident throughout the history of Whitehorse. In December 1962, about two feet of water and slush covered the streets and evacuation was necessary. High precipitation over a short period broke the record precipitation for June in 1985, resulting in localized flooding. A mudslide along Robert Service Way was created when 50.5 mm of rain fell on the area, blocking half of the road. In February 1968 there was an important flood on Sixth and Seventh avenues, particularly in the low-lying west end of the city. Flooding was caused by unseasonably warm weather which melted the snow. The resulting melt-water exceeded the coping capacity of the local sewage system. To complicate matters, the city crew did not want to increase the pressure in the sewers in case the water backed up into other basements. Another early spring thaw occurred on March 4th, 1968. The problems started when basements on Jarvis, fifth, Sixth Avenue and beyond were flooded by melting surface water. Heavy flooding along Second Avenue in Whitehorse submerged a vehicle in about a meter of water in 1985. That same year heavy precipitation in the summer negatively affected the tourism season and the local economy.

The Marwell subdivision in Whitehorse has historically experienced greater issues with flooding than anywhere else. Floods levels in Marwell have measured up to about one metre of water. A flood in January 1982 reached more than 100m into Marwell, threatening houses along Silver Road. Home owners prepared for the flood by moving furniture and vehicles and building snow dams to divert flood waters. Residents blamed the new sewer construction and historic dredging of the Yukon River. Flooding occurred again in December 1992 when water forced its way into some local basements. Water levels reached up to 125 mm and at least one family was forced to evacuate their home. No long-term emergency shelter could be provided for the family due to the lack of available housing. Flooding occurred again in Marwell in 2000 when debris torrents and mudflows occurred downstream of the subdivision. This event caused the highest level

[10] Phone conversation with City of Whitehorse's employees, October 2009.

of damage from flooding and ice-jams in twenty-five years. Fearing typhoid fever, many Marwell residents poured bleach into their wells.

In June 1997, an extreme thunderstorm hit Porter Creek and resulted in flooding and extensive damage along Jupiter and Hemlock Streets. About 20 mm of rain fell in two hours. The storm itself felled many trees, which damaged power lines and houses along the street. Yukon Electric was forced to shut down power to give employees time to clear trees from the lines. Flooding was so severe that residents were observed kayaking on Tamarack Crescent. In November 2001, localized flooding resulted in the contamination of a domestic well as flood water flushed the contents of the septic tank into well waters. Yukon government engineers have been working on similar flooding vulnerability in Copper Ridge.

Localized flooding remains an issue, especially in winter. During winter months, water does not easily flow through storm sewers and can even freeze, forming blockages. When these conditions occur, the city crew has to open the storm drains so as to melt the ice and pump up the water[11]. The director of community infrastructure was quoted, saying that this was not an easy problem to resolve because they are not sure about the source of the flooding (CBC NEWS, August 11th 2009).

3.2.3 Community Responses to Flooding

In 1993, city council bought a $127,000 ($163,333.33 adjusted to 2009) drainage system in the wake of persistent spring flooding problems in country-residential developments within city limits - especially in the Hidden Valley subdivision and on Loganberry Lane. In 2009, the city continues to upgrade drainage systems where necessary. Additional measures are required to address ice build-up in the storm drains. Despite efforts to upgrade drainage systems, community level responses are still required. Residents should always check their pipes and private sewers in cold weather.

Flood relief for residents has been problematic in the past. A family was displaced by local flooding in 1992, and left without permanent shelter. Concern was expressed that there was no contingency plan in place to provide disaster relief to residents. For example, it was not known how relief would be provided if 20 families were flooded out. When a flood does result in disaster conditions, social services personnel are responsible for providing relief.

The alternative to flood relief is flood forecasting to ensure vulnerable people and property can be moved from danger. Unfortunately, flood forecasting is not very straight-forward, especially in the North. Flood forecasts are based on information collected from hydrometric stations through the winter, which are then incorporated into a computer model. Forecasting in the North is complicated by these models, the majority of which were developed for populated areas in the south and are not directly applicable to northern conditions. They do not account adequately for cold climate factors like permafrost, seasonally frozen soil, and sublimation (where snow evaporates directly into the water vapour without entering a liquid state). For example, the Wolf Creek Research Basin near Whitehorse has demonstrated that up to 60% of snow can disappear through sublimation and never reach the stream channel (Yukon Flood Study, 627.42, Fe Y. Rm.

[11] Phone conversation with City of Whitehorse's employees, October 2009

2002). The Department of Water Resource and the Division of Indian and Northern Affairs, Canada, has been working on following and understanding the northern phenomenon of flooding.

3.2.4 Flooding: Adaptive Capacity and Climate Change

Flooding in Whitehorse is characterized by irregular, sporadic events that are relatively difficult to predict (YourYukon column 256, December 7, 2001). However, the city has consistently up-dated drainage infrastructure to accommodate local flooding and so has decrease the overall damage of flooding events. The positive effects of climate change on flooding events may include changes in freeze-up and break-up dates, increases in the number of heavy precipitation events, duration of the ice season, and ice-cover thickness[12] [13]. Flooding events depend on numerous variables driven by climate that interact through a variety of geophysical processes (e.g. geo-mechanics, micro-meteorology, hydrology, and hydraulics). While it is not yet clear how climate change may ultimately affect flooding, there are certain flooding events that may be more likely to be aggravated by a changing climate, such as ice jam flooding due to large fluctuations in spring temperatures[7]. Ice jam flooding can be serious, even if the discharge is modest compared to open water floods. While open water flooding is generally predictable, ice jam flooding is often sudden and capable of substantial bank erosion[13]. Quick, institutional responses to flooding events in the past suggest that damage induced by flooding will likely be minimized due to preemptive improvements to infrastructure and good communication of river conditions. Moreover, most subdivisions rest on banks that are relatively elevated above normal river water levels. However, new developments should consider possibility of sudden, unpredictable flooding and should take into consideration the historical extent of flooding in vulnerable areas, such as the Marwell subdivision.

3.3 Weather Fluctuations: Ice

Icy conditions are usually created by very cold weather and rapidly fluctuating temperatures, which can produce fog and flooding. Rapidly changing weather can also produce ice during seasons when residents may not be prepared for it. As a result, anticipating and accommodating ice and icy conditions is an important feature of life in Whitehorse.

3.3.1 Impact of Icy Conditions

Every winter accidents related to icy conditions result in tragedy. For example, on March 1957, a driver failed to accommodate icy road conditions and collided with a child on a toboggan. In January 1962, three residents were admitted to the Whitehorse General Hospital after two vehicles collided due to the icy road conditions. A major series of

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[12] Prowse, T.D., B.R., Bonsal, C.R., Duguay, M.P., Lacroix. 2007. River-ice break-up/freeze-up: a review of climate drivers, historical trends and future predictions. Annals of Glacialogy 46:453-451

[13] Beltaos, S. and Prowse, T.D. 2001. Climate impacts on extreme ice-jam events in Canadian rivers. Hydrological Sciences- Journal-des Sciences Hydroliques 46(1)

accidents was reported on November 25th, 1968 with the onset of winter conditions, resulting in $600 ($3,587.50 adjusted value) damage. Unsurprisingly, the majority of vehicle accidents occur in downtown Whitehorse, where the traffic is heavy. A number of accidents occurred again in November 1965 and January 1969. About $3,150.00 ($17,991.04 2009 adjusted value) in vehicle damages occurred during this period. Heavy snowfalls occurred throughout the early winter in 1988. About 110 mm of snow fell in one day in November 1988. This anomaly was surpassed soon after when 270 mm fell in a single day in December 1988. The heavy snow and icy road conditions resulted in a three vehicle accident on Mountainview Drive, closing the road. Accidents resulting from driving in icy conditions continue to persist today.

Accidents due to icy conditions are not limited to vehicle use. Often, simply being out in icy conditions can result in the injury of residents. In December 1964, slips and falls on icy streets resulted in injuries across the city within a mere 48 hours. Five people were admitted to the Whitehorse Hospital during that period. In December 18th 1981, warm temperatures of 5°C resulted in about 4.2 mm of rain to fall over the course of the day. This rainfall then froze causing a rash of injuries due to slips and falls. In November 2000, mild weather was responsible for serious and non-serious pedestrian injuries who slipped on the sidewalk. Fourteen people were treated at the Whitehorse General Hospital in one day. The warmer temperatures melted the snow, which then turned into ice, causing slippery conditions for pedestrians. As with vehicle accidents, slippery streets can still affect Whitehorse’s residents. The aging population of Whitehorse is currently vulnerable to icy conditions.

3.3.2 Effects of Ice and Icy Conditions

Injury is the most common result of ice and icy conditions. Icy conditions in 2005 resulted in 198 admittances - 75% of total hospital visits to the Whitehorse General Hospital Emergency Room. Warmer temperatures during the same period in 2006 resulted in 113 individuals or 45% admittances to the Emergency because of a fall[14].

Icy conditions also affect infrastructure. In December 1962, electric power to Porter Creek was interrupted by heavy ice created by mild weather, sleet and rain. Ice built up on the power lines, which ultimately snapped under the load. Ice and ice fog can potentially block metal chimneys. Heat converts ice fog to water, which condenses inside the chimney and later refreezes. This ice gradually builds up until the chimney passage is completely blocked, forcing carbon monoxide levels in the building to rise. Unfortunately, this situation resulted in the death of a couple in the 1970’s. Another, more fortunate family was saved in December 1977 after a public safety warning alerted them to ice blockage in their chimney. At that time the Fire Chief had stressed the importance of checking household chimneys in cold weather after an episode of ice fog.

In addition to issues of safety and security, historic ice damage to buildings in Whitehorse can be expensive. For example, a resident who lived on Redwood Street in Porter Creek for seven years had his pipe-line freeze for the first time because road improvements had lowered the road surface about 1m. He had to pay $150,000 (~$250,000.00 in adjusted dollars) for pipe steaming. Municipal services crews have

[14] Wendy White. Health Records Department, Whitehorse General Hospital, 2009

since noted that the several mild winters have put Whitehorse residents out of the habit of using frost protection devices.

Cold conditions can also create challenging conditions for city operations. On January 3, 1991, ice fog and temperatures of -45°C reduced visibility and forced the Whitehorse airport to shut down. On the same day, the record low temperatures halted work by city crews, who could not use certain equipment for fear of damage. The metal equipment became so brittle it could snap or shear when it hit curbs.

3.3.3 Community Responses to Icy Conditions

In 1960, Red Cross Water Safety officials stressed safety measures to ensure the security of residents engaged in winter outdoor activities. Following safety rules helps to prevents accidents and aids rescue operations. For example, one must ensure that the ice on the rivers, sloughs and lakes is four inches thick before it is traversed (REF).

Warnings and official messages are the standard method for creating awareness in the community of dangerous driving conditions and ensuring motorists use the proper amount of caution. In December 1981, the RCMP issued an official warning to motorists to be very careful on streets. Yukon Government officials have also told residents to avoid the Yukon highways unless it was absolutely essential to make a trip. The highways around Whitehorse are sanded to increase traction and create safer driving conditions.

Historically, Whitehorse has responded well to infrastructure concerns associated with icing. On August, 1989, the city made a change to their Water and Sewage bylaw, such that the city was to now be responsible for pipes freezing on city property. However, the Municipal Services Director cautioned that residents were still responsible for their own frost protection devices (bleeders, recirculation pumps and transformers being the most common). In September 1989, the city addressed concerns about potential pipeline freezing in Porter Creek. These pipelines were fairly close to the surface and solutions were established to protect the system and prevent a freeze-up, including placing a heat trace, a bleeder and a recirculation system.

Whitehorse has been searching for a sewage treatment system that can accommodate ice since 1977. For example, sewage lagoons work best between 14 and 30°C, and are frost free only 60 days of the year as a result. Only in the warmest summer months do the lagoons get enough light and oxygen to mix up bacteria. In 1985, the city spent a few thousand dollars to clean the sludge from the Whitehorse lagoons to meet the federal standards.

3.3.4 Icy Conditions: Adaptive Capacity and climate change

The city has responded consistently to episodes of icy conditions by making improvements to water and sewage infrastructure and is continually searching for new ways to improve the efficacy of sewage systems. Residents remain responsible for ensuring that the necessary precautions are taken to reduce ice build-up on housing structures and sidewalks in front of houses. However, injuries due to accidents involving icy conditions continue to occur each year, likely aggravated by the negligence of some property owners to remove ice build-up on public walkways. The enforcement of such bylaws is necessary, however this process becomes complicated when homeowners leave on vacation or are home infrequently. The importance of good communication of current weather conditions remains a key component to reducing injuries related to icy conditions. Although it is not mandatory for vehicles to have winter tires, an emphasis on the benefits of installing season-appropriate tires is an effective way to prevent accidents. Recently (2009), the province of Quebec made winter tires an obligation. Support for such a bylaw in Whitehorse would likely reduce the number of accidents related to vehicles on the road in icy conditions. Climate change induced fluctuations in winter temperatures may increase the number of days that Whitehorse will experience icy conditions (IPCC 2007). Potentially milder winters may lead to residents being less prepared for icy conditions on the basis that they are expecting fewer colder days. However, the combination of relatively cold nights and warmer days creates potentially good conditions for ice build-up, making communication between advisory organisations and residents all the more important.

3.4 Weather Fluctuation: Weather Variability

Whitehorse weather is heavily influenced by it's proximity to the Pacific coast. When combined with the climatic influence of the surrounding mountains, the result is a distinct microclimate around the city (Whitehorse Star, October 1962). Winters are influenced by the Kuroshio Current, which is a strong western boundary current in the Western North of the Pacific Ocean. Because Whitehorse is located close to the Pacific Ocean, local weather can be affected by this current. The resulting rapid weather fluctuations can create dangerous conditions for residents, especially those engaged in outdoor activities.

3.4.1 Impacts and Community Responses to Weather Variability

As early as December 1938, significant variability with rapid fluctuations between warm and cold weather in late winter was reported in Whitehorse. During that period, which persisted over several years, the Yukon River froze intermittently, increasing the risk of flooding. Poor conditions were reported for outdoor sports like skiing and curling. In March 1938, an unexpected thaw made it impossible to have curling competitions. Skating on the river was dangerous. Poor winter conditions were reported again in November 1939 when a long-term resident made the 75 mile trek from Livingstone Trail to Whitehorse by dog-sled, stating it was the hardest trip of his life because of the changing weather.

Unusually warm weather also characterized the winter of 1940. The Yukon River was still open in January and remained so into February. Temperatures fluctuated again in January 1941 when temperatures rose from 51°C to 3°C in the space of three to four days, a variation of 54°C. Warm conditions continued and mild weather surprised residents again in January 1942. Interviews with community elders reported they did not remember having such warm weather. Fluctuating weather conditions occurred once more in December 1944 when warm weather conditions generated heavy snow fall and left the river unfrozen. In 1953, February temperatures reached 10°C.

Unusually warm weather occurred again in March 1967, this time leading to localized infrastructure problems. A resident from the roadhouse in Lot 19 had her house surrounded by sewage leaking from the Department of Transport line up the hill.

Variable conditions persisted for some time. The first week was relatively mild and temperatures reached 12°C. Record high temperatures occurred again in February 1968 due to a flow of warm air that persisted for four days. Whitehorse recorded 9°C, six degrees higher than the previous record in 1949.

Weather conditions also vary in summer. Temperatures three degrees lower than normal were reported in July 1962. Lower than normal precipitation (61.7 mm below normal) accompanied low temperatures. At one point in the month, 101.6 mm of snow fell - the highest record of snow precipitation for July at that time. The summer of 1994 was also cooler than the accepted norm, until it warmed significantly in August. After August, summer temperatures soared to record highs. Summer temperatures over 30°C have only been recorded three times over the past 53 years. These periods of have additionally been characterized by below average precipitation. Moreover, during the record highs recorded in 1994, Whitehorse received only 29.4 mm of precipitation - 76% of the July norm. In October 1998, unseasonably warm fall temperatures prevented the normal freezing of roots undermining the anchorage of trees. When a severe storm inevitably struck, wind thrown trees fell onto power lines cutting power to the community.

A combination of hot weather and low precipitation can create dust devils. Dust devils form due to a combination of high temperatures and unstable air over hot surfaces such as pavement and/or dusty and sandy surfaces can cause updrafts that lift dust, rocks and other surface debris off the ground. Dust devils also occur when the relative humidity drops dramatically. Environment Canada Whitehorse reports that dust devils are a common local phenomenon; although very hard to predict. It should be noted that Whitehorse has increased the paved surface area of the over the last 10 years because of the new developments. For example, 178 new residences were constructed in 2007 and another 212 in 2008 – in addition to the construction of new commercial developments across the City[15]. The increase in paved surface area has increased the vulnerability of city areas to the incidence of dust devils.

Dust devils often die down less than a minute after forming and generally don't have wind speeds higher than 70km/h, thus they usually do little damage. However, dust devils can be hazardous when the heavy dust obscures vision. This scenario occurred in July 1951 when two vehicles collided due to poor visibility, injuring 8 people at McCrae. Another dust devil hurled dust and debris several thousand feet into the air in May, 1978. Again, in May 1989, a giant dust devil struck the Lobird trailer park, ripping a quilt off of a clothesline - transplanting it 300m. Paper and garbage bags were reported to have flown 1000 feet into the air. Serious damage occurred when the roof of a mobile home was peeled off and folded back on top of itself. Another strong dust devil occurred in June 1996. This dust devil ripped through a short stretch of downtown Whitehorse and was observed throwing 4"x8" sheets of plywood up in the air. A carpenter for Cardinal Contracting Ltd. renovating the roof of the Whitehorse Elementary School roof subsequently reported missing 20 sheets of plywood. Injuries did not occur because the school was closed for the summer. One piece of plywood was reported to have caused about $2000 (2,559.64 adjusted value) to a Norcan Leasing pickup truck parked nearby.

[15] Housing Market information, CHML, Whitehorse

3.4.2 Weather Variability: Adaptive Capacity and Climate Change

Climate change may increase weather variability and thus the frequency of related environmental stresses. Incidences of drastic weather have become more frequent and scattered over the last 20 years. Potential impacts of increased weather variability include an increased uncertainty in lake and river ice stability and decreased reliability in predicting weather conditions. Quick changes in temperatures can rapidly create potentially dangerous conditions such as heavy rain, snow, ice, high winds, and/or very warm or very cold whether. Increasingly variable weather could also affect ground integrity, as it may take longer for soil to freeze. Falling trees may therefore become more common if there is an associated high wind during the fall, increasing the chance of power failure. Damages or injuries can be minimized in by maintaining appropriate infrastructure built to withstand a wide range of conditions, insuring a quick response time for clearing transportation routes, and emphasizing public advisory warnings. Government services are responsible for dealing with most public infrastructure damage that result from ice and snow build-up due to rapid temperature fluctuations. However, prevention of injuries, vehicle accidents, and damage to private property are strongly dependent on the awareness and conscientiousness of residents. While such events are sometimes predictable, being prepared with the proper equipment and knowledge is necessary to reduce injuries and further damage. Government programs related to public awareness will be important assets in spreading information and building adaptive capacity in this regard.

3.5 Weather Fluctuations: Snow

The 1990’s were marked by a considerable change in the timing and amount of snow fall. Over the past few decades, the first snowfall of the season has been observed to occur earlier. Annual snowfall is reportedly thicker and heavier.

3.5.1 Source of Winter Precipitation

Heavy winter precipitation is caused by the collision of the cold Arctic air mass and the warm, humid pacific coastal air mass which combines to created an Arctic front. The warm, wet coastal air slides above the cold arctic air, condenses and falls as snow. The Arctic front frequently stalls along the Ogilvie Mountains and jumps directly to Prince George, BC - skipping Whitehorse as a result. Snowfall in Whitehorse is also influenced by the St-Elias Mountains and The Coast Range, which can act as a barrier to the warm and wet weather coming from the south.

Regardless, communities in Southern Yukon – including Whitehorse - generally receive more snow than the rest of the Territory. Large lakes like Lake Laberge, Lake Bennett, Marsh Lake and Tagish Lake also influence snowfall in Whitehorse, contributing to increased amounts of snowfall in the area.

3.5.2 Impacts and Community Responses to Problematic Snowfall

Snow generally impacts the community in two ways; directly through the amount of snow that falls or through the amount of water released when it melts. One example of problematic snowmelt occurred in April 1952 when heavy snowmelt created flooding in city streets, causing damage to basements and furnaces and decompressing wells.

Other examples of the damage caused by problematic snowmelt can be found in 3.2.2. The remainder of this section describes the impacts of snow itself.

Structural damage due to heavy snow loads occurred in April 1954 when a large snow slide off the roof of the Civic Center damaged a part of the building. The heavy snow load also forced the walls out of line and destroyed the windows. The cost of the damage was about $3,000 ($24,425.53 2009 adjusted value). In October 1968, newly fallen snow caused a number of motor vehicle accidents. The same conditions occurred again in November 1968, which was the first time that the airport runways were closed due to heavily falling snow. In December 1980, Whitehorse missed a record snowfall by only two inches (the record was set in 1967 with a snowfall of 272 mm). Snow clearing crews worked non-stop on Christmas day to clear the road to the hospital and the priority streets in the downtown. Nine minor accidents occurred regardless.

The late 1980's and 1990's are seemingly marked by a considerable change in the amount of snowfall in the Whitehorse area. The record for snowfall was broken several times over this period, causing localized damage around the city. For example, a significant amount of snow fell on Whitehorse in September 1986, which far surpassed the normal monthly total snow water equivalent for that month. The mix of snow and freezing rain created dangerous driving conditions, compounded by driver error. In at least one case a resident failed to properly clear their vehicle windows and accidentally backed into another vehicle. In the case of this storm, public warnings constituted the community response. City crews were unable to keep up with the snow clearance levels that the storm demanded, which resulted in poor driving conditions on the highway. City crews subsequently warned residents against using the highway if it wasn't necessary. At this time, the highway to Carcross was still under renovation which further increased the infrastructure stress. The 1986 storm set a record for precipitation with 67.2 mm of snow and rain. About 53.9 mm of precipitation fell in 4 days, 2.2 mm fell as rain with another 31.4mm falling as snow.

In December 1991, the 1986 snowfall record was broken with 677 mm. The city experienced high snow fall again in 1992; the warm wet snow dump caused an afternoon blackout for 1000 people living between McCrae and Teslin. Moist snow had fallen onto an insulator, which then broke off an electrical pole near Miles Canyon, resulting in a short. A diesel generator was used to provide power for the Teslin area until the damage could be repaired. Three megawatts of power were lost in the blackout. In the same storm the weight of 300 mm of snow caved in the roof of a vehicle.

In February 1996, a combination of mild weather and high winds resulted in a heavy snowfall that caused trees to snap and fall on power lines. Problems reportedly began at the Robinson subdivision and then expanded to include Annie Lake, Cowley Creek and Horse Creek. Residents became frustrated as they lost power. The damage was so extensive that ultimately the electric company opted to wait for temperatures to rise to 5°C and melt the ice and snow along power lines. As a result of this incident, Yukon Electrical installed a breaker that would allow isolation of a particular subdivision in the event that repairs would have to be made. Breakers are standard across the territory such that power outages due to repairs are limited to particular areas.

3.5.3 Snow: Adaptive Capacity and Climate change

Climate change models for the Yukon predict that winters will warm more than summers; however predictions related to precipitation changes are more uncertain (IPCC 2007). In general, models predict increased winter precipitation with more pronounced changes towards the north. Models also suggest that the Yukon will experience more extreme precipitation events, with large amounts of precipitation falling in a short time periods (IPCC 2007). The ability of Whitehorse institutions to cope with the hazards induced by heavy snowfall is primarily dependent on equipment and personnel capacity, and budget allowance. Currently, the Public Works Department is responsible for snow and ice control on municipal roads and approximately 300 kilometres of highway within the municipal boundaries (excluding the Alaska Highway which is government maintained). Due to a limited budget, the city prioritizes snow removal based on traffic levels on the roadway (City of Whitehorse, Public Works Department). In the even of a snowstorm, only certain roadways will be continuously cleared and the frequency of clearance of secondary roadways is dependent on time available and the snow removal budget. A flexible and potentially larger snow-removal budget may be necessary if snow fall events increase in frequency and intensity. The resistance of buildings and other structures to heavy, dense snow is currently being studied with the interest of improving structure resistance to future snowfall events. Individual capacity to respond to large snowfall events or substantial snow accumulation depends on both the awareness of individuals to the potential related hazards and the potential for taking preventative measures if given appropriate warning. Thus government monitoring of weather and incidental reporting of predictions is an important variable in preventing accidents related to adverse weather conditions.

4.0 Conclusion

This report identifies common environmental stressors in Whitehorse likely to be influenced by climate change and describes historical events in an attempt to consider adaptive capacity on an institutional and individual level. Climate change in the Yukon is predicted to enhance and or change the frequency of occurrence of the environmental stresses identified (forest fires, flooding, and weather fluctuations).
Overall, institutional responses to environmental stresses provide evidence of adaptive capacity as defined as improvements to infrastructure, upgrading personnel capacity, improving quality/quantity of equipment, and initiating education and awareness programs. However, a rapid rate of change may outstrip the adaptive capacity of the city to keep up with climate change given the limited tax base and potential increases associated with maintaining extensive response units.

Adaptive capacity at the individual level was also considered. This report provides some evidence to suggest that individual capacity is consistently weaker than institutional capacity. This conclusion is not unexpected considering that individuals tend to be more reactive rather than proactive when responding to a particular stress. Institutions often promote proactive responses to potential hazards as they rely on logical planning processes to consider how best to respond to a future or immanent stress; however clear, complete planning is necessary for successful implementation. For example, individuals tend to head evacuation warnings concerning potential forest fire or flooding risks but also require institutional support for knowing where to find shelter and safety. Individuals that are accustomed to relying on institutional direction for proper risk response are not only less likely to be injured or severely impacted by an environmental stressor, but may also facilitate institutional attempts to control and neutralize the source of danger by staying out of the way and following directions. Thus, an effective response requires the institution to provide residents with enough information to dissuade them from taking action themselves and thus potentially complicating efforts to lessen a particular threat. It is important to note that despite a noticeable effort by Whitehorse's institutional departments to improve responses to environmental stresses, there is persistence in individual injuries and private property damage that result from a particular stress, despite a lessening of overall impact. For example, heavy snow falls or icy conditions tend to consistently result in accidents and injuries despite a priori warnings about the potential hazards. Thus, the community's adaptive capacity is low where behavioural rather than institutional level change is required. This will likely affect future climate change adaptations as they are implemented. Environmental stresses such as flooding and forest fires are more easily mitigated with institutional support, as they their impacts tend to be more localized and they often require access to specialized equipment. Educational programs and ensuring the community is aware of the benefits associated with city programs such as FireSmart will likely be pivotal for future adaptation programs, especially on an individual level.

While climate change may result in new environmental stresses that carry unknown risks, it will also exacerbate known stresses and the hazards. For example, structural issues arising form snowfall that exceeds the loading capacity of buildings may become increasingly common. Ice on roadways may become more frequent due to unseasonable rain and changing weather and could be of major concern given that there are more drivers and pedestrians in Whitehorse than ever before. Accidents due to poor driving conditions or icy walking conditions are therefore also likely to increase. Finally, the risks associated with a potential increase in the number of forest fires and flooding events will test both the adaptive capacity of the institution and the individual. The environmental stresses documented in this report provide a basis for evaluating how climate change may affect the community of Whitehorse. This report indicates which of these historic hazards has proven problematic for residents, and which hazards continue to result in the damage of property and the injury of residents. The impacts and responses to these stresses are something that we should consider and evaluate for years to come. As a result, these stresses should be considered in the development of the Community of Whitehorse Climate Change Adaptation Plan.

WHITEHORSE CLIMATE CHANGE ADAPTATION PLAN

APPENDIX E:
CLIMATE CHANGE IN WHITEHORSE: SUMMARY OF PROJECTIONS

Summary of Projected Climate Changes for the Whitehorse Region

The effects of climate change are apparent in the Yukon. These effects represent very early evidence of the changes that climate change will have on Yukon, which are anticipated to escalate as the climate continues to warm. To assess how climate change may affect the Whitehorse area, 65 maps projecting future climate conditions were generated for use in the development of the Whitehorse Adaptation Plan. These maps project a warmer Whitehorse which experiences increased precipitation.

The intention of the projections is to illustrate a conservative range of anticipated changes to our local climate over time. The projections are based on two time cuts (2030 and 2050) and two standard IPCC scenarios (B1 and A1B), presented in the *Special Report on Emissions Scenarios*[1]. These scenarios anticipate how various drivers (demographic development, socio-economic development and technological change) may influence greenhouse gas emissions (GHGs). The B1 scenario projects moderate to low increases in CO_2 over the next century. The A1B scenario anticipates medium to high increases in CO_2 by 2100. These two scenarios were selected to provide the greatest range in possible shifts in temperature and precipitation by 2050.

Projected climate changes to the Whitehorse area were generated by the Scenarios Network for Alaska Planning[2] (SNAP). SNAP is located at the University of Alaska-Fairbanks. The projections are based on the use of General Circulation Models (GCMs), which are complex models that anticipate how future climate may be influenced by GHGs. Because of the many variables that determine global climate and the varying ways of constructing a GCM, different GCMs perform differently, and are likely to have differing accuracy for any one region of the globe..

SNAP has selected five GCMs as the basis for projecting climate change based on the work of Walsh et al[3], which evaluated the performance of GCMs in northerly regions by comparing model back-casts to historical climate date. 15 GCMs were compared to ERA-40 (the European Centre for Medium-Range Weather Forecasts Re-Analysis) – one of the most consistent and accurate representations of temperature and precipitation. Of the fifteen evaluated models, the models ECHAM5 (Germany), CM2.1 (US), MIROC3.2 (Japan), HADCM3 (UK) and CGCM3.1 (Canada) were found to perform best over Alaska and Yukon.

The GCMs were then regionally downscaled using data available from the Parameter-elevation on Independent Slopes Model (PRISM). GCMs typically have a large-scale output with grid squares between 1° and 5° in latitude or longitude (~300km^2). Once correlated to the GCM output, PRISM allows for a resolution of 2km^2 and accounts for regional topography.

It should be noted that although SNAP models have been shown to provide valid data regarding climate trends over time, uncertainty is inherent in this type of projections. These model outputs incorporate the same degree of year-to-year variability found in real weather patterns, but cannot anticipate the timing of highs and lows.

Temperature

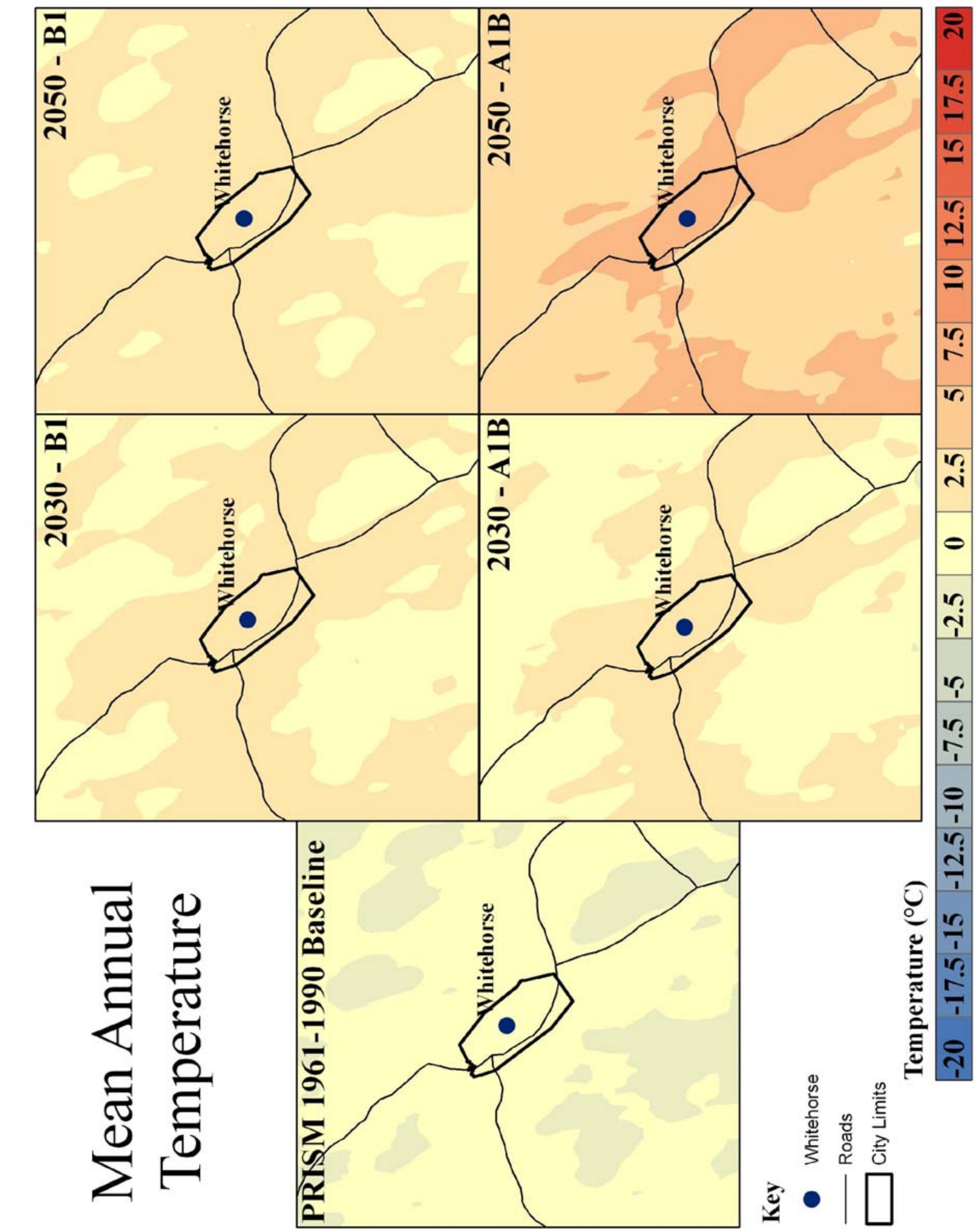
Projected mean annual temperature (MAT) and seasonal temperatures for the Whitehorse area were estimated for 2030 and 2050 using mean values from the five selected GCMs. These maps are provided below. The projections provide an estimate of anticipated increases in temperature compared to baselines established for the 1961-1990 climate normal. Annual and seasonal baseline and projected temperatures are provided in Table 1.

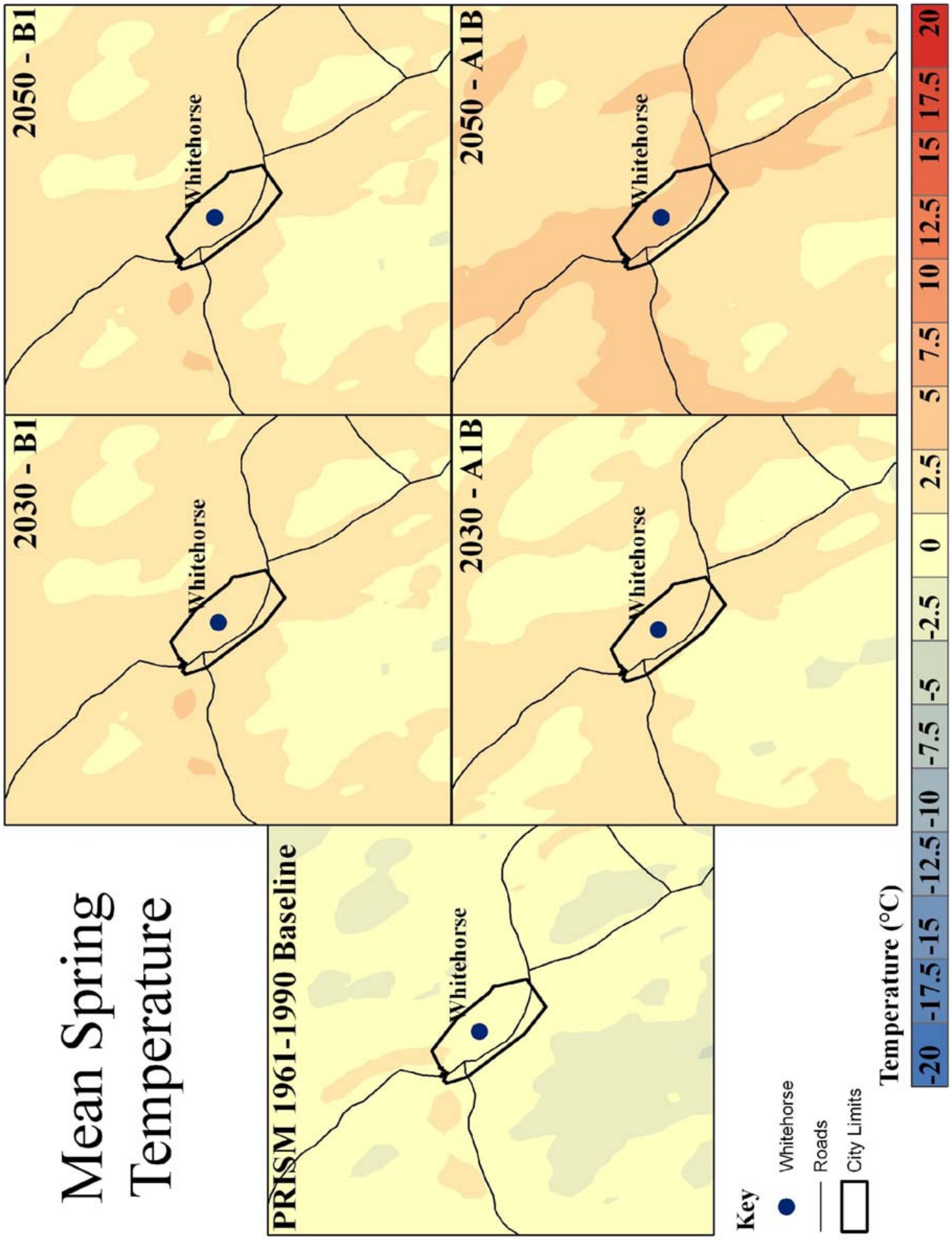
[1] http://www.ipcc.ch/pdf/special-reports/spm/sres-en.pdf
[2] www.snap.auf.edu
[3] Walsh, J.E., Chapman, W.L., Romanovsky, V., Christensen, J.H., Stendel, M. 2008. Global Climate Model Performance over Alaska and Greenland. Journal of Climate, 21: 6156-6174.

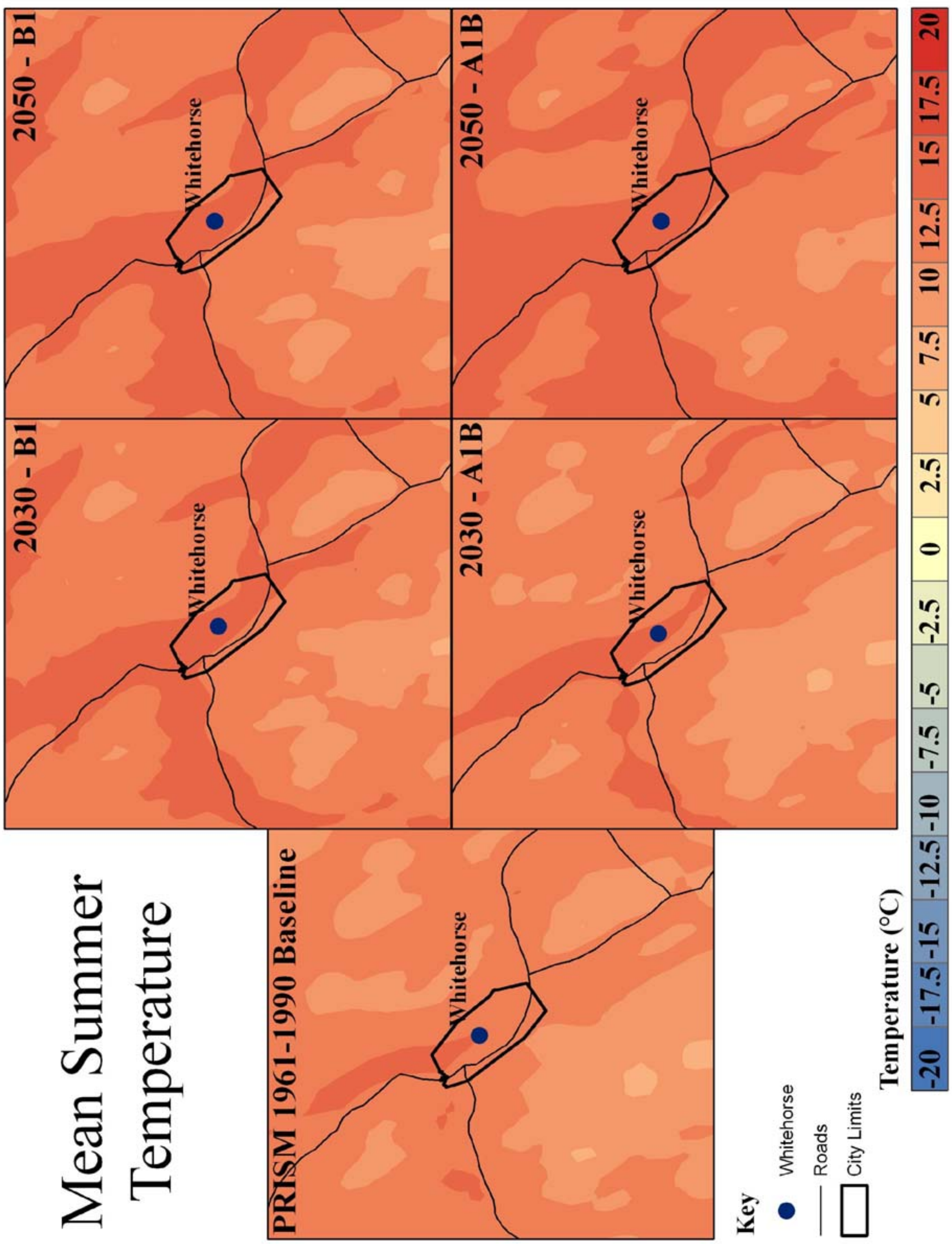
Table 1: Baseline and Projected Temperatures for the Whitehorse Area (°C)					
Season	Baseline (1961-1990)	B1		A1B	
		2030	2050	2030	2050
Annual	-5.39	-3.31	-2.94	-3.50	-1.73
Spring	-5.10	-2.91	-2.86	-3.44	-1.66
Summer	10.33	11.49	11.83	11.05	12.26
Autumn	-5.91	-3.88	-3.08	-3.98	-2.02
Winter	-20.86	-18.00	-17.57	-17.62	-15.50

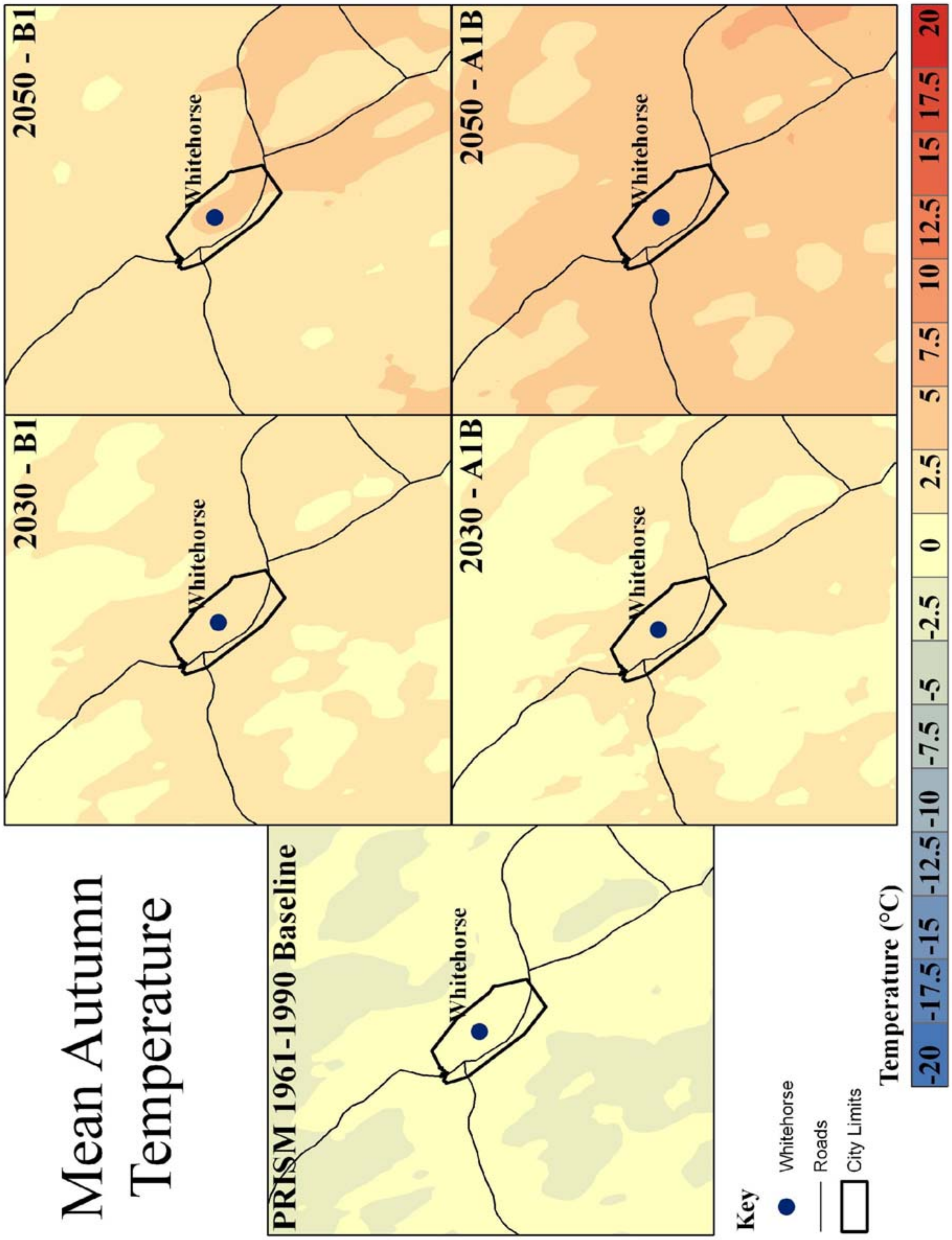
The increase in temperature anticipated between 1990 and 2050 is provided in Table 2. Projected increases indicate that warming will differ seasonally, and that winter period will experience the most significant warming – increasing 3.29°C to 5.36°C.

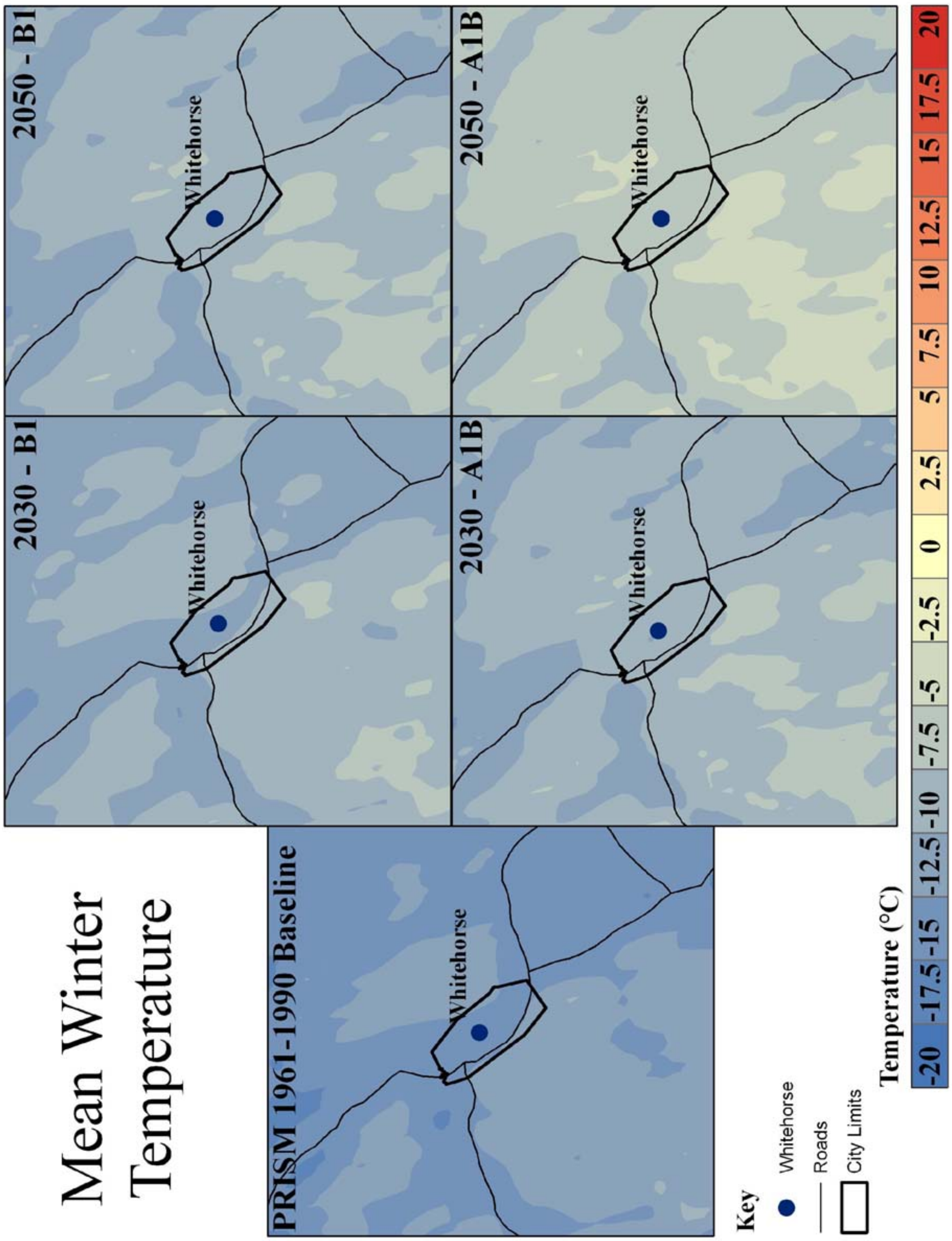
Table 2: Projected Changes in Temperature (°C) for Whitehorse from 1961-1990 to 2050				
Season	B1 (Increase from 1961-1990)		A1B (Increase from 1961-1990)	
	2030	2050	2030	2050
Annual	2.08	2.45	1.89	3.66
Spring	2.19	2.24	1.66	3.44
Summer	1.16	1.50	0.72	1.93
Autumn	2.03	2.83	1.93	3.89
Winter	2.86	3.29	3.24	5.36


Mean Annual Temperature
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Temperature (°C)
-20 -17.5 -15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15 17.5 20


Mean Spring Temperature
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Temperature (°C)
-20 -17.5 -15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15 17.5 20


Mean Summer Temperature
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Temperature (°C)
-20 -17.5 -15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15 17.5 20


Mean Autumn Temperature
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Temperature (°C)
-20 -17.5 -15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15 17.5 20


Mean Winter Temperature
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Temperature (°C)
-20 -17.5 -15 -12.5 -10 -7.5 -5 -2.5 0 2.5 5 7.5 10 12.5 15 17.5 20

Precipitation

Mean annual precipitation (MAP) was also projected for the Whitehorse area based on the 1961-1990 baseline (below). Projected annual mean precipitation in the City of Whitehorse area is anticipated to increase from 585mm to between 638mm to 657mm by 2050.

Seasonal precipitation was also projected (below). Seasonal precipitation is expected to increase throughout the year. Projected increases to seasonal precipitation by SRES scenario are provided in Table 3.

Table 3: Baseline and Projected Precipitation for the Whitehorse Area (mm)

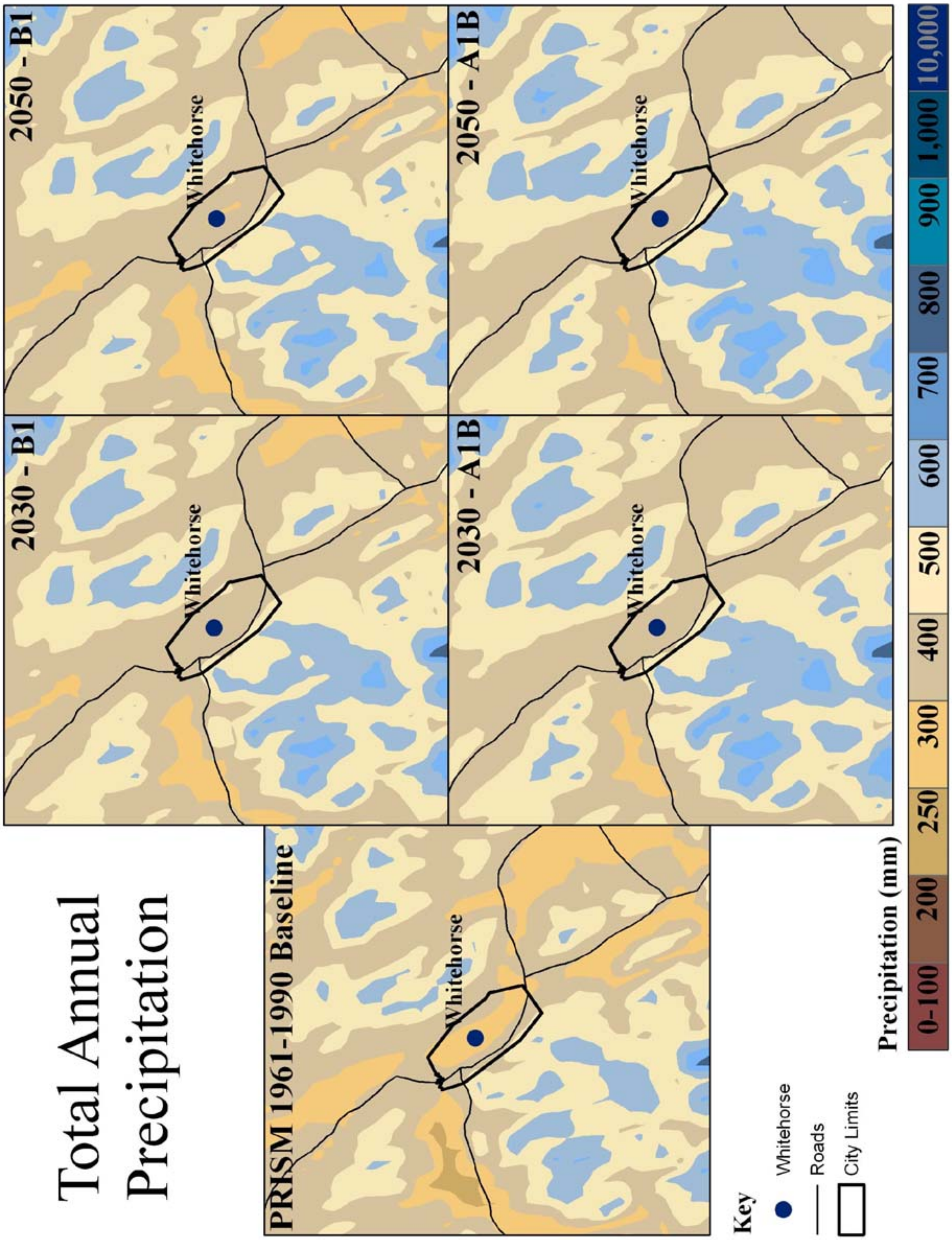
Season	Baseline (1961-1990)	B1		A1B	
		2030	2050	2030	2050
Annual	585	620	632	638	657
Spring	89	96	99	100	100
Summer	211	224	224	225	234
Autumn	170	178	183	186	192
Winter	115	121	123	128	131

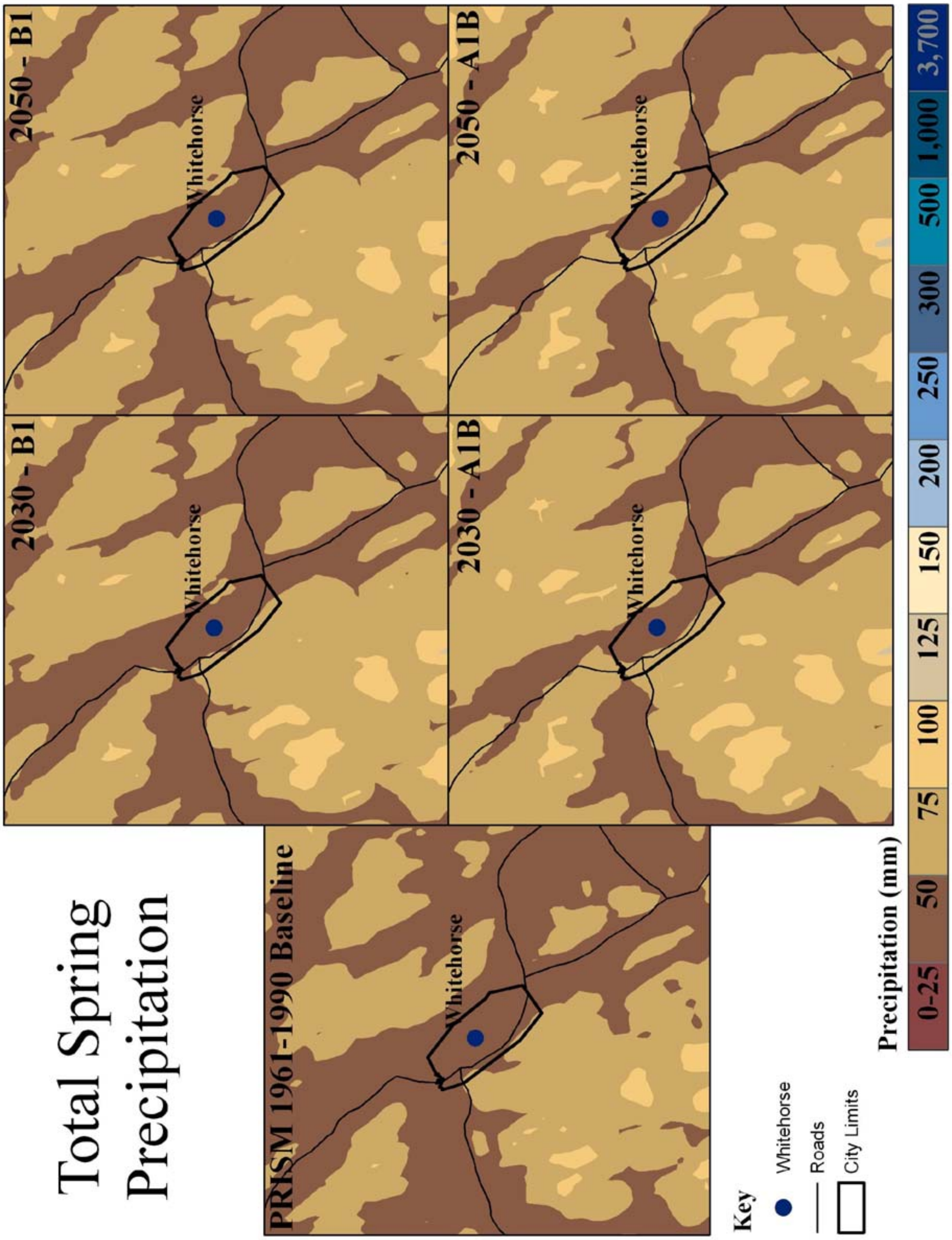
Seasonal precipitation is anticipated to increase the most in winter and fall. Winter precipitation is projected to increase between 11.3% and 13.9%, while autumn precipitation is projected to increase between 9.4% and 12.9%. Increases in MAP and seasonal precipitation in the Whitehorse area by 2030 and 2050 are provided in Table 4.

Table 4: Projected Changes in Precipitation for the Whitehorse Area

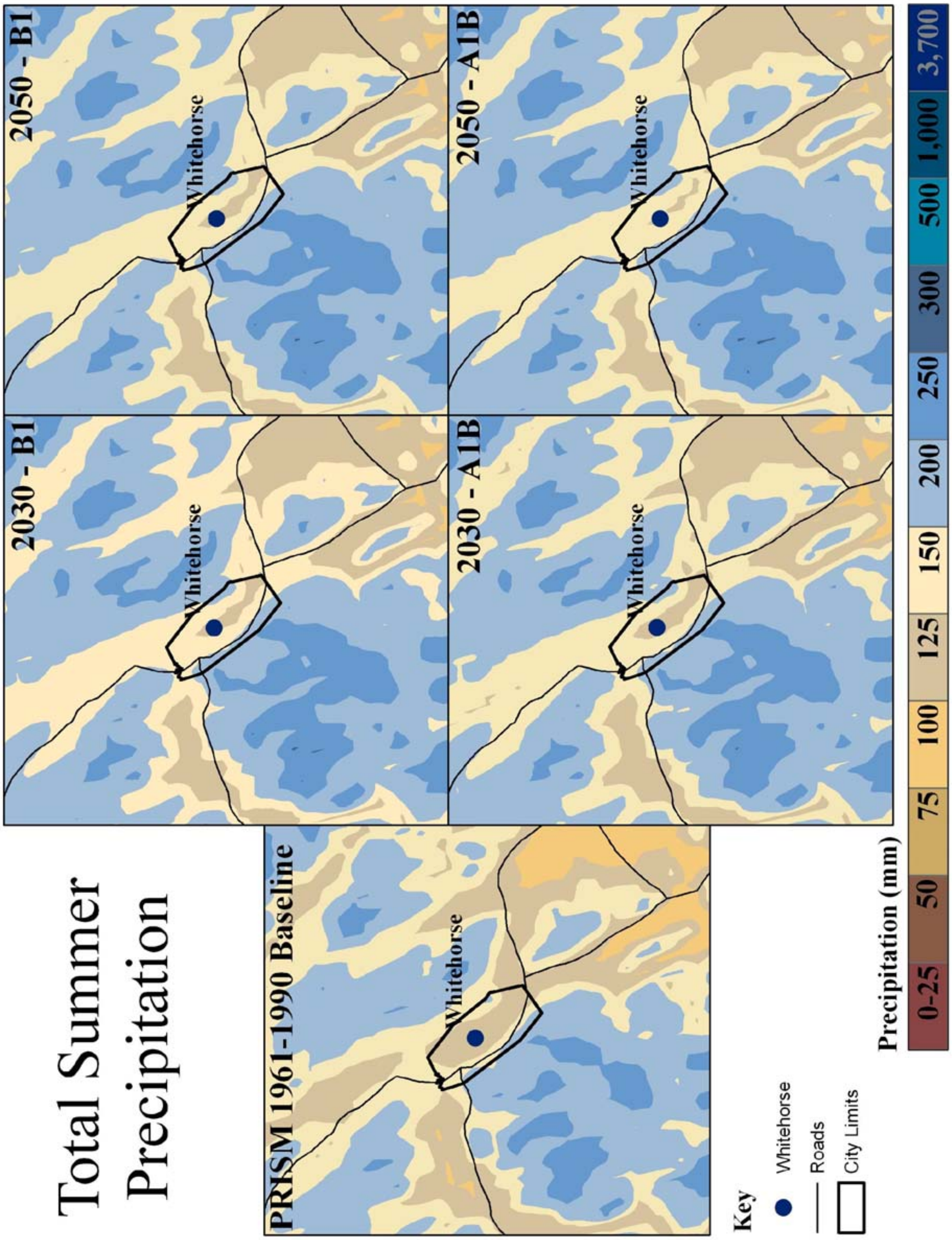
Season	B1 (Increase from 1961-1990)				A1B (Increase from 1961-1990)			
	2030		2050		2030		2050	
	mm	%	mm	%	mm	%	mm	%
Annual	35	5.9	47	8.0	53	9.1	72	12.3
Spring	7	7.9	10	11.2	11	12.4	11	12.4
Summer	13	6.2	13	6.2	14	6.6	23	10.9
Autumn	8	4.7	13	7.6	16	9.4	22	12.9
Winter	6	5.2	8	7.0	13	11.3	16	13.9

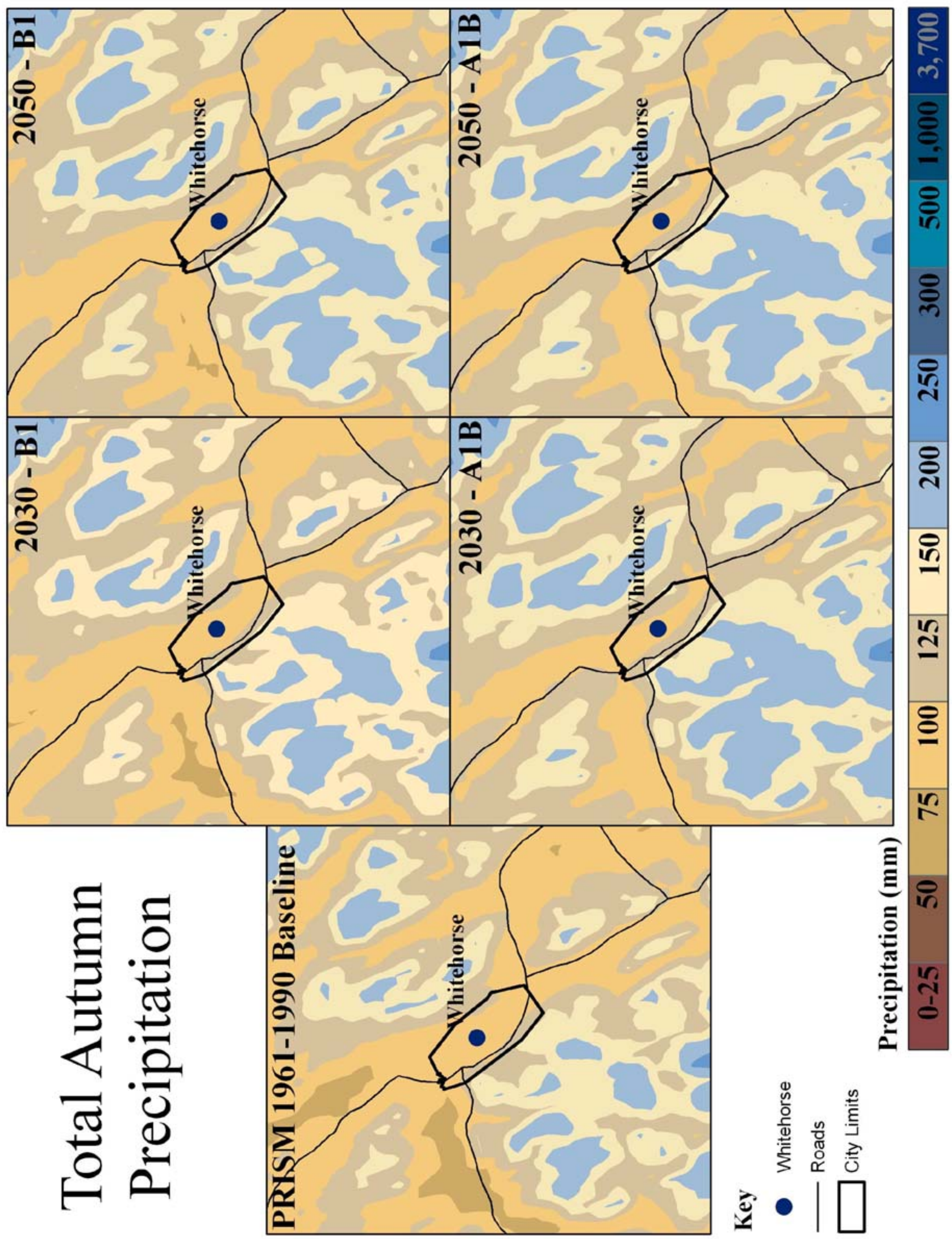
Note that although precipitation is expected to increase, higher temperatures are likely to drive higher evapotranspiration, meaning that soil moisture and water availability may actually decrease.

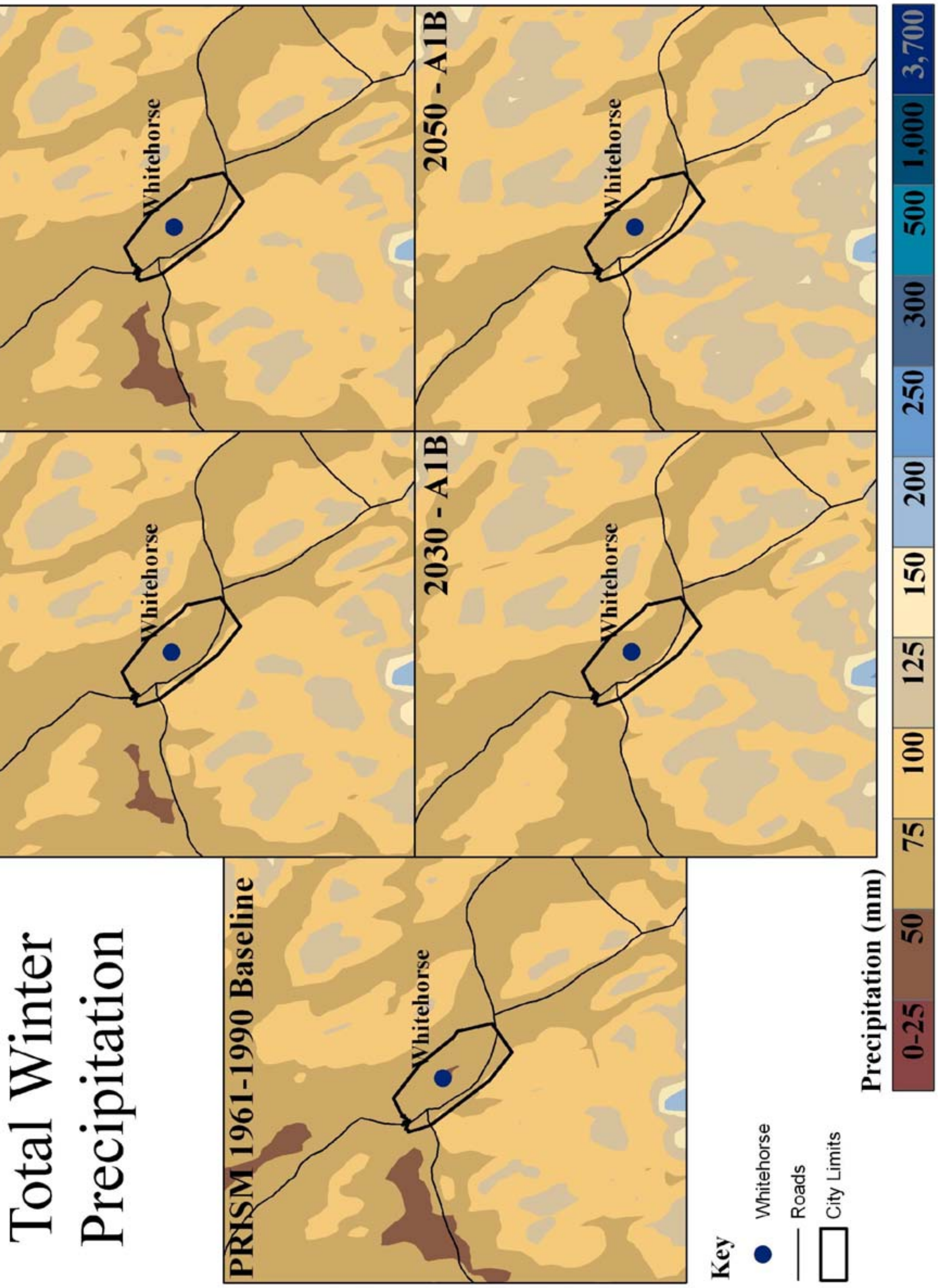

Total Annual Precipitation
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Precipitation (mm)
0-100
200
250
300
400
500
600
700
800
900
1,000
10,000



Total Spring Precipitation
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Precipitation (mm)
0-25
50
75
100
125
150
200
250
300
500
1,000
3,700


Total Summer Precipitation
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Precipitation (mm)
0-25
50
75
100
125
150
200
250
300
500
1,000
3,700


Total Autumn Precipitation
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Precipitation (mm)
0-25
50
75
100
125
150
200
250
300
500
1,000
3,700


Total Winter Precipitation
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
Precipitation (mm)
0-25
50
75
100
125
150
200
250
300
500
1,000
3,700

Freeze-Up

These maps (below) show projections for the shift in the date of fall freeze-up, as defined by the time at which mean temperatures cross 0°C. Note that this date does not necessarily correspond to river, lake, or sea ice formation.

These data were derived by interpolating daily temperature values based on linear temperature ramps between monthly means. Mean values were assumed to occur in the middle of each month.

The date of freeze-up is anticipated to occur later in all projections; moving from late September into early/mid October. The freeze-up date in Yukon is therefore anticipated to occur 11-16 days later by 2050.

Thaw Date

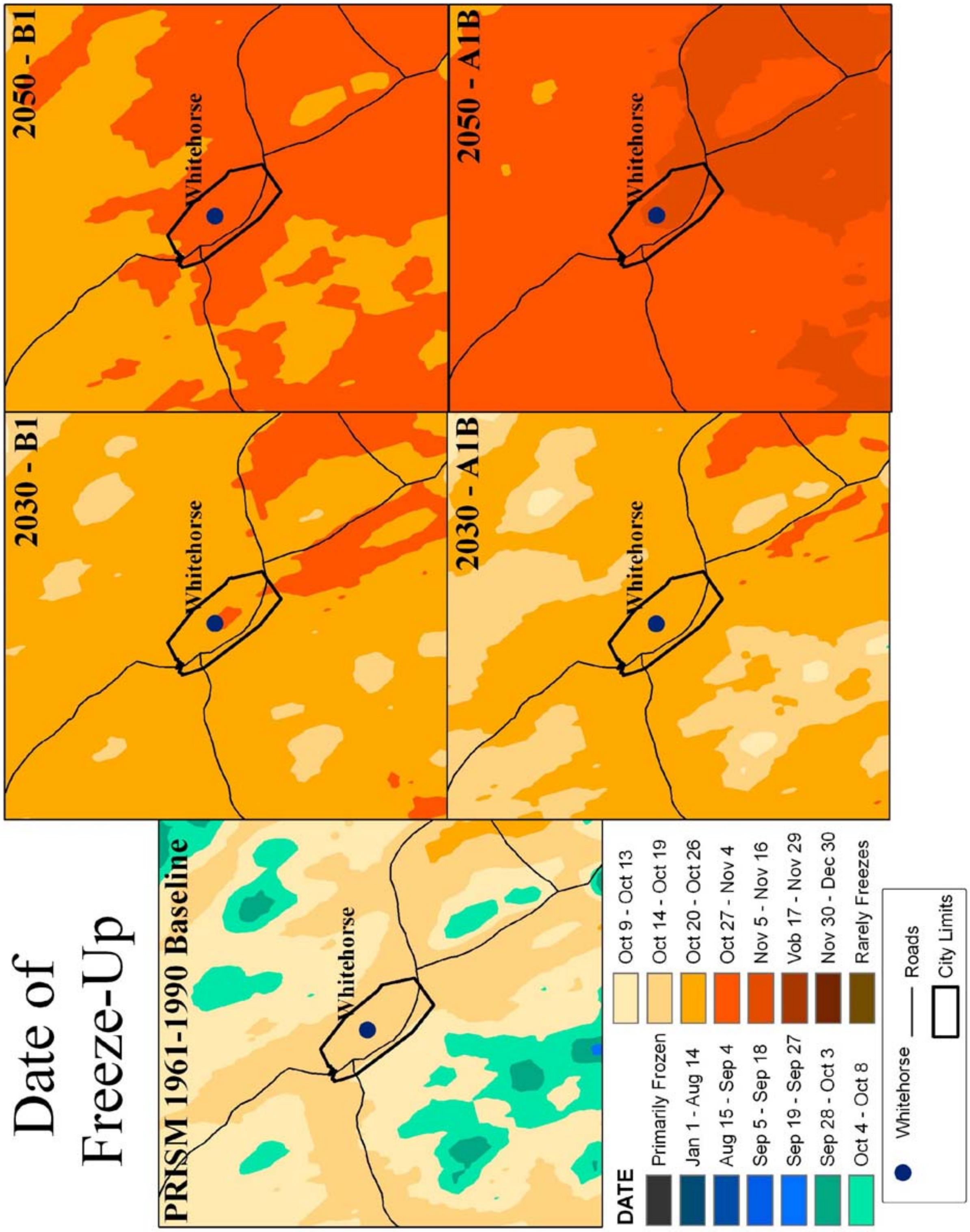
Projected changes to the thaw date in Yukon were also provided by SNAP (below). For the purposes of these projections the date of thaw is defined as the date at which mean temperature rises above freezing (0°C). This date does not necessarily correspond to ice breaking up or ground surface thaw. Projected thaw dates were derived by interpolating daily temperature values based on linear temperature ramps between monthly means. Mean values were assumed to occur in the middle of each month.

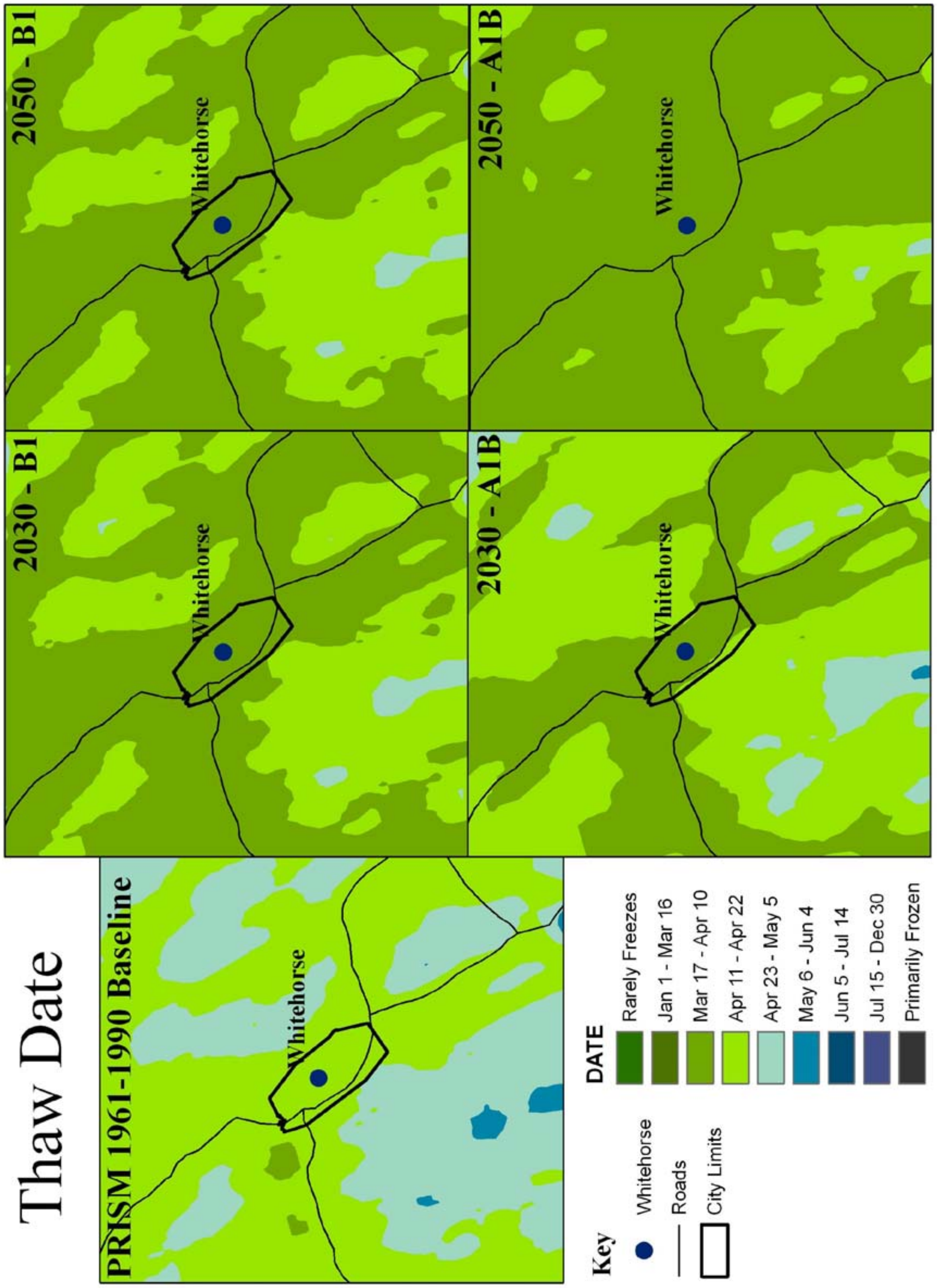
Projected thaw dates are expected to occur earlier in all projections. The thaw date in Yukon is projected to occur 8-12 days earlier by 2050.

Changes in the number of days projected to occur at freeze-up or thaw are provided in Table 5.

Table 5: Projected change in Freeze-up and Thaw dates (days)

	Baseline (1961-1990)	B1		A1B	
		2030	2050	2030	2050
Freeze-up dates	September 28	October 6	October 9	October 6	October 13
Δ Change	-	8	11	8	16
Thaw dates	May 3	April 26	April 25	April 28	April 21
Δ Change	-	7	8	5	12


Date of Freeze-Up
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
DATE
Primarily Frozen
Jan 1 - Aug 14
Aug 15 - Sep 4
Sep 5 - Sep 18
Sep 19 - Sep 27
Sep 28 - Oct 3
Oct 4 - Oct 8
Oct 9 - Oct 13
Oct 14 - Oct 19
Oct 20 - Oct 26
Oct 27 - Nov 4
Nov 5 - Nov 16
Vob 17 - Nov 29
Nov 30 - Dec 30
Rarely Freezes
Whitehorse
Roads
City Limits


Thaw Date
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
Key
Whitehorse
Roads
City Limits
DATE
Rarely Freezes
Jan 1 - Mar 16
Mar 17 - Apr 10
Apr 11 - Apr 22
Apr 23 - May 5
May 6 - Jun 4
Jun 5 - Jul 14
Jul 15 - Dec 30
Primarily Frozen

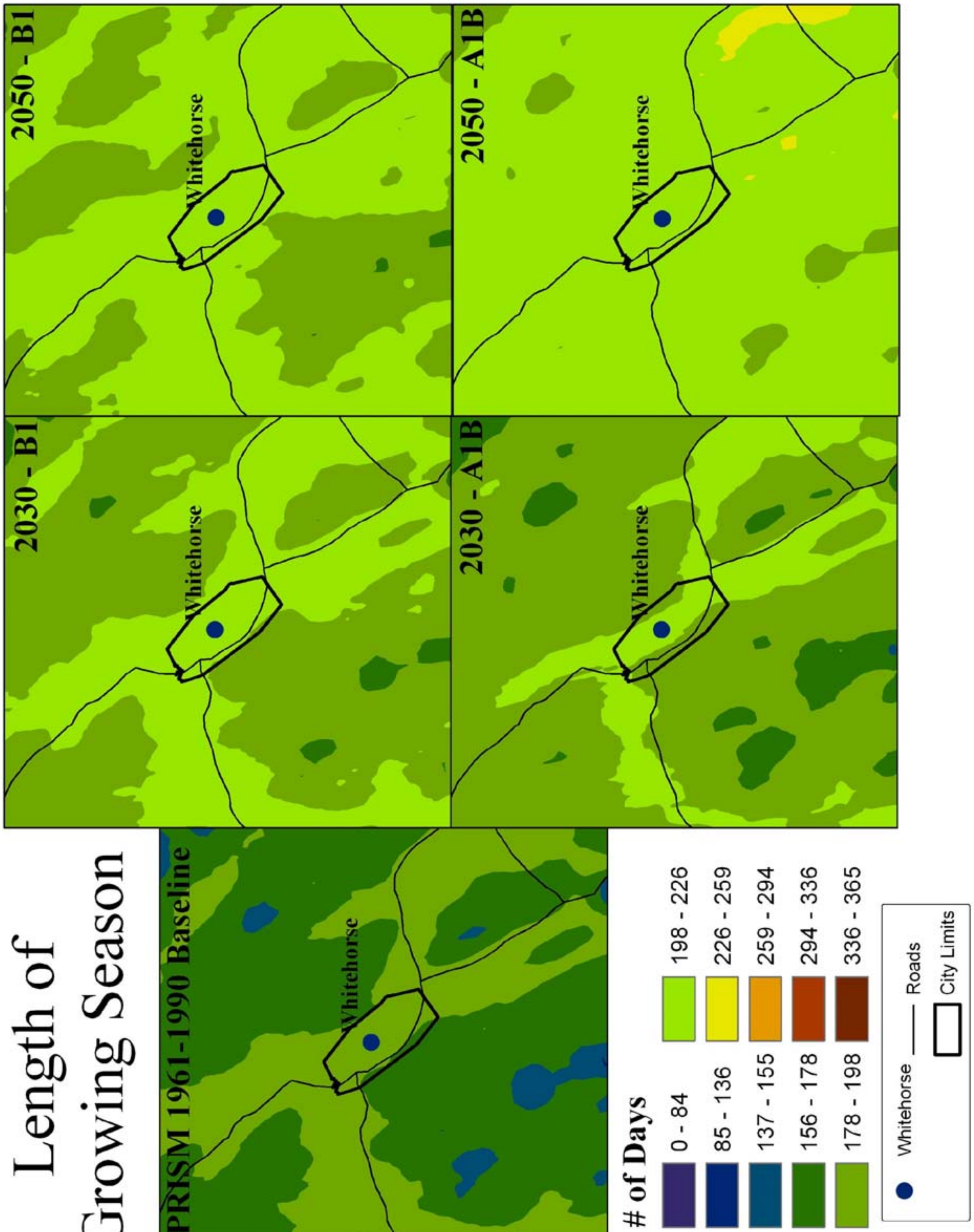
Growing Season

The projected growing season projected below corresponds to the number of days between spring thaw and autumn freeze-up, as defined by the time at which mean temperatures cross 0°. This time span does not correspond to growing season for crops, and is a simple measure of how a warmer climate may affect Yukon in the spring and fall. These data were derived by interpolating daily temperature values based on linear temperature ramps between monthly means. Mean values were assumed to occur in the middle of each month.

The growing season for the Whitehorse area is projected to increase in all projections; rising from 150 days to 168-175 days by 2050, an addition of 18-25 days. Table 6 shows the number of days that will be added to the growing season over time and by SRES scenario. The area benefiting from a longer growing season is also expected to increase in size with a more significant onset of climate change.

Table 6: Projected change in Growing Season (days)

	Baseline (1961-1990)	B1		A1B	
		2030	2050	2030	2050
Growing Season	150	165	168	162	175
Δ Change	-	15	18	12	25


Length of Growing Season
PRISM 1961-1990 Baseline
2030 - B1
2050 - B1
2030 - A1B
2050 - A1B
Whitehorse
# of Days
0 - 84
85 - 136
137 - 155
156 - 178
178 - 198
198 - 226
226 - 259
259 - 294
294 - 336
336 - 365
Whitehorse
Roads
City Limits

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