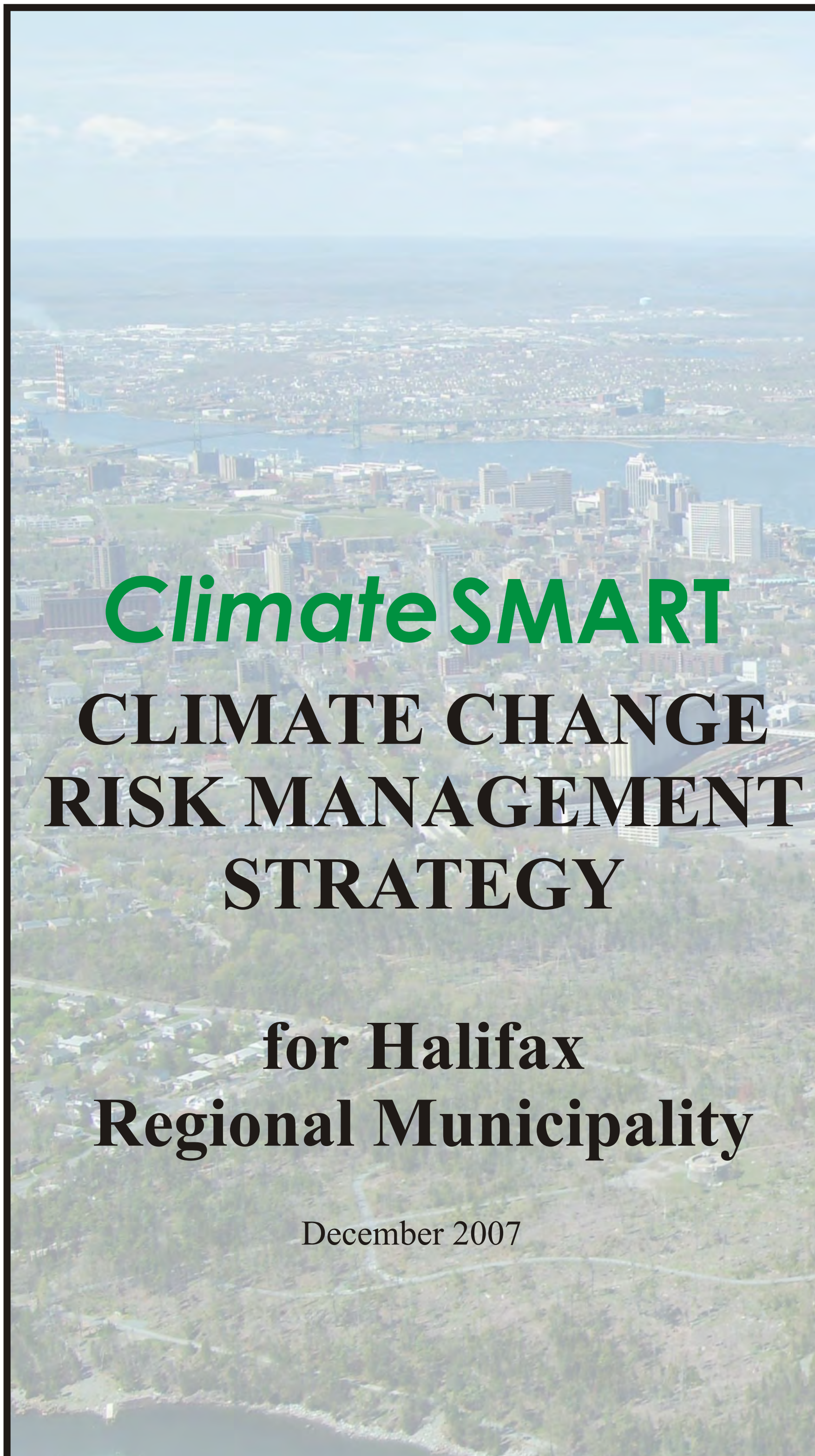

ClimateSMART

CLIMATE CHANGE RISK MANAGEMENT STRATEGY

for Halifax Regional Municipality

December 2007


NOAA


K. March

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HALIFAX REGIONAL MUNICIPALITY

Canada

NOVA SCOTIA

Federation of Canadian Municipalities
Fédération canadienne des municipalités

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Acknowledgements

This report was prepared with financial support and/or in-kind contributions from the Government of Canada's Climate Change Impacts and Adaptation Program; Halifax Regional Municipality; Environment Canada; and the Province of Nova Scotia. As well, the authors would like to thank the following technical contributors to the project:

- Halifax Regional Municipality (HRM policy; operations; communications; document review and guidance)
- Environment Canada Climate Change Section (statistical climate model downscaling; climate change data tools; GIS mapping);
- Inter-Cultural Development Innovations (web site development; community action guide);
- CEF Consultants (land use planning; regional plan review);
- CBCL Limited (land use planning; regional plan review);
- Marbek Resource Consultants (cost/benefit assessment); and
- GeoNet Technologies Inc. (coastal inundation mapping; Coastal DSS®).

Executive Summary

Background

According to the Inter-Governmental Panel on Climate Change (IPCC) and other leading climate change researchers, climate change is impacting and will continue to affect the health and well being of people and communities throughout the world even if global greenhouse gas emissions are reduced to the Kyoto Protocol target levels. If left unmitigated, these climate changes are likely to exceed the capacity of natural, managed and human systems to adapt[1]. Furthermore, one of the world's largest reinsurers, Munich Re, states:

"Climate change will significantly increase the frequency and severity of heatwaves, droughts, bush fires, tropical cyclones, tornadoes, hailstorms, floods, and storm surges in many parts of the world."

[1] Globally, estimates of the annual cost of climate change impacts range from $300 billion to over $2,000 billion.

Globally, estimates of the annual cost of climate change impacts range from $300 billion to over $2,000 billion. While there is no consensus that either Hurricane Juan that affected Nova Scotia, or Hurricane Katrina that devastated New Orleans and other Gulf Coast communities were caused by climate change, the devastating physical, health, and social impacts may foretell the type of impacts on vulnerable coastal communities that are likely to become more frequent in the future as a consequence of global climate change. Halifax Regional Municipality (HRM) has been witness to the physical and social impacts of extreme weather, notably Hurricane Juan in September 2003, and the one-metre snowfall and high winds experienced during the 'Great Maritime Blizzard' of February 2004. These extreme events significantly impacted the region, and severely impacted the region's electrical and communications infrastructure as well as impeding public access to health and emergency service facilities throughout the Province of Nova Scotia but most particularly here in the HRM.

The Conference Board of Canada in a recent briefing note[2] concluded that there as been a lack of discuss on how Canada will adapt to climate change. In addition, the Conference Board concluded that adaptation is not currently a basic consideration in infrastructure or corporate decision making. Because it is a public trust responsibility to do so, adaptation should become as germane to policy and development discussions as public safety and security are today.

In response to HRM's experience with extreme events and the projections that indicate these events are expected to be become more frequent, the Sustainable Environment Management Office (SEMO) in collaboration with members of ClimAdapt (a network of private sector companies in Nova Scotia that provide climate change adaptation expertise) partnered with, the Federation of Canadian Municipalities, Natural Resources Canada, Environment Canada and the Province of Nova Scotia to develop an approach that could be implemented to reduce HRM's contribution to greenhouse gases and manage the impacts of climate change. The result of this initiative was **Climate SMART** (Sustainable Mitigation and Adaptation Risk Toolkit) with the overall objective of mainstreaming climate change into municipal decision making.

This initiative is helping HRM achieve its goal of being ***a leader in the mitigation of pollutants to the environment and adaptation to climate change*** by providing direction on the incorporation of climate change risk management and adaptation in future corporate business unit plans**.** The project will provide HRM with tools to assess vulnerability and to adapt to climate change and supports HRM's overall corporate goal of a ***Healthy, Sustainable, Vibrant Communities*** theme.

[2] Operationalizing Adaptation to Climate Change. February, 2007. 7 pp.

Projected Climate Changes for HRM

Based on Environment Canada modeling to date, within the next 80 years climate change impacts on HRM are projected to include:

- an increase in mean temperature from 2^o to 5^oC, more days above 30^oC, longer heat wave duration;
- a decrease in days with temperatures below -10^oC;
- longer frost free season;
- increase in precipitation by up to 12% and an increase in rainfall intensity;
- a rise in sea-level of between 50 and 88 cm;
- an increase in peak wind speeds associated with tropical cyclones; and
- introduction of new and exotic pasts.

Implications

The Inter-governmental Panel on Climate Change (IPCC) has concluded that where extreme weather events (floods, droughts, heat-waves, storm events) are expected to become more intense and/or more frequent, the economic and social costs of those events will increase. These increases will be substantial in the areas most directly affected, e.g. areas susceptible to coastal inundation, and the impacts will have a trickle down effect spreading from directly impacted areas and sectors to other areas and sectors indirectly through, environmental, economic and social linkages.

Overall, HRM is vulnerable to climate change due to its coastal location and the significant role played in the economy by transportation; health services; forestry; and fishing. The majority of HRM's infrastructure and population is based on the coastline and the municipality has numerous areas of susceptibility to coastal erosion and inundation.

The vulnerability assessment component of the strategy determined a number of key HRM sectors or aspects have the potential to be impacted by the above climate changes including: coastal zones; communities; infrastructure; water resources; human health; fisheries; forestry and agriculture; and environment/ecosystems.

Furthermore, this impact will have a direct effect on a number of HRM's business units, including: Transportation and Public Works (road maintenance); Infrastructure and Asset Management (coastal road infrastructure; recreational park management); Community Development (projected impacts will require possible changes to land uses); Fire and Emergency Services (will be required to respond more often due to extreme events; Communications (dissemination of information on how to adapt to climate change); Legal Services (possible by-law revisions; inclusion of climate change in risk management protocols); and Halifax Regional Water Commission (water quality; stormwater design; dam management).

Understanding these vulnerabilities allows prioritization of what actions to be taken. To that end, one of the key deliverables of the Climate SMART (Sustainable Mitigation and Risk Tool) project is the development of a climate change ***risk management strategy***. This strategy provides HRM decision makers with an approach to adapt to the changing climate, that is, to minimize risks from climate change. These adaptation measures can take many forms including planning tools, design tools, legal tools, infrastructure changes, and changes in behavioral patterns.

Recommended Actions

The IPCC suggests that the best approach to addressing climate change impacts is a mix of strategies that includes mitigation (such as HRM's GHG Reduction Plans), adaptation, technological development (to enhance both adaptation and mitigation), research (on climate science, impacts, adaptation and mitigation), and education. This approach needs to combine policies with incentive-based approaches, and actions at all levels from residents through to provincial and federal governments.

A key barrier against the incorporation of climate change in decision making is that municipalities and private enterprise are unsure of or do not know how to assess the risks of climate change as rigorously as risk assessment for other risks such as commercial or security risks[3]. This ***risk management strategy*** provides HRM with the information necessary and the protocols to assess risks from climate change by adapting risk management guidance from other jurisdictions such as Australia and the Caribbean to HRM.

In addition to implementing a risk management strategy, a number of enabling priorities were identified during the Climate SMART project that need to be in place prior to implementing specific adaptation measures. These key enablers include:

- Leverage innovative and responsive funding through external partnerships for climate change adaptation projects.
- Enhance community outreach and education on climate change to encourage participation and prepare stakeholders for possible controls; e.g. land use planning.
- Integrate up-to-date climate hazard mapping and asset inventory for each business unit with LIDAR mapping.
- Incorporate climate change one of the risk considerations into the integrated risk management program being implemented by HRM.
- As part of a life cycle assessment management system include climate change for building assets and groundwater, in particular.
- Continue to enhance inter-governmental collaboration, communication and coordination that integrates HRM's activities with federal and provincial climate change activities and clarifies lines of responsibility.
- Update of design criteria to account for climate change impacts.

[3] Ibid.

Needs for Future Actions (from external parties)

The assessment highlights the need for additional data to support and improve the risk management capacities of HRM from other jurisdictions, including the federal and provincial governments, as well as universities and non-governmental organizations to facilitate decision making. These data needs include:

- more downscaling of climate change modeling specific to HRM;
- detailed digital elevation model of the vulnerable areas of HRM;
- assessment of the costs of climate change on the economy of HRM;
- development of a monitoring program and indicators to track changes in water quantity and quality;
- design criteria based on forecasting including climate change;
- improved understanding of coastal changes in response to climate change; and
- further research on the response of ecosystems to climate change.

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1.0 Introduction

Global climate change is expected to have significant impacts on coastal communities, such as Halifax Regional Municipality (HRM), due to projected rise in sea-level and increase in intensity and frequency of extreme events (floods, droughts, heat-waves, storms). As well, projected changes in precipitation patterns and an increasing temperature will challenge residents, businesses, and governments in the years to come to minimize the social, economic and environmental impacts. The 2006 *Report of the Commissioner of the Environment and Sustainable Development* summarizes the climate change risks faced by Canada as follows:

"Canada is vulnerable to the impacts of climate change. More extreme and intense weather events, such as extended heat waves and winter storms, increase the risk to Canadians' health and safety. Climate change is expected to create additional stresses on Canada's water resources. It is also likely to trigger adverse socio-economic impacts in regions that depend on natural resource industries such as forestry and agriculture. The effects of warming are expected to be greater in Canada's northern latitudes than in other regions; many aspects of life in the North are already affected by melting permafrost and reduced sea ice."

The Commissioner's report also acknowledged that a strategy for adapting to a changing climate is a critical need, given the potential vulnerabilities of regions such as HRM and the number of players that will need to participate in adaptation efforts. However, the Conference Board of Canada recently concluded that adaptation is not currently a basic consideration in infrastructure or corporate decision making. The Conference Board of Canada goes on to say that because it is ultimately a public trust responsibility, it recommends that climate change adaptation becomes as germane to public and corporate policy and development discussions as public safety and security are today.

In it's most recent report, *Climate Change 2007: Impacts, Adaptation and Vulnerability – Summary for Policy Makers*, the Intergovernmental Panel on Climate Change (IPCC)[4] concluded that on a global basis significant climate change impacts are likely or highly likely to occur including[5]:

[4] Prompted by growing public concern, several United Nations agencies, led by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP), in response to requests from many countries, established in 1998, the Inter-governmental Panel on Climate Change (IPCC). This Panel was charged with summarizing from the extensive available scientific literature, the state of knowledge of anthropogenic climate change. IPCC has produced four authoritative main reports (in 1990, 1995, 2001 and 2007) involving several thousand climate scientists and economists from more than 70 countries. These main findings have been endorsed by the National Academies of Science of 20 countries.

[5] Climate Change 2007: Impacts, Adaptation and Vulnerability – Summary for Policy Makers. Intergovernmental Panel on Climate Change. February, 2007.

- Increasing risks to coastal areas, including coastal erosion and flooding, due to climate change and sea-level rise. This effect will be exacerbated by increasing development pressures on coastal areas.
- In areas such as HRM, where extreme weather events become more intense and/or more frequent, an increase in the economic and social costs of those events. These increases will be substantial in the areas most directly affected.
- Increased frequency of cardio-respiratory diseases due to higher concentrations of ground level ozone related to climate change.
- Altered spatial distribution of some infectious disease vectors.
- A poleward shift in ranges in plant, animal species as well as pests.
- Shifts in ranges and changes in algal, plankton and fish abundance in high-latitude oceans with regional changes in fish distribution to continue with adverse effects projected for some aquaculture and fisheries.

- Effects on agricultural and forestry management at Northern Hemisphere higher latitudes, such as earlier spring planting of crops, and alterations in disturbance regimes of forests due to fires and pests. Crop productivity is projected to increase slightly.
- An increase in the spread of infectious disease vectors in some areas, and allergenic pollen in Northern Hemisphere high and mid-latitudes.

In HRM, specifically, these impacts are projected to include:

- increase in damage to coastal infrastructure, roads, wharves.
- increased incidence of storm and sanitary sewer overflows.
- increased disruption to critical utilities such as power and telephone lines.
- increase in vector-borne diseases such as Lyme's disease and West Nile virus.
- decreased availability of ground water for homes and businesses
- increased risk of forest fires.

Overall, the IPCC concluded that current adaptation is uneven and readiness for increased exposure is low.

In the debate over climate change, the discussion has primarily been focused on mitigating the causes of climate change by reducing our emissions of greenhouse gases (GHGs). Increasingly, however, many public and private entities are beginning to assess what mechanisms need to be in place to minimize the impacts cited above. In order to minimize the impacts of climate change on HRM's health and sustainability, HRM must adapt. *Adaptation* is defined as adjustments in natural and human systems in response to actual or projected climate changes and their effects.

The Commissioner's report also acknowledged that a strategy for adapting to a changing climate is a ***critical need,*** given the potential vulnerabilities of regions such as HRM and the number of players that will need to participate in adaptation efforts. However, the Conference Board of

Canada recently concluded that adaptation is not currently a basic consideration in infrastructure or corporate decision making. The Conference Board of Canada goes on to say that because it is a ultimately a public trust responsibility, it recommends that climate change adaptation becomes as germane to public and corporate policy and development discussions as public safety and security are today.

In order to understand what adaptation measures to take and how to prioritize the measures a number of steps must be completed as shown below.[6] The sections of this strategy corresponding to each of the Steps are provided in parentheses.

[6] *CAN/CSA-Q634-M91 – Risk Analysis Requirements and Guidelines, and CAN/CSA-Q850-97 – Risk Management: Guidelines for Decision-Makers.*

Step 1 – Understand the Context (Section 2)

Step 2 – Identify Climate Change Impacts (Section 3; Appendices A, B, C)

Step 3 – Identify, Quantify and Qualify the Risks (Section 4)

Step 4 – Prioritize the Risks (Section 5)

Step 5 – Identify the Options to Manage the Risks (Section 6)

Step 6 – Identify the Resources, Barriers and Timeframes (Section 7)

As HRM moves forward with the implementation of the Regional Municipal Planning Strategy, HRM will be developing Functional Plans dealing with hazards to development. This document, together with the resources contained in the appendices and the HRM website (http://www.halifax.ca/climate/index.html), will be the key reference in identifying potential hazards to development related to climate change and describing an approach to addressing these hazards.

Step 1 – Understand the Context

This step provides the overall context for the Municipal Business Units and affected environment in which climate change impacts are or have the potential to occur. It identifies those elements that are under the control of the Municipal Business Units and those elements that have influence on the Business Units as well as those elements the Business Units do not have direct control of.

2.0 Context for the Risk Management Strategy

In order to assess risks and to identify priorities and adaptation options related to climate change, a risk management strategy for any entity must first document the context in which the entity operates. This context consists of the administrative context e.g., HRM governance and management structure, and the broader physical, social and regulatory environment that has influence on the entity.

2.1 HRM Administrative Structure and Assets

In HRM, as in all municipalities, Council is the main governing and legislative body for the Municipality. Regional Council is responsible for overall municipal direction, policy and decision making. Regional Council, in turn, is supported by an administrative organization that implements and administers the policies and programs established and approved by Regional Council (Figure 2-1). Table 2-1 summarizes the responsibilities and assets of the administrative, strategic and operational business units of HRM. Assets are divided into physical assets under control of the business units and those assets the business units have influence or control over.

2.2 Physical Character

HRM's climate is heavily influenced by its proximity to the Atlantic Ocean. While HRM exhibits a continental climate, due to the predominantly eastward movement of winds across North America, surrounding waters modify the climate, making winters milder and summers cooler than areas to the west.

Atmospheric currents from the south and northwest also converge over the Atlantic region, with a warm moist storm track from the south and cold dry air moving with the Jet Stream from the northwest. These atmospheric systems are more intense during winter months and produce a wide range of natural weather extremes, including heavy snowfalls and rainfalls, winter thaws and ice storms, gale to hurricane force winds, high waves and storm surges. In the recent past, hurricanes and extreme wave action have proven devastating to the HRM's ecosystems and human populations alike.

Figure 2-1 Halifax Regional Municipality Organizational Chart

Table 2-1 HRM Business Units and Functions

Business Unit	Responsibility	Physical Assets	Controls or Influences	Relevance to Climate Change
Chief Administative Officer	• Information, support, guidance to Regional Council • Lead and manage administrative functions • Implementation of policies and priorities of Regional Council	None.	• Overall HRM business systems • Intergovernmental affairs • Internal and external communications • Economic development	• Sets overall policy direction and priorities
Communications	• Internal and external communications	None.	• Information provided to internal and external parties. • Electronic, e.g., website and print communications.	• Can provide internal and external communications regarding GHG reduction and adaptation to climate change
Fire and Emergency Services	• Provision of fire, ambulance and emergency response services • Fire safety and emergency preparedness	• Fire and emergency equipment and buildings. Ambulance services contracted out.	• Emergency response and ambulance services. • Fire and emergency communications.	• Often, especially in communities served by volunteer departments, are the first responders in emergencies • Potential for increase in susceptibility of urban/forest to forest fire • Increase in intensity and frequency of extreme events may place burden and response resources
Police Services	• Provision of services for community protection and control • Communications related to police services activities	• Enforcement equipment and buildings.	• Emergency response services.	• Maintenance of order during emergencies resulting from extreme events

Business Unit	Responsibility	Physical Assets	Controls or Influences	Relevance to Climate Change
Community Development	• Land use policy and planning • Regional policy and planning • Building permits and inspection • Land use zoning • Heritage property	None.	• Land use • Development form and subdivision layout • Designated hazard areas, e.g., floodplains • Land use restrictions • Input to by-laws	• Land use planning and development of communities will be affected by climate change impacts such as sea-level rise • Changes in zoning, land use by-laws may be required to adapt to climate change
Transportation and Public Works	• Waste management policy and implementation • Public transit • Street and road (HRM owned) maintenance • Snow and ice removal • Fleet services	• Otter Lake residuals disposal facility. • Highway 101 Landfill (closed) • Collection, recycling, composting are contracted out. • Buses, ferries • Street maintenance equipment • HRM vehicle fleet	• Residential and commercial/industrial waste management practices • Input to By-Laws	• Type of equipment and amount of deicing agents available may change due to climate change
Infrastructure and Asset Management	• Transportation planning • Sustainable environment policy • Design and construction of roads • Management of HRM owned/controlled buildings • Real estate • Management of business parks • Management of recreational parks	• Streets and roads not under jurisdiction of the province • Buildings and land • Business parks • Recreational parks	• Overall policy regarding environmentally sustainable approaches to Municipal activities • Encourages, in cooperation with other business units, residential, commercial/industrial, and institutional environmentally sustainable practices • Input to By-Laws	• Climate change is a key consideration in sustainability • Has taken the lead on climate change issues for HRM • Location and protection for coastal roads • Building design standards may need to be revisited due to climate change • Management of parks and gardens may be affected by climate change

Business Unit	Responsibility	Physical Assets	Controls or Influences	Relevance to Climate Change
Halifax Regional Water Commission[7]	• Water and wastewater treatment and related infrastructure • Stormwater infrastructure design, construction and maintenance	• Water treatment plants • Dams • Wastewater treatment plants • Water and sewer piping • Stormwater culverts and retention ponds • HRWC vehicle fleet	• Input to By-Laws	• Wastewater and stormwater piping design criteria will need to consider climate change impacts • Potential impacts on HRM controlled dams need to consider climate change
Finance	• Corporate financial management • Fiscal and tax policy • Procurement	None.	• Overall HRM budget decisions • Allocation of capital and operational funds • Tax rates and fees	• Anticipated that additional funding to business units will be required to address climate change • Tax rates and fees may need to be used to cover the cost of adaptation measures
Business Systems and Control	• Geographic information services • HRM intranet and internet • HRM information technology • Call centre/dispatch services	• Information management hardware and software.	• Provides mapping and data to various business units including Community Development and Transportation and Public Works	• GIS mapping to include inundation model results and downscaled climate change data that can be used in for planning and engineering design
Legal Services; Risk Management	• Writing By-Laws • Interpretation of legal statutes for staff and Council • Prosecutions and defence on matters under HRM	None.	• Policies and programs	• Implements corporate wide risk management approaches that can include climate change considerations • Drafting of by-laws that may be required as part HRM's approach to climate change

Business Unit	Responsibility	Physical Assets	Controls or Influences	Relevance to Climate Change
	jurisdiction • Corporate (HRM) Risk Assessment and Management			adaptation

Historically, settlements by the Mi'kmaq as well as Europeans were centered in coastal areas, especially in sheltered bays and along estuaries, as water was the primary route for transportation and source of food. Present day communities, many continuing from historical settlements, including those in HRM, e.g., Lawrencetown, Prospect, are located on the coast, as well as along estuaries and river systems. Several major rivers empty into the Atlantic Ocean along HRM's coastline and support numerous communities along their shores. These rivers extend far inland and include the Musquodoboit River and the Porter's Lake system.

2.3 Physical Character

Landform and climate within HRM can be categorized within two distinct landforms, based on "theme regions" as described in the *Natural History of Nova Scotia*[8]. For the purposes of this discussion, the theme regions have been amalgamated as Interior and Coastal regions, as discussed below and shown on Figure 2-2.

Coastal
HRM is bounded by the Atlantic Ocean to the south, which modifies the weather experienced throughout the extensive reaches of the Municipality. Because the sea is much slower to warm up and cool down than the land, cold winds from coastal areas delay the arrival of spring, extend the fall season and delay the onset of winter. Additionally, daily temperatures in coastal areas and inland can differ by as much as 20°C due to the influence of sea breezes, particularly in late spring and early summer.

The Atlantic Coast is an exposed, high wave energy environment, a mixture of resistant granite and Meguma group headlands interspersed with extensive sand or gravel beaches in protected areas and bays. Landforms include rocky headlands, large bays, small coves, and natural harbours. The coastal bedrock is low lying and elevations rarely exceed 100 m. Tidal range may reach over 2 m. Coastal areas are exposed to significant erosional forces from tidal action, storm surges and wind. While offshore winds do not have an erosive effect on the Atlantic coastline, storm events do produce onshore waves that rework exposed glacial deposits, with Atlantic coast drumlins being eroded at a mean rate of 1 m per year[9].

In general, this is a cool water coast. The ocean moderates seasonal and daily temperatures, resulting in high precipitation and humidity, high winds, fog and salt spray. Winters are relatively mild and summers are short and cool. Mean winter temperatures are above -5°C and in

[8] Davis, D and Browne, S. (Eds.) 1996. The Natural History of Nova Scotia. Halifax. Nimbus and Nova Scotia Museum.

[9] Geological Society of Canada CoastWeb Fact sheet. http://www.gsca.nrcan.gc.ca/coastweb/facts_e.php. 2002.

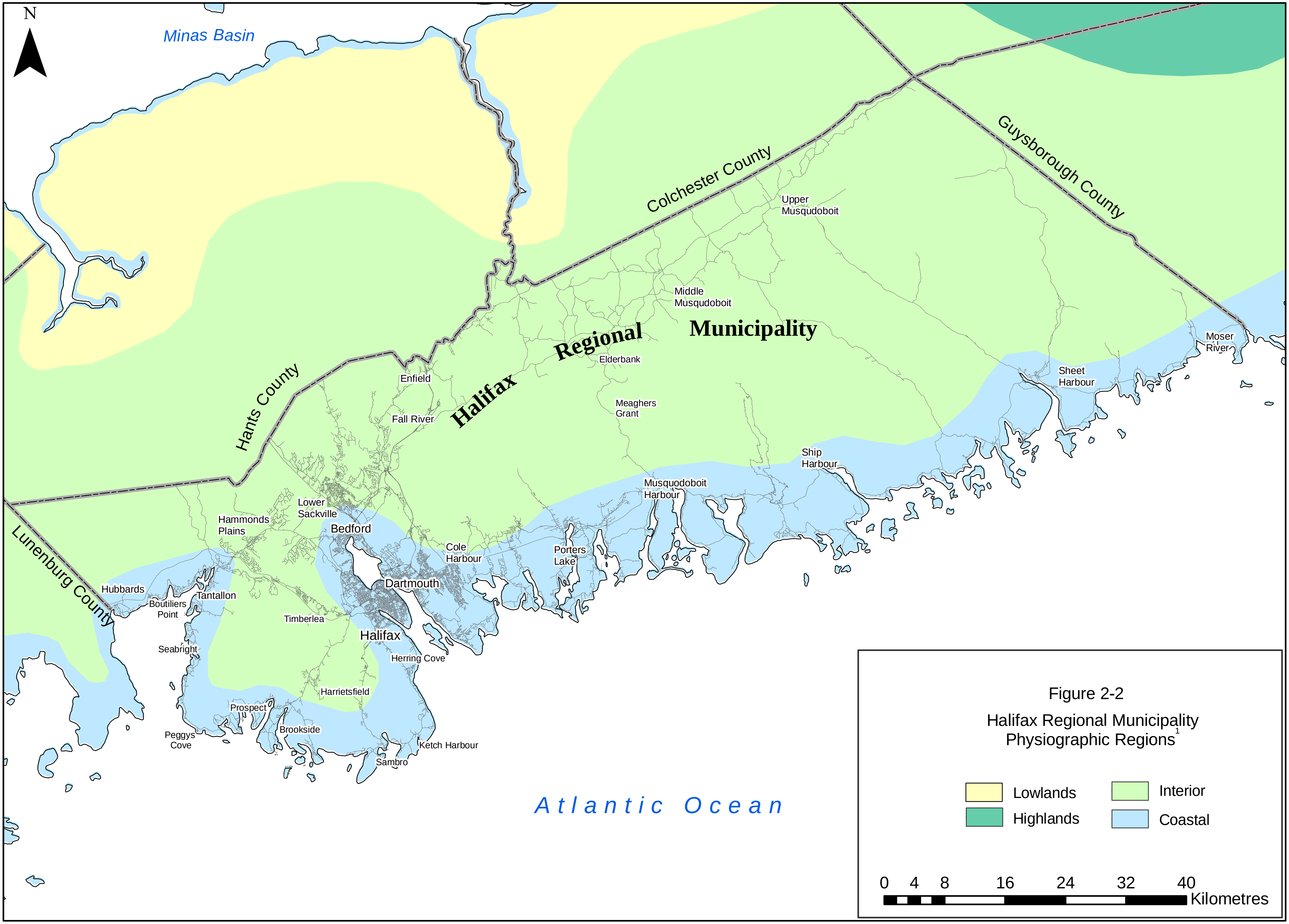


Figure 2-2
Halifax Regional Municipality
Physiographic Regions[1]

[1] After Davis and Browne (1996)

some areas remain above 0°C. Spring starts early but is long and cool. Because of frequent fogs and the cooling influence of ocean waters, the mean summer temperature is 15-20°C compared to 20-25°C throughout the rest of the Province. HRM receives fairly high precipitation, usually between 1400 and 1500 mm. Only about 15% falls as snow because of mild winter temperatures, with most of the region receiving less than 200 cm of snow annually. Ice forms only locally in bays[10].

Interior
The Interior region represents the inland portions of HRM. The region is primarily a uniform plateau with some low ridges and shallow valleys. Elevations range from about 150 m to 275 meters above sea level.

2.4 Special Natural Features, Factors and Processes

Climate patterns vary with proximity to the ocean and according to latitude. While there is considerable climatic variation, the Interior essentially has an inland, lowland climate sheltered from direct marine influences and characterized by cold winters and warm summers. Mean annual temperature ranges from 1 to 5°C and higher.

Rainfall averages 1000 mm per year inland, whereas the average annual rainfall in regions near the coast exceeds 1400 mm. Snowfall averages 150 cm near the coast to 250 cm or more in higher areas and further inland[11].

Land Emergence
Land emergence in Nova Scotia is a result of post-glacial rebound and tilting of the coastline. During glacial retreat at the end of the Wisconsin period, sea level rose and flooded the present day land areas. The land then underwent isostatic rebound and the sea level receded, leaving evidence of marine habitat stranded above high water. Raised beaches and estuarine delta sediments several metres above high tide, wave cut platforms, and fossilized marine organisms above high tide are evidence of lower sea levels from 15,000 to 8,000 years ago.

Since the last recession of glacial ice, sea level has been rising worldwide - at a rapid rate until about 6,000 years ago, and at a much slower rate since then. Uplift had varying results in Nova Scotia. In the Bay of Fundy, the coastline was raised several tens of meters above the present high tide mark. The south coastline around Yarmouth was left in the same position relative to the

[10] Environment Canada. 2004. Atlantic Climate Centre website. http://atlantic-web1.ns.ec.gc.ca/climatecentre/default.asp?lang=En&n=61405176-1

[11] Ibid.

sea. While the southeast coastline, from Shelburne County to Guysborough County, including HRM, was drowned as the sea moved landwards across the continental shelf[12].

Submergence

Once the glaciers retreated and the Earth's crust rebounded, some regions began to subside. Evidence of past submergence of terrestrial habitats are shown in the remains of ancient forests exposed several metres below the present high tide level. Tide records for the past century in Nova Scotia indicate an increase in sea level of more than 35 cm since 1896; however, Roland Gehrels, of the University of Plymouth, has recorded a rise in sea level at Chezzetcook, in HRM, of 60 cm since 1750 by reconstructing the deposition of salt marsh sediments[13].

Part of the reason for the increase in sea levels can be attributed to subsidence of the crust following post-glacial rebound. According to Webster et al.[14], approximately 20 cm per century of sea level rise can be attributed to subsidence of the Earth's crust; the remaining 10 to 12 cm (this number varies within the Maritime Provinces) is considered to be due to sea level rise. For Nova Scotia increases in sea level will vary across the province but within HRM it is estimated to be 0.65 m by 2100[15].

The Geological Survey of Canada maintains coastal monitoring sites in Nova Scotia to provide baseline information about long-term changes in shoreline position, morphology and the impacts of extreme storm events. Recent monitoring of two beaches on the Eastern Shore of Nova Scotia has shown the variations of coastal change. One low beach has been retreating landward at a rate of eight metres a year, whereas a higher-crested beach a few kilometres away shows little retreat. In areas where the coastline is rocky the rate of retreat is barely noticeable over historical time. In other areas, where the coast is composed of loose sand, gravel and mud, the rate of retreat is much higher. In Atlantic Canada, rates of erosion can reach up to 10 metres per year, but are generally less than one metre per year. Historical records show the loss of entire islands along the coast of Nova Scotia[16].

[12] Nova Scotia Department of Natural Resources . "Natural Resources", Volume 2, Number 1, Fall 1998.

[13] Gehrels, Roland et al., 2001. High –resolution Reconstruction of Sea-Level Change During the Past 300 Years. Geological Society of America, November 2001.

[14] Webster et al. 2003. Geospatial Solutions Online. www.geospatial-online/geospatialsolutions/article/articledetail.jsp?id=58322

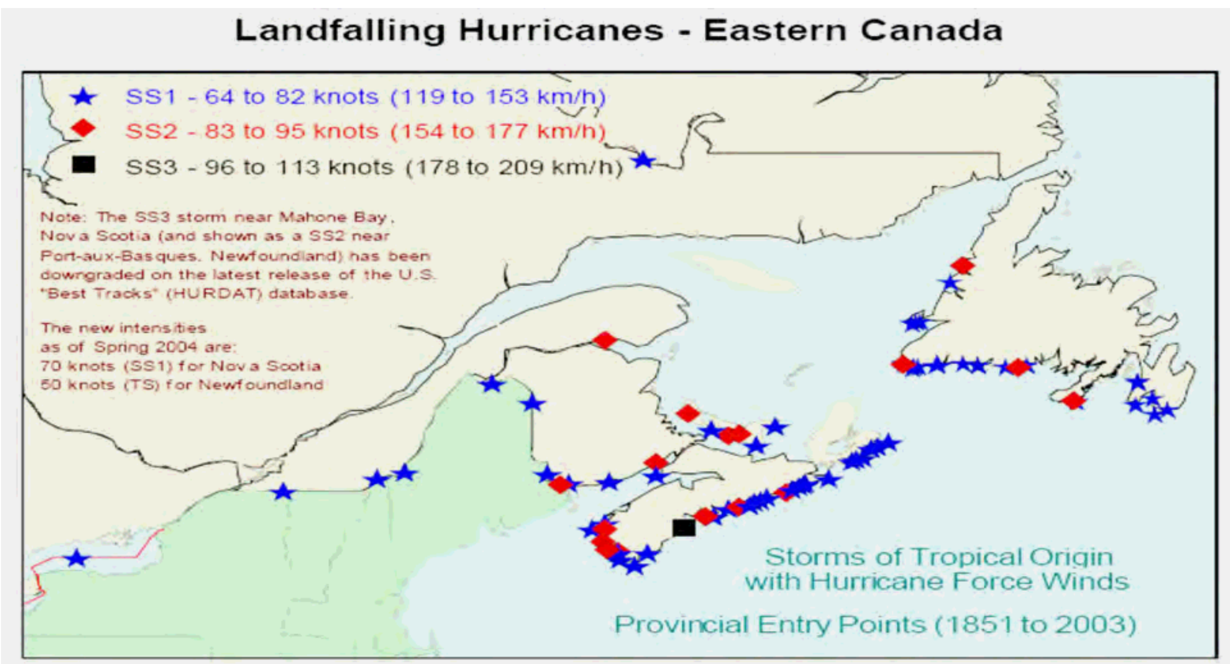
[15] D. Forbes, Atlantic Geosciences Centre, personal communication.

[16] Natural Resources Canada, http://www.gsca.nrca.ga.ca/coastweb/facts_e.php#fast

2.5 Regional/Local Climatology and Related Phenomena

Variability in Rainfall and Temperature
Precipitation has historically been slightly greater in the late fall and early winter because of the more frequent and intense storm activity. In most years there is a good supply of rain during the growing period. However, droughts have occurred in Nova Scotia. A dry month is considered to be one in which 25 mm or less of rain falls. In our current climate, dry months are not common anywhere in the Province, but are more likely to occur outside HRM. A prolonged warm, dry, and sunny spring in 1986 contributed to the worst forest fire outbreak in the province's history. The previous summer, several months of below normal precipitation dried up wells and streams.

Vulnerability to Storms, Hurricanes and Other High-Energy Events
According to Environment Canada, HRM and more generally, Nova Scotia and Newfoundland and Labrador receives the most storms of any region in Canada due to the provinces' proximity to the Gulf Stream (as illustrated by Figure 2-3). This is attributed to nor'easters, which are most prominent during the winter and early spring. These storms can generate wave heights in excess of 14 metres and storm surges of more than one metre.



Source: Environment Canada

Figure 2-3 Landfalling Hurricanes – Eastern Canada

The coastal areas of HRM are often subjected to high-energy wave action associated with hurricanes and other tropical storm systems. Typically tropical storms and hurricanes weaken as they approach Nova Scotia once they pass over the cooler water north of the Gulf Stream. In the recent case of Hurricane Juan in September 2003, the waters along the Atlantic coast of Nova Scotia were 3^{o}C warmer than normal, which allowed the storm to retain its strength as it made landfall.

Since 1970, 17 hurricanes and tropical storms have made landfall in Nova Scotia, three in HRM. A summary of these events is provided in Table 2-2.

Table 2-2 Hurricanes and Tropical Storms Affecting HRM 1970-2003[17]

Year	Storm	Type	Landfall Location
1991	Unnamed 'The Perfect Storm'	Tropical Storm	HRM
1996	Hortense	Hurricane	HRM/Guysborough
2003	Juan	Hurricane	HRM

2.6 Important Natural Features

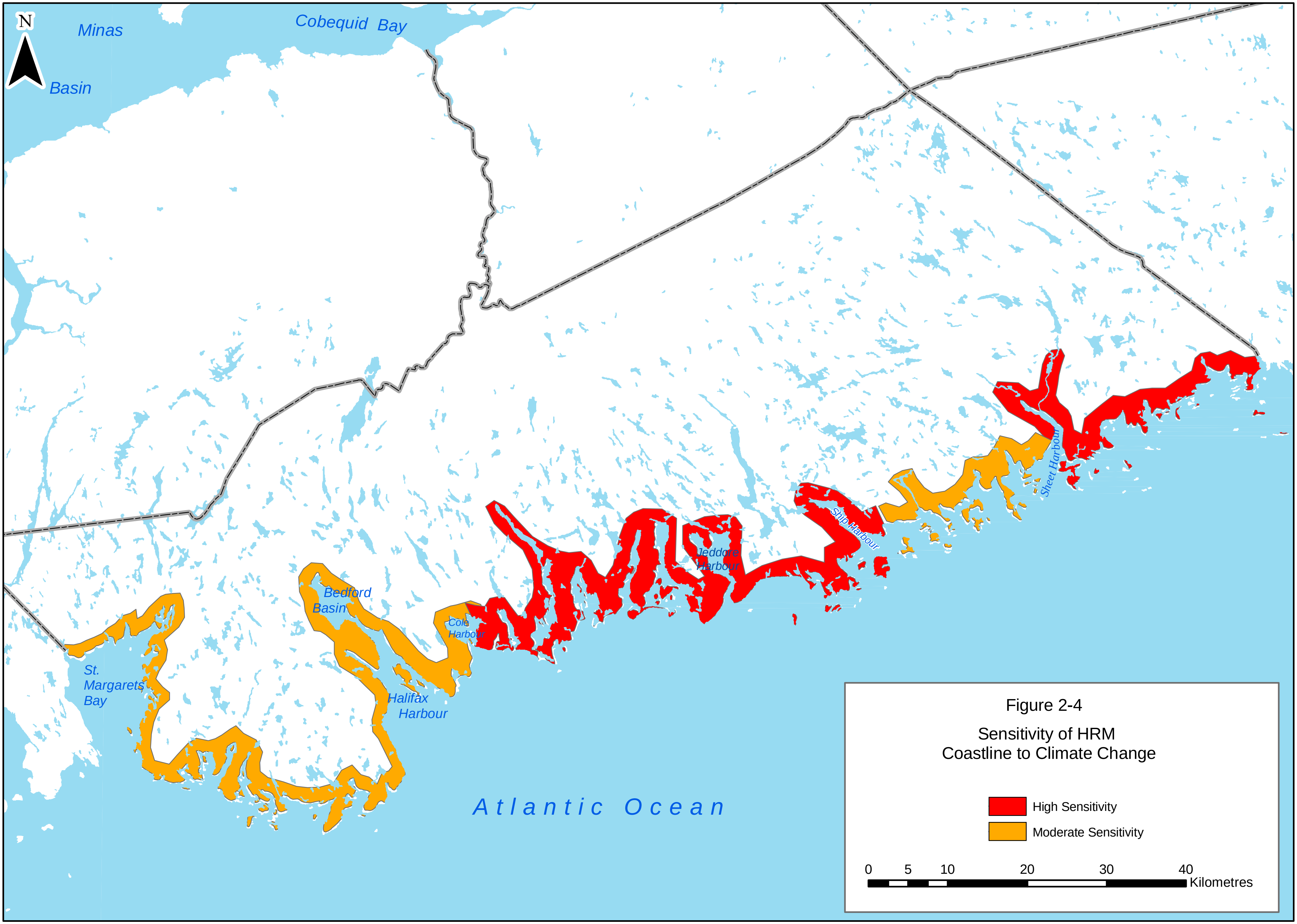
Natural Resources Canada reports, "Much of the coast of Atlantic Canada is highly sensitive to the effects of sea-level rise. The most sensitive coasts are commonly low-lying, with salt marshes, barrier beaches, and lagoons. They will experience such effects as increased erosion, rapid migration of beaches, and flooding of coastal freshwater marshes. A higher sea level on the coast will affect wetlands and ecosystems at the edge of the ocean, disrupting the habitat and life cycle of marine life, birds and wildlife in those areas."[18]

Figure 2-4 depicts the sensitivity of HRM's coastline to an accelerated rise in sea level and storm surge events. All of HRM's coastline is ranked as having either medium or high sensitivity to sea level rise.

Wetlands

HRM has about 36,000 hectares of freshwater and saltwater wetlands that cover more than 6% of the Municipality. The majority of wetlands throughout HRM are classed as peatlands. Wetlands provide a natural system of filtration and storage of freshwater and serve to control flooding by absorbing surface water during periods of precipitation and releasing water during drier periods.

[17] Canadian Hurricane Centre
[18] Natural Resources Canada
atlas.gc.ca/site/english/maps/climatechange/potentialimpacts/coastalsensitivitysealevelrise/1-45k – 14 May 2005



Source: Natural Resources Canada

Forests

Approximately 78% of HRM is forested (refer to Figure 2-5). Of the 582,837 hectares of land area, 372,033 ha is productive forest land. As with many other aspects of HRM's natural history, its forest type is a transition between two major vegetation regions. Nova Scotia is in the Acadian Forest Region with the Boreal Forest to the north and the Deciduous Region to the south.

HRM's coastal forests are primarily dominated by Red and Black spruce and Balsam Fir. The vegetation found along the coast is heavily influenced by the moisture and fog resulting from the proximity to the ocean.

HRM's forests support a variety of important habitats for native and rare wildlife species. For example, forests provide important nesting habitats for several species of birds including Great Blue Heron, Osprey, Common Goldeneye and the Bald Eagle.

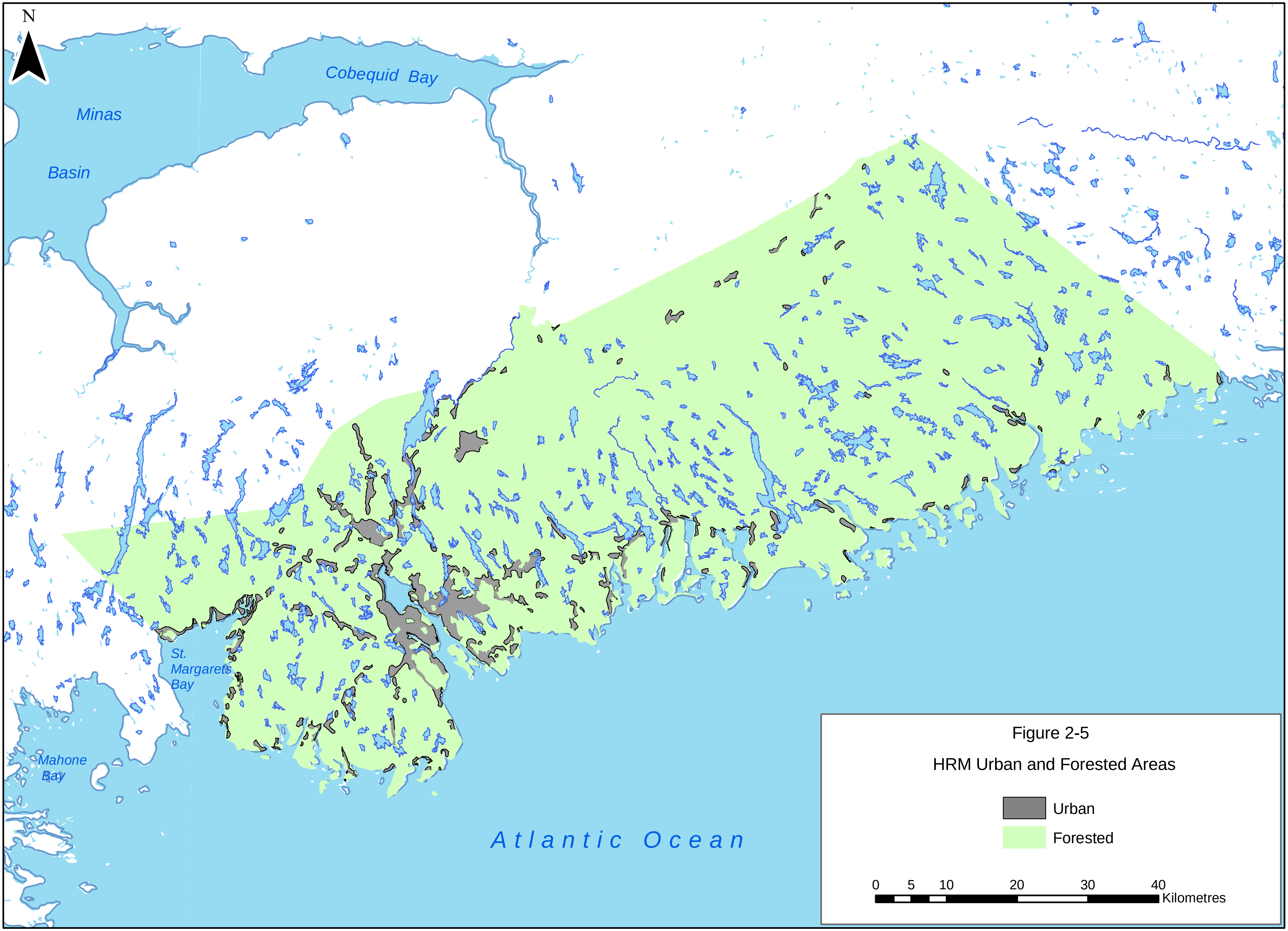
Nova Scotia forests, as a whole, are estimated to provide a minimum of $1.68 billion (1997$) worth of services annually in climate regulation, soil formation, waste treatment, biological control, food production, recreation and cultural benefits[19]. Other important forest ecosystem services such as soil erosion control, water supply and watershed protection, nutrient cycling, gas regulation, pollination, habitat, disturbance regulation and genetic resource were not included in the estimate but are nevertheless important.

By extrapolating from the above numbers for the entire province, HRM forested areas provide an estimated $168,000,000 (1997$) worth of services in climate regulation, soil formation, biological control, recreation and cultural benefits. HRM's forests store approximately over 1,000,000 tonnes of carbon, and estimated to avoid over $21,000,000 in climate change damage costs.

Water Resources

HRM has approximately 7,600 lakes (Figure 2-6) and extensive groundwater resources. Water resources supply potable and industrial water, irrigate farmland, support freshwater aquaculture and generate hydro-electricity, as well as providing a foundation for the tourism industry and recreation for the Province's residents.

[19] Wilson, S. and R. Colman, November 2001. The Nova Scotia Genuine Progress Index, Forest Accounts: Summary of Volume 1: Indicators of Ecological, Economic & Social Values of Forests in Nova Scotia, Atlantic Provinces Economic Council, January 2003. The Forest Industry in the Nova Scotia Economy (2002 Update).



Source: HRM Regional Planning Strategy

Source: Government of Nova Scotia

Eight primary watersheds are found either entirely or partially within HRM and all but one, the Shubenacadie River watershed, empty south into the Atlantic Ocean. The Shubenacadie River watershed empties into the Bay of Fundy to the north. The watersheds of HRM range in size from approximately 100,000 ha to 260,000 ha.

Groundwater and surface water supply potable water to HRM's residents, businesses and industries. Approximately 88% of the Municipality's population relies on treated water from municipal water supply systems; approximately 12% rely on groundwater, supplied through private wells. The Halifax Regional Water Commission (HRWC) owns and operates two large treatment plants (94 million litre and 227 million litre per-day capacity), eight small treatment plants, 16 storage reservoirs, 1,229 km of transmission and distribution main, 7,234 fire hydrants, and approximately 75,000 customer connections.

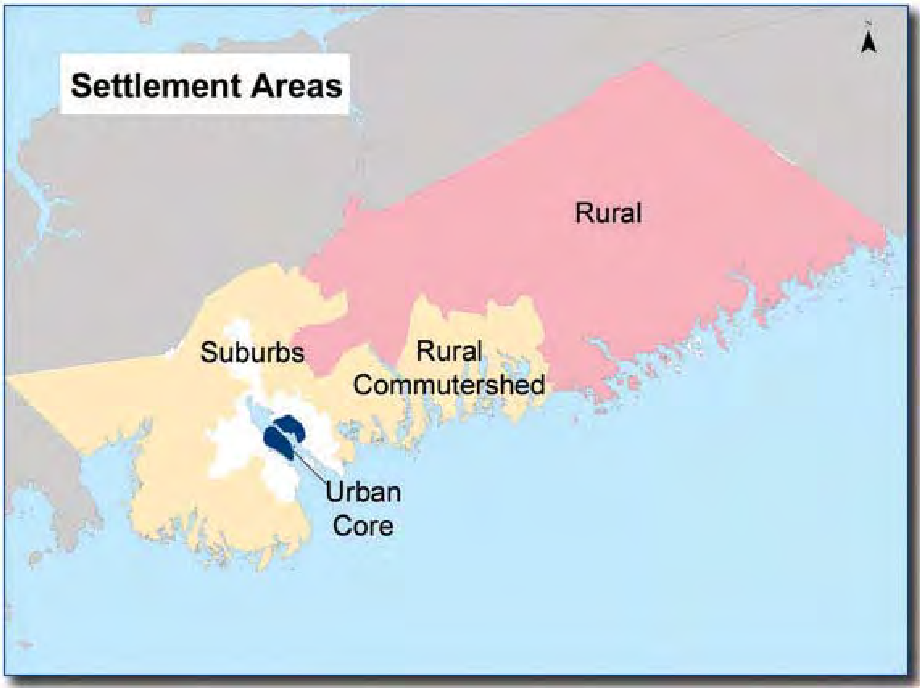
The HRWC has two major water supply sources for the urban area of HRM. Pockwock Lake, west of Halifax, is the source of supply for the Western portion of HRM providing water for the communities of Halifax, Bedford, Sackville and surrounding areas. Lake Major, near Cherry Brook, is the source of supply for the Eastern portion of HRM providing water for the communities of Dartmouth, Cole Harbour, Eastern Passage and surrounding areas.

The watersheds around these lakes are designated as protected areas under the Nova Scotia Environment Act.

2.7 Socio-Economic Profile

According to Statistics Canada, the population of HRM in the 2001 Census was 359,111. The majority of the population is centered around Halifax Harbour and along the roads, lakes and rivers leading out from the greater Halifax area. Figure 2-7 shows the generalized settlement patterns described by HRM's Municipal Planning Strategy. According to the Regional Municipal Planning Strategy, population growth in HRM has focused around rural and suburban areas that are within commuting distance to the urban core. Population growth in the urban core decreased between 1971 and 2000 and has only recently seen a slight increase in population.

Figure 2-7 Settlement Areas



Source: HRM Regional Planning Strategy

HRM's economy is valued at approximately $10 billion. The service sector is the largest contributor to HRM's GDP generating approximately 83%, followed by the goods sector at 17% of the municipality's total GDP[20]. Table 2-3 presents a breakdown of the GDP by sector. In the service sector, the financial, insurance and real estate activities lead in total contributions followed by public service and health services. The primary or resource sector make up only 4% of the GDP in HRM, compared to approximately 25% for Nova Scotia. Manufacturing leads the goods sector at 5.5% and construction is at 4.2%.

Table 2-3 HRM GDP by Sector, 2001[21]

	$ millions	%
Goods Sector		
Primary (fishing, agriculture, mining, oil and gas)	400	4.0
Manufacturing	550	5.5
Construction	425	4.2
Utilities	340	3.4
Service Sector		

[20] Gardner Pinfold Consulting Economists. 2004. Economic Potential of HRM and Halifax Harbour.

[21] Ibid.

	$ millions	**%**
Wholesale trade	530	5.3
Retail trade	655	6.5
Transportation and warehousing	370	3.7
Information and cultural	590	7.0
Finance, insurance, and real estate	2,360	23.5
Professional services	340	4.4
Administrative services	155	3.2
Educational services	570	5.7
Health services	770	7.7
Arts, entertainment, and recreation	75	0.7
Accommodation and food service	260	2.6
Public administration (incl. Defence)	1,260	12.5
Total	10,040	100.0

First Nations

The Mi'kmaq live throughout HRM but their population is concentrated in four areas: Shubenacadie (398.7 ha), Beaver Lake (48.9 ha), Sheet Harbour (30.5 ha), and Cole Harbour (18.35 ha). According to Statistics Canada (2001), there are approximately 3,500 First Nations people living in HRM (Figure 2-8).

Resource use by Mi’kmaq includes hunting, fishing and forestry as well as harvesting resources needed for use by traditional artisans such as basketry, carving, painting, and leatherwork. Another important aspect includes the preservation of traditional environmental resources for medicines and food. Fishing is the largest use of natural resources by First Nations people in HRM with bands participating in the inshore fishing sectors, particularly the crab and lobster fishery.

Commercial Fisheries

According to the Nova Scotia Department of Agriculture and Fisheries’ Business Plan 2002-03, the commercial fishery is a vital economic sector in the Province's Economic Growth Strategy. Agriculture, commercial and recreational fishing, and aquaculture drive the economy of our rural and coastal regions, employing over 28,000 Nova Scotians and contributing some $1.5 billion to the Provincial economy. Seafood continues to dominate Nova Scotia exports, posting a record over $1 billion in 2001.

There are 30 small craft harbour facilities along the coast of HRM. These harbours support relatively small fleets generally less than 20 boats. Aquaculture operations in HRM are focused on two major areas; the eastern side of St. Margarets Bay to Prospect and from Jeddore to Quoddy Harbour on the Eastern Shore (Figure 2-9). The main species farmed in these sites are mussels, oysters, sea scallops, Atlantic salmon and steelhead salmon.

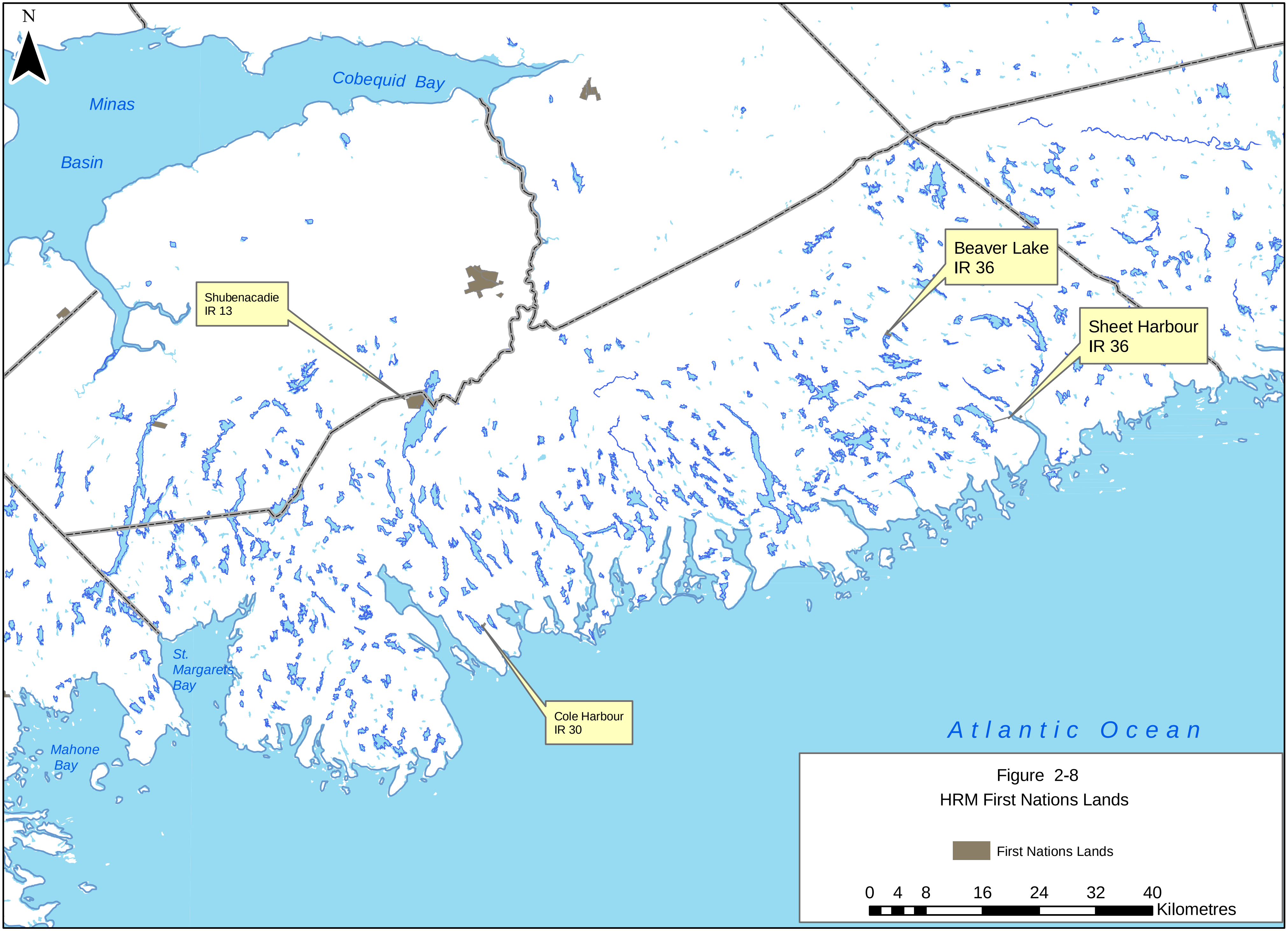
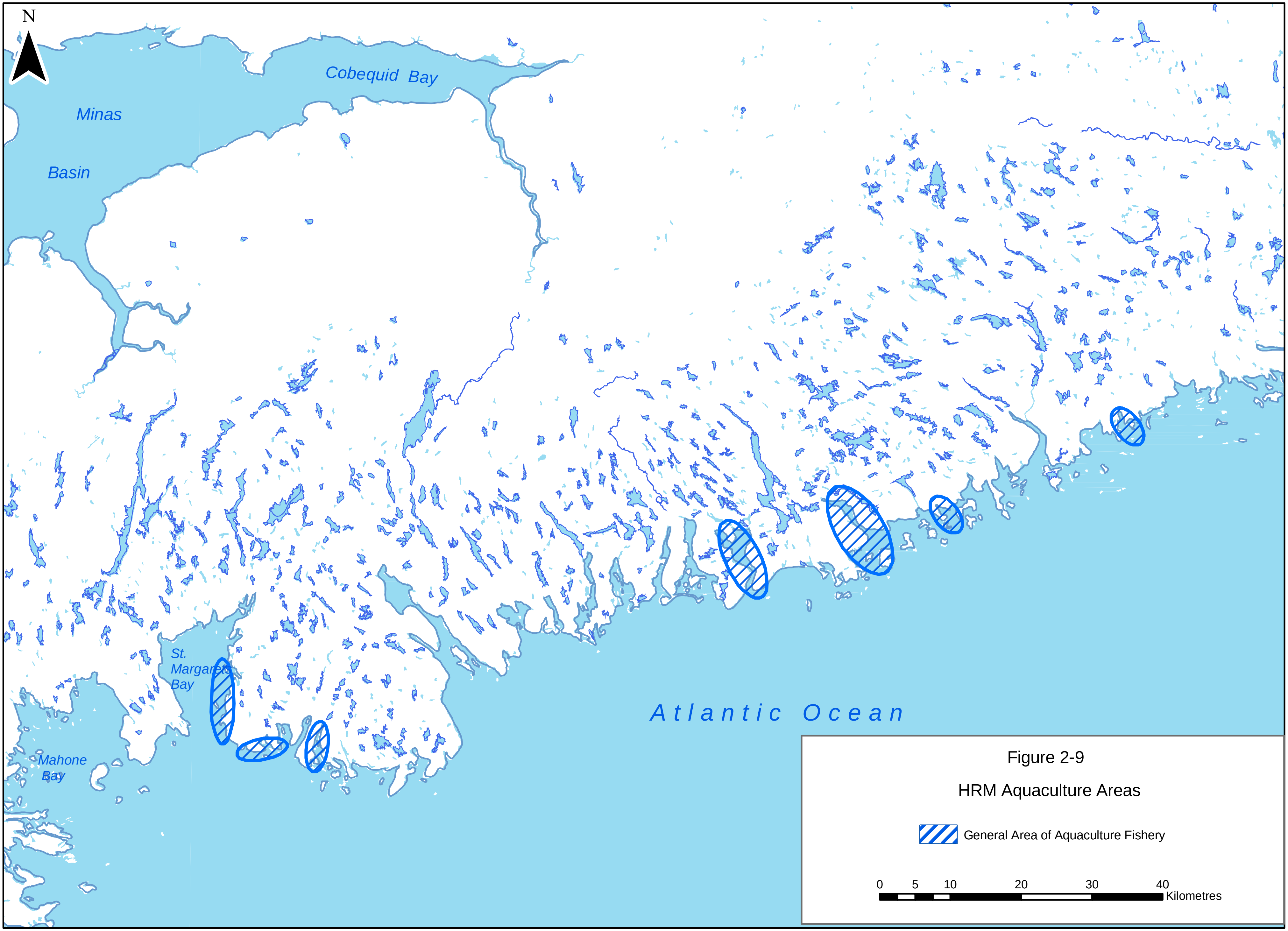


Figure 2-8
HRM First Nations Lands



Source: Nova Scotia Dept. of Aquaculture and Fisheries

Forestry

Forestry activity is a minor component of the Municipality's economy, however, it is important to rural communities throughout HRM. HRM's forestry industry makes up approximately 12% of the total production for Nova Scotia. Much of the timber is sent to local sawmills.

Agriculture

Agriculture in HRM, like forestry and fishing, is a minor component of the total value of GDP for the municipality. Much of the agriculture in HRM is concentrated along the upper reaches of the Musquodoboit River (Meaghers Grant, Elderbank, Middle and Upper Musquodoboit), around the eastern side of Cole Harbour and West Lawrencetown, and in the Carrolls Corner and Dutch Settlement area north of the Halifax International Airport near the border with Hants County (Figure 2-10). Total area of land involved in active farming is approximately 13,000 ha.

Agriculture in HRM consists of beef, dairy, mixed vegetables, horticulture and greenhouse operations. Most of the product is sold within Nova Scotia.

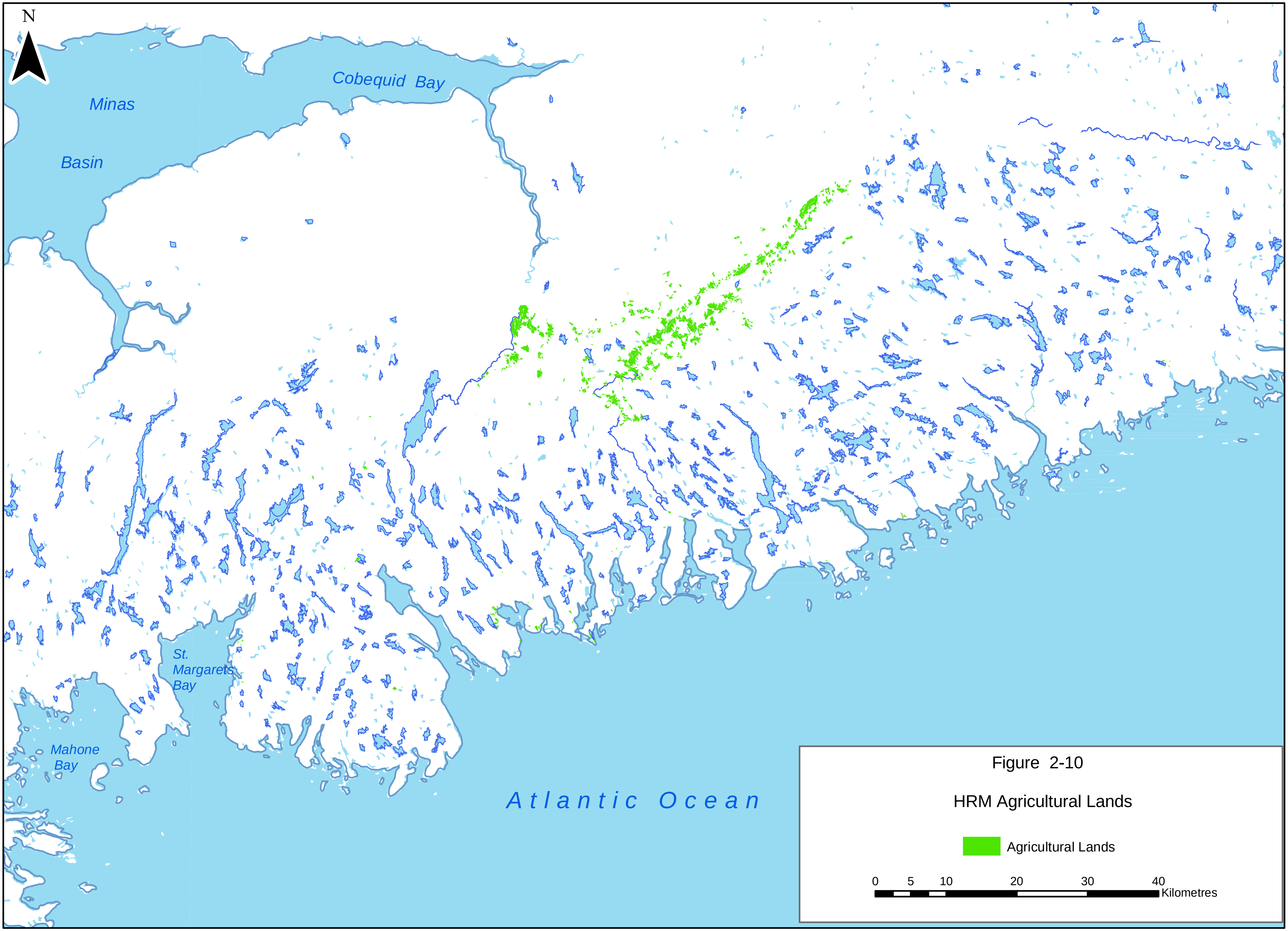
Farmland was also created or reclaimed in HRM from saltwater marshes through the construction of dykes by European (Acadian) settlers. Dykeland in HRM is found around the low-lying shores of Cole Harbour and Chezzetcook Inlet. Dykes protect tracts of farmland from inundation by the sea and historically provided a source of marsh hay for the military and civilian horses and local cattle herds.

Tourism

Wilson and Colman[22] state that

> "Nova Scotians spend $250 million a year on nature and wildlife-related pursuits… of which 70% is non-consumptive (e.g., hiking, bird watching, canoeing) and 27% is consumptive (mostly hunting and fishing). In addition, total tourism revenues rose to a record $1.26 billion in 1999, contributed $430 million to the provincial GDP, and generated $200 million in tax revenues (current dollars), with nature tourism the fastest-growing sector of the industry. The tourism industry directly employs more than 12 000 Nova Scotians, with direct and indirect tourism jobs increasing by 23.4% between 1997 and 1999."

[22] Wilson, S. and R. Colman, November 2001. The Nova Scotia Genuine Progress Index, Forest Accounts: Summary of Volume 1: Indicators of Ecological, Economic & Social Values of Forests in Nova Scotia, Atlantic Provinces Economic Council, January 2003. The Forest Industry in the Nova Scotia Economy (2002 Update).



Source: HRM Regional Planning Strategy

HRM's coastline and coastal waters also provide natural resources in support of the municipality's tourism industry. The sand beaches of Lawrencetown and Clam Harbour have an international reputation and many of HRM's formal tourist destinations are located along the coast. Activities such as sailing, boating, sea kayaking, windsurfing, surfing, deep-sea fishing, whale watching, and scuba diving form basic components for existing and new ventures in tourism and eco-tourism.

Infrastructure
Halifax Harbour is important to the economy of HRM, providing essential access to marine transportation for many of Nova Scotia's resource industries. Halifax Harbour is the second largest deep-water ice-free harbour in the world. The Port of Halifax is the fifth largest port in the North Atlantic seaboard and handles 7.5% of the total container traffic of that market[23].

HRM's urban core and numerous small coastal communities within HRM depend on a transportation network that is at medium to high risk of impact from climate change. Much of the roads within metro Halifax (peninsular Halifax, Dartmouth and Bedford) are located within the zone of medium coastal sensitivity coastal as well as the road network linking these areas. Rail infrastructure, which services HRM's container terminals and commercial and industrial operations along Halifax Harbour, is located within the medium risk zone. The three 100 series highways that service HRM are also located within the coastal zone. Highway 107 is located within coastal zones with medium and high sensitivity to climate change. Much of the length of Highways 103 and 102 within HRM is located in areas of medium sensitivity. Major routes, including 333, 349, and 7, are located within medium to high sensitivity zones. These routes provide the only access for numerous small coastal and rural communities in HRM.

2.8 Legislative and Jurisdictional Responsibilities for Responding to Climate Change Issues

2.8.1 Allocation of Responsibilities

General environmental and coastal management responsibilities that are most relevant to climate change adaptation rest with a number of federal, provincial, municipal agencies. A summary of management functions and the agency or agencies responsible are provided in Table 2-4. In Nova Scotia, there is generally clear division between the levels of government and their responsibilities as shown in Tables 2-4 and 2-5. Where there is overlap, the agencies tend to complement each other. For example protection of water quality in inland waters falls within both federal e.g., Fisheries and Oceans Canada and provincial e.g., Nova Scotia Department of Environment and Labour agencies.

[23] Gardner Pinfold Consulting Economists. 2004. Economic Potential of HRM and Halifax Harbour.

Table 2-4 Environmental and Coastal Management Responsibilities

Management Function	Agency Responsible
Aboriginal Issues	Indian and Northern Affairs Canada, CIER, CMM, UNSI, Individual Bands
Agricultural Marshlands Conservation	Nova Scotia Department of Agriculture and Fisheries (NSAF)
Beaches	Nova Scotia Department of Natural Resources (NSNR)
Crown Lands Management	NSNR
Ditching and Watercourses	NSNR
Economic Development	Atlantic Canada Opportunities Agency, Nova Scotia Business Inc., Nova Scotia Department of Economic Development
Emergency Response	Emergency Measures Organization Nova Scotia
Endangered Species Protection	NSNR, Environment Canada (EC)
Fisheries and Coastal Resources	NSAF, Fisheries and Oceans Canada (DFO)
Forest Management	NSNR
Infrastructure	Nova Scotia Department of Transportation and Public Works (NSTPW), HRM, Public Works and Government Services Canada (PWGSC)
Marine and Freshwater Habitat Protection	DFO
Municipal and Regional Planning	Service Nova Scotia and Municipal Relations (SNSMR), HRM
Oceans Management	DFO
Pollution Abatement	Nova Scotia Department of Environment and Labour (NSEL), DFO, EC, HRM
Protection of Migratory Birds	EC
Protection of Wildlife	NSNR, EC
Water Quality Protection	NSEL (Freshwater), DFO, Halifax Regional Water Commission
Works in Coastal Areas	HRM, NSNR

From Table 2-4, it can be seen that all three levels of government share responsibility for and are provided with regulatory opportunity to address climate change within each of their mandates. While no existing legislation specifically addresses climate change, as demonstrated in Table 2-5, legislation, regulations and policies are generally broad enough that in most cases, climate change considerations can be systematically incorporated without the requirement of a formal amendment.

2.8.2 Legislation and Statutory Provisions

Table 2-5 provides a summary of existing legislation relevant to environmental and coastal management.

As noted above, consideration of climate change is not specifically addressed in current federal or provincial legislation, however, as environmental and natural resource management legislation mandates protection, climate change issues can be addressed as it directly and indirectly can affect the resource protected or managed by legislation. Apart from the Nova Scotia Departments of Environment and Labour; and Energy; Environment Canada; and Natural Resources Canada,

Table 2-5 Summary of Relevant Legislation

Legislation	Agency	Description	Relevance to Climate Change
Agricultural Marshland Conservation Act	NSAF	Permits the construction and maintenance of works to develop marshlands for agricultural purposes.	Works constructed under the Act may be susceptible to sea-level rise and storm surge events.
Beaches Act and Regulations	NSNR	Provides protection for beaches and associated dune systems. Regulates and enforces land use activities on beaches	In addition to the above, sea-level rise will impact designated beaches and dunes systems.
Beaches and Foreshores Act	NSNR	Allows the Minister to give a grant or enter into a lease of a flat, beach or foreshore.	Activities carried out on the granted or leased lands may be susceptible to sea-level rise.
Canadian Environmental Assessment Act	CEAA	Requires projects meeting criteria set out in regulations to undergo an environmental impact assessment.	Climate change is generally considered in relation to a project's GHG emissions and the effects of the environment on the project. CEAA has published guidance on including climate change in environmental assessments.
Crown Lands Act	NSNR	Minister is responsible for the administration, leasing and disposal of Crown lands in the Province.	Crown lands include the area between the high and low water mark.
Ditches and Watercourses Act	NSNR	Sets rules for the approval, construction, and maintenance of ditches.	Establishes broad requirements for ditch design, location and construction.
Emergency Measures Act	NS Executive Council	Act addresses the organization of emergency response measures in the Province and describes the powers of the Emergency Measures Organization.	Response to extreme events.
Endangered Species Act	NSNR	Provides for protection, designation, and recovery of species at risk and their habitats.	Listed species and their habitats may change as a result of climate change.
Environment Act	NSEL	Purpose of the Act is to support and promote the protection, enhancement and prudent use of the environment.	Works approved under the Act such as watercourses, water/wastewater facilities are potentially impacted by climate change.
Environmental Assessment Regulations	NSEL	The regulation defines the type of projects requiring environmental impact assessment in the Province and minimum requirements for impact assessments.	Environmental effects of projects may be modified by climate change. Climate change can also be considered as an effect of the environment on the project.
Environmental Goals and Sustainable Property Act (Proposed)	NSEL	Long term environmental and economic objective to fully integrate environmental sustainability and economic prosperity	Sets objectives for GHG reduction allows Governor in Council to establish environmental Goals. Permits Governor in Council to establish or participate in programs related to adaptation to climate change.

Legislation	Agency	Description	Relevance to Climate Change
(2nd Reading – March 29, 2007)			
Fisheries Act	DFO	Concerns the protection of fish, fish habitat and management of commercial fisheries.	Climate change may impact fish habitat and effect the management of commercial fisheries.
Fisheries and Coastal Resources Act	NSAF	Promotion and implementation of programs to sustain and improve the recreational/sport fishery and aquaculture. Fosters community involvement in the management of coastal resources.	Sustainability of sport fishery. Sea-level rise will impact the management of coastal resources.
Forest Act	NSNR	Act applies to many aspects of forest management including improvement of yield, improvement in management, enhancing habitat and recreational opportunities, and job creation.	Possible changes in forest habitat and management due to climate change.
Forest Sustainability Regulations	NSNR	Requires buyers of primary forest products to prepare a plan on how it intends to maintain forest sustainability (e.g. through silvaculture or financial contributions).	Act requires sustainability plans that should factor in climate change.
Migratory Birds Convention Act	EC	Provides for the protection of migratory birds.	Migration patterns and habitat.
Municipal Government Act	SNSMR HRM	Enables municipalities to govern themselves through development of policies and by-laws within their jurisdiction.	Policies and by-laws to management development in hazard areas.
Oceans Act	DFO	The Act, in part, directs the Minister to develop and implement a national strategy and integrated management plans for the management of estuarine, coastal and marine ecosystems.	Impact from climate change on marine physical and biological environment may impact strategies and management plans.
Species At Risk Act	EC	The purposes of this Act are to prevent wildlife species from being extirpated or becoming extinct, to provide for the recovery of wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened.	Listed species and their habitats may change as a result of climate change.
Wildlife Act	NSNR	Develop and implement policy and programs to maintain diversity, integrate protective measures on Crown lands, regulate hunting and fishing, and provide continual renewal of the resource.	Wildlife resource management practices may require modification due to impacts from climate change.

the degree of awareness within the responsible departments varies. For example, in environmental assessments carried out under the Canadian Environmental Assessment Act, climate change can be considered with respect to GHG emissions and climate change effects on the project. Many activities undertaken in HRM do not fall within the scope of federal or provincial environmental assessment legislation nor required by HRM's bylaws or planning rules, therefore, climate change risks are not evaluated by a formal environmental process. On the whole, climate change factors are generally not being addressed in policies, plans and decisions made under provincial and in many cases, federal legislation.

The lack of consideration of climate change, particularly at the federal and provincial levels and specifically related to climate change adaptation, is primarily due to a lack of policy direction and where required, complementary legislative mechanisms. Further hindering action on climate change is the uncertainty of the federal government's direction on climate change. While, the proposed Clean Air Act addresses GHGs as part of an overall clean air approach, there is no published policy or legislative direction with respect to adapting to climate change.

Climate change is increasingly being recognized as a factor in maintaining the sustainability of municipalities, however, with the exception of HRM, few are formally incorporating climate change considerations into policy with the exception of GHG reduction initiatives. In the case of Nova Scotia, municipalities are restricted in the measures that can be taken by the Municipal Governance Act which narrowly focuses a municipality's control over environmental issues within its boundaries. For example, HRM's Municipal Planning Strategy does not address protection of significant habitats or environmentally sensitive areas as these are considered the jurisdiction of the province.

2.8.3 Other Relevant Institutional Considerations

HRM has recently instituted risk assessment and management protocols for each of its Business Units in which each Business Unit evaluates the risks to the assets and programs under the Business Unit's control and develop plans to mitigate the risks. Climate change can be considered as risk that will be applicable to most Business Units.

In addition, there are several other initiatives external to that are underway and may have some influence on HRM in the future. Provincially, Nova Scotia is party to the New England Governors and Eastern Canadian Premiers *Climate Change Action Plan*, which in addition to setting priorities for GHG reduction, also emphasizes the undertaking of adaptive measures recognizing that climate in the region is changing now. One of the Guiding Principles of the *Action Plan* directs the Governors and Premiers to "explore ways to adapt to the already changing climate, to take advantage of any benefits that might come from these changes, and to adapt our infrastructure and natural resource base accordingly." This may result in subsequent policy or legislation direction from the province.

First Nations organizations and bands are active both nationally and locally in monitoring changes in the ecosystem and identifying strategies for adapting to climate change. The

Assembly of First Nations is active in international initiatives to mitigate and adapt to climate change through CUSO and First Nations organizations and governing bodies in the United States.

Non-governmental organizations in the province such as Clean Nova Scotia, Sierra Club, and the Ecology Action Centre are actively working to promote a climate change agenda, but with a focus on mitigation and environmental protection. Adapting to climate change has not, to date, been a focal point for NGOs. Likewise, financial, insurance institutions and utilities, have focused efforts on mitigating climate change through greenhouse gas reduction rather than planning for change by developing adaptation strategies.

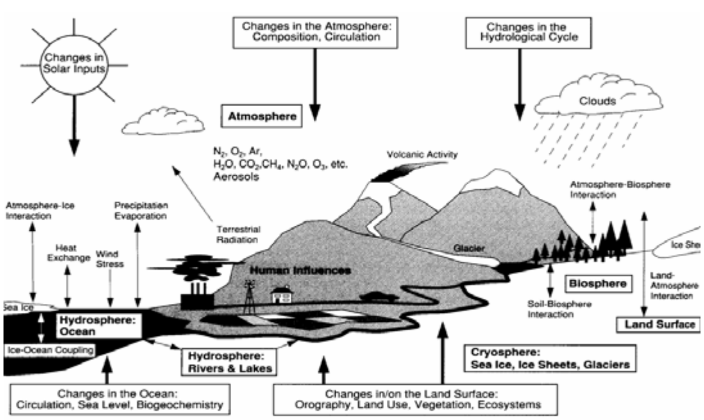
> **Step 2 – Identify Climate Change Impacts and Risks**
> Assemble available information on climate change specific to the jurisdiction of the Municipal Business Unit and affected environmental, social and economic elements. The ***impacts*** identified in this step are used as a basis for describing the potential ***risks*** relevant to the Municipal Business Unit and affected environmental, social and economic elements.

3.0 Climate Change In HRM

3.1 Climate Change - Overview

Climate is considered to be average weather measured over a period of time in a geographic area described in terms of the mean and statistical quantities. For example, you expect Atlantic Canada to have a moderated climate with a particular mean temperature and elevated annual precipitation that is different from other areas of the country.

Figure 3-1 Climate System Components

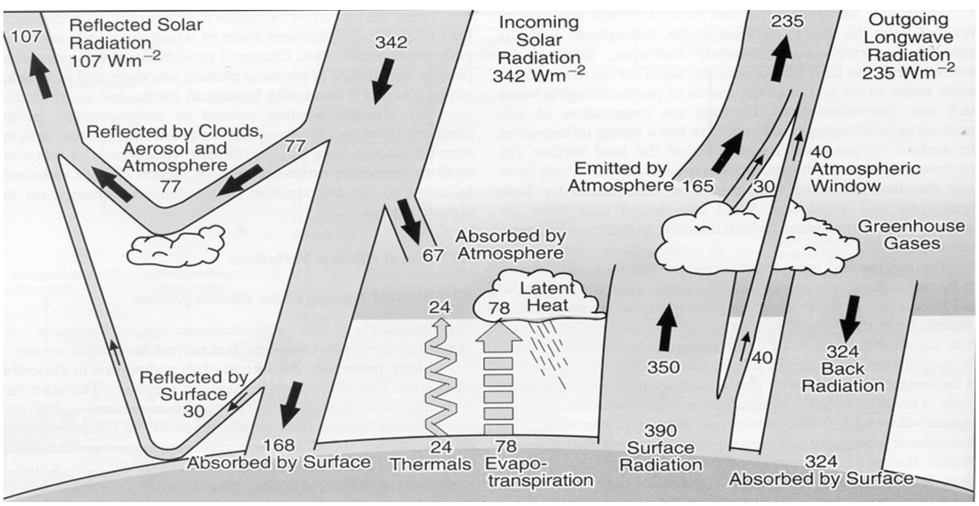


The internal components in the climate system include the atmosphere, the oceans, sea ice, the land and its features, including the vegetation, albedo (ratio of reflected to incident light), biomass, ecosystems, snow cover, land ice, and hydrology (Figure 3-1). The external components in the climate system are: the Sun and its output; the Earth's rotation; Sun-Earth geometry and the slowly changing orbit; the physical components of the Earth system such as the distribution of land and ocean, the geographic features of the land, the ocean bottom topography and basic configurations; and the mass and basic composition of the atmosphere and ocean.

When solar energy enters and leaves Earth at the same rate, the climate system stays in balance and the average temperature remains relatively constant. If there is a change in the rate at which energy either enters or exits the system, or in how that energy is distributed, the balance is upset. Global temperature will change and other elements such as precipitation or wind patterns will adjust. Local and regional climates are affected by latitude, altitude, topography, and proximity of large bodies of water and ocean currents.

The Earth's atmosphere contains naturally occurring "Greenhouse Gases" (GHGs) such as water vapour, carbon dioxide, ozone, methane and nitrous oxides as well as man-made (anthropogenic) greenhouse gases. These gases are relatively transparent to incoming short wave radiation but absorb the re-radiated long-wave energy and heat up Earth's atmosphere (Figure 3-2). This results in the greenhouse effect that insulates Earth from heat loss. Without this natural greenhouse effect, the average temperature of Earth's surface would be 33 ^{o}C colder than the present 15 ^{o}C. This is a naturally occurring phenomenon in a delicate balance.

Figure 3-2 Radiation Balance



Source: Environment Canada

By releasing more greenhouse gas into the atmosphere through human activity, including burning fossil fuels, that balance is disrupted. Both the oceans and the biomass on the land take up carbon dioxide in a natural cycle called the carbon cycle. At the moment the science indicates that so much extra carbon dioxide is being added to the cycle that both of those "carbon sinks" cannot handle the extra amount. The result is an accumulation of carbon and warming of the atmosphere from the increased carbon dioxide.

3.1.1 Historical Change

Climate Change refers to long-term (months, years, decades) changes in climate variables such as mean temperature, annual precipitation and related events such as storm frequency or intensity as a result of natural and/or man-made climate interference. Most natural changes are well understood; dust and ash from volcanic eruption can lower global mean temperature by several degrees over the span of 3-5 years while changes in Earth's orbit affect solar radiation, and hence global mean temperature on a scale of 10,000's of years.

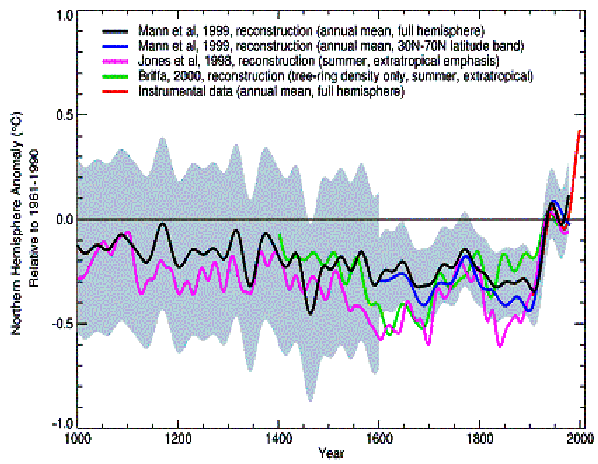


Figure 3-3 Northern Hemisphere Temperature Over the Last Millenium

Most recently scientists have discovered that the addition of ever-increasing GHGs to the atmosphere since the Industrial Revolution (approximately 150 years ago) has "warmed" the atmosphere by 0.5 to 1 ^{o}C (Figure 3-3).

It is now believed that such a human impact on our climate, especially over the past 50 years, has resulted in dramatic melting of ice and permafrost in our Arctic Regions as well as accelerating the ongoing sea-level rise globally.

3.1.2 Historical Change in Nova Scotia

For Nova Scotia, the long-term trend in temperatures (from 1895-1998) show an increase of approximately 0.5 degree Celsius (Figure 3-4).

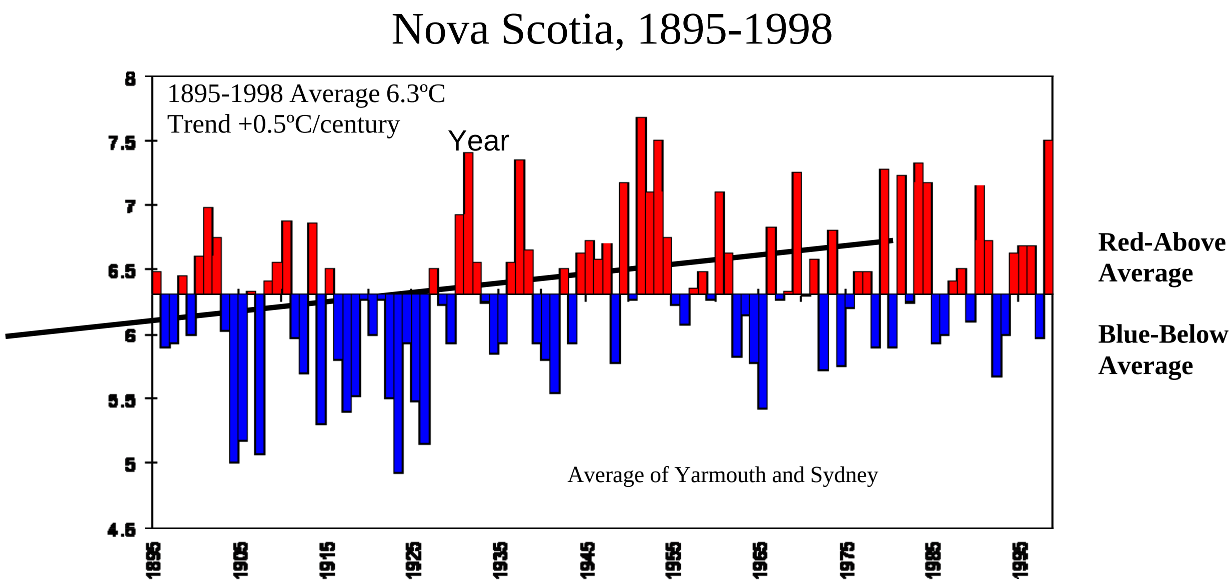


Figure 3-4 Long-Term Temperature Trend – Nova Scotia

For precipitation, the variability across the region, and between years, makes any trend to increased or decreased amounts more difficult to discern. Parts of Nova Scotia have experienced increase in total annual amounts of precipitation, but snow cover has been decreasing (Figure 3-5).

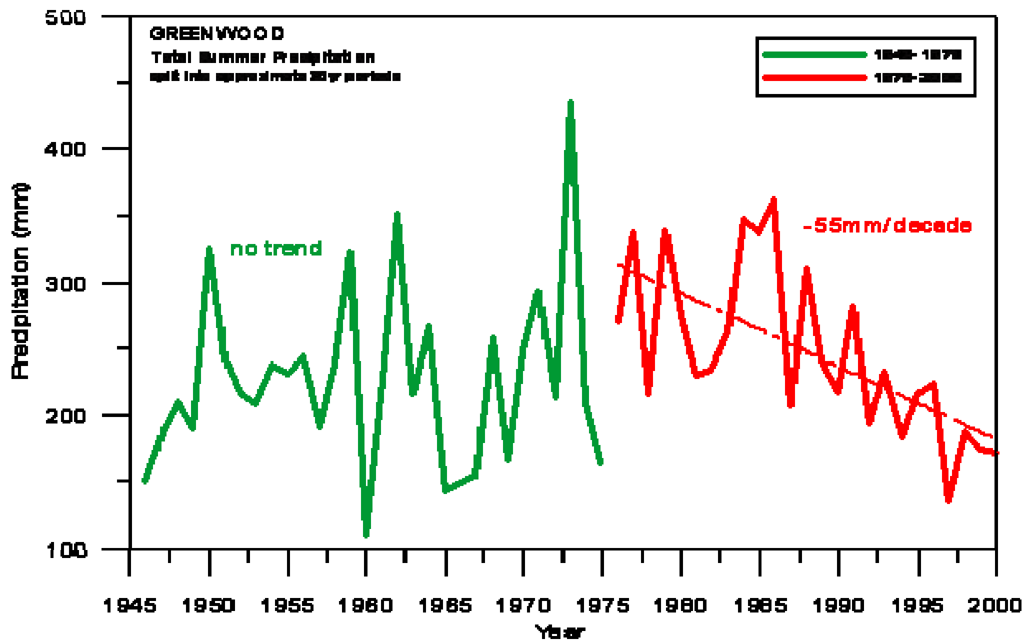
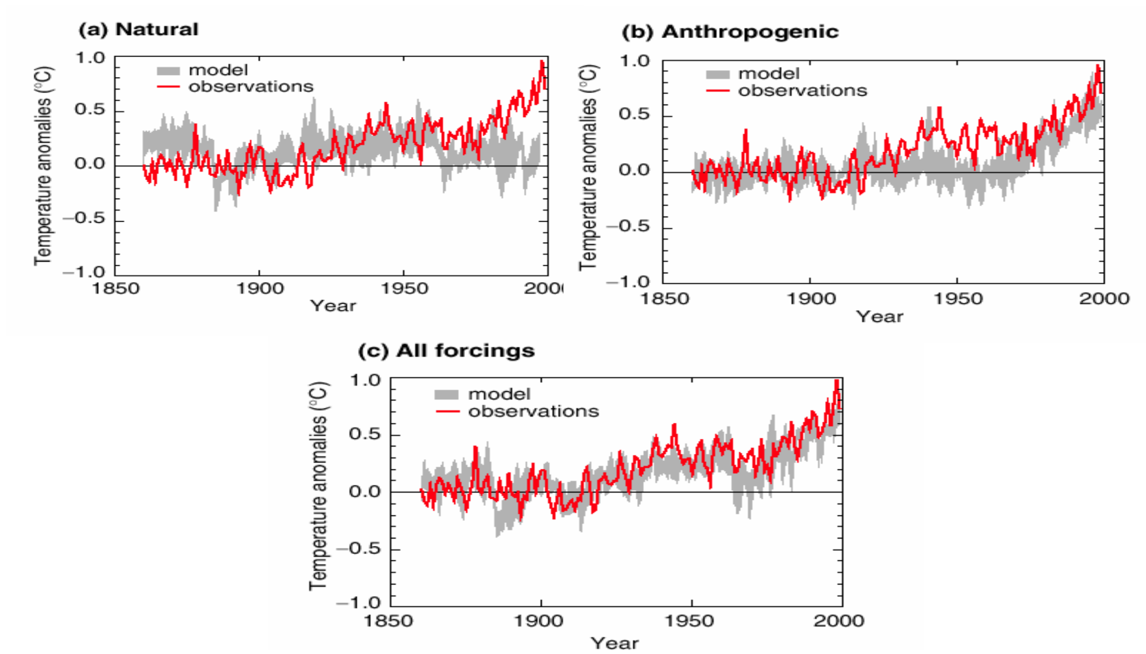


Figure 3-5 Total Summer Precipitation – Greenwood, NS

3.2 Projections of Future Climate

Climate modelers use the most advanced physics and mathematics available today to develop complex climate models. Models are first tested against observed climates and climates of the past to ensure they can adequately simulate real climates. Once they have passed these and other tests, they are used to project future climates for various scenarios of future greenhouse gas and aerosol emissions. Modelers have become confident that they can provide useful indicators of how the climate will respond to continued human interference with the climate system. Figure 3-6 illustrates an experiment where natural and anthropogenic changes were applied to the climate model and compared to the historical record. Only when both the natural and anthropogenic influences on climate are considered, the climate model portrays the changes fairly accurately.

Figure 3-6 Comparison of Natural, Man-made (Anthropogenic) and Combined Temperature Models



Comparison of observed changes in globally average surface temperatures (red line) with model simulations of different combinations of radiative forcing (grey lines): a) natural forcing due to solar and volcanic activity; b) forcing due to human activities only (greenhouse gases, aerosols, stratospheric ozone depletion; c) forcing due to both natural and human causes. IPCC TAR Synthesis Report Figure 2.4.

General Circulation Models (GCMs) are designed to best describe how the three main drivers of Earth's climate; the atmosphere, the oceans and the icecaps, work together to give us our planet's varied climates. Also, they are the only tool available to help us project the impact of changes on future climates. The most current Canadian model is the Canadian Coupled Climate Model Version 3 (CGCM3). There are a number of other climate models of varying but relatively equal capability to project future climate. The most noteworthy are the HadCM3 from the Hadley Research Centre in the UK, the GFDL model from the US and the CSIRO Model from Australia.

Based on the outputs from the models and extensive scientific research, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report[24] identified a number of projected global climate change impacts. In summary, these impacts include the following (confidence levels indicated in parantheses):

- More heat waves (Very Likely)
- Fewer cold waves (Virtually Certain)
- Increased flooding due to more intense rain events (Very Likely)
- Increased risk of drought (Likely)
- Increased tropical cyclone peak wind intensities (Likely)

3.2.1 Understanding Future Climate Scenarios

In order to properly assess the impacts of a changing climate, relevant projections of that climate must be developed. This can be approached several ways, each way has advantages depending on the assessment approach you wish to take. The first choice that has to be made is to decide how to generate the future climate scenario.

It has been recommended by the Intergovernmental Panel on Climate Change (IPCC) that a scenario of future climate be developed based on a range of assumptions concerning the future of Greenhouse Gas emissions (socio-economic) and a range of climate models with varying skills and assumptions as to the behavior of the climate system. By doing so, the assessor can acquire the full range of possibilities of plausible future climates and reduce the uncertainty inherent in making projections out to 100 years.

Climate scenarios should be built using either a range of models appropriate for the geographical region or several very specific models that represent the regional climate well. The scenario developer must then decide which GHG emission scenario that best applies socio-economically. A range of emission scenarios can be chosen but the combinations of models and scenarios can become quite complex and assessing their impact even more so.

In the case of Atlantic Canada, projections of temperature and precipitation change are based on the Canadian Climate Model (CGCM1) and the GHG emission scenario equivalent to the IS92a, business-as-usual future. Since the Canadian model produces climate results, when compared with other global models, that are “middle-of-the-road” and the emission scenario is considered an average, doubled CO_2 future, the resulting values for temperature and precipitation change can be assessed as “average” projections.

[24] Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

This means that there exists, when using other climate models, equally plausible but different climate futures. It also means that, if you used a more fossil-fuel intense emission scenario, you would get more dramatic (higher) results.

3.2.2 Future Emission Scenarios

Future climate projections are made by modifying a Global Circulation Model (GCM) with changes in greenhouse gas emissions and aerosol concentrations over the next 100 years. These changes have been determined through the development of "emission scenarios", i.e., different future greenhouse gas and aerosol concentrations based on changing socio-economic conditions. The first series of emission scenarios were completed in 1995 and can be summarized by the three curves illustrated in Figure 3-7.

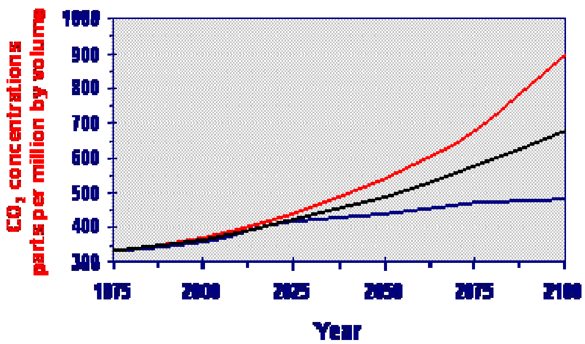


Figure 3-7 Comparison of $C0_2$ Concentrations Under Different Scenarios

Based on an energy-intense (fossil fuel dependent) future, the red curve in Figure 3-7 indicates an almost tripled GHG concentration, while a future where renewable energy technologies are adopted and developing countries follow energy conservation steps; the resultant change (blue line) is a more modest 50% increase.

International scientists have agreed however that to study climate change and be able to compare results across more than one GCM model, a "standard" emission scenario is required. The black line, typically described as the "Business As Usual" scenario, is based on a GHG increase of 1% a year for 100 years, effectively doubling the concentration of GHGs by 2100 and was chosen as that "standard".

In 2001, scientists decided to expand the emission scenario possibilities and developed what has come to be called the "SRES" (Special Report on Emissions Scenarios) group of emission scenarios. Instead of three basic futures, the scenarios were expanded to over 40 possible emission futures. As shown in Figure 3-8, there still exists a "high" and "low" estimate and a "middle" or "business as usual" one, noted as "A2". It is across this range of scenarios that the climate modelling community has developed their results for temperature and precipitation to 2100.

Refer to Appendix A for technical specifics describing the development of SRES scenarios.

Projections of mean global temperature; based on the SRES scenarios, range from 1.4 to 5.8 degrees Celsius. For comparison of models scientists have agreed on the A2 scenario as the "standard" giving 3.2 degrees Celsius as an average projection to 2100. Precipitation amounts are projected to increase ranging from 10-30% over mid-northern latitudes. Also, projections point to more variability in climate, with the possibility of more frequent and more intense extreme events.

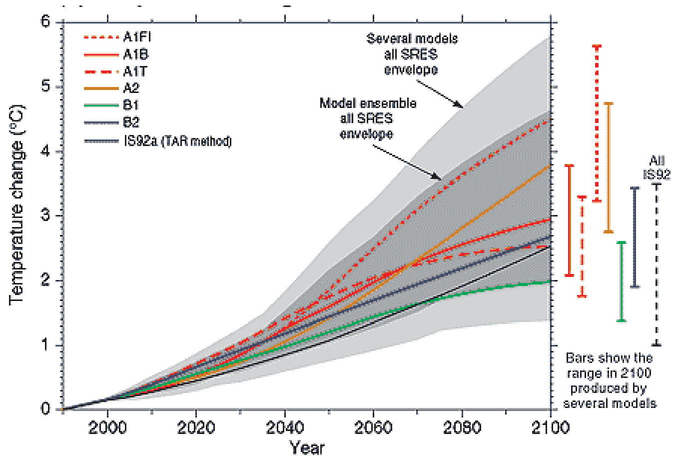


Figure 3-8 Results of "SRES" Group Emissions Scenarios

3.2.3 Temperature and Precipitation Projections for HRM

For HRM, scenarios of temperature and precipitation change can be extracted from the Canadian Climate Impacts and Scenarios (CCIS) (www.cics.uvic.ca). These scenarios are based on results from a large suite of climate models and provide ranges for temperature and precipitation change. As an example, the models are projecting for Shearwater a mean temperature change range of 4-5°C by 2100 and a percent increase change in annual precipitation amounts of -2% to 7% (Table 3-1).

Although such projections are useful, they are based on a large geographical area and are not reflective of the micro-climate influences at play at a specific site in Nova Scotia. To refine these projections for Shearwater, their historical climate records are statistically combined with global climate model projections and used to calculate specific temperature, precipitation and growing season lengths over the next 100 years. This technique is called downscaling and has been completed for Shearwater as part of this project. These data are summarized in Figures 3-9, 3-10 and 3-11.

Table 3-1 Projections for Shearwater

	Maximum Temperature			**Minimum Temperature**			**Precipitation Amount**		
Tri-decade	**2020s**	**2050s**	**2080s**	**2020s**	**2050s**	**2080s**	**2020s**	**2050s**	**2080s**
	Δ°C	**Δ°C**	**Δ°C**	**Δ°C**	**Δ°C**	**Δ°C**	**%**	**%**	**%**
Shearwater	1.7	2.8	4.7	1.2	2.2	3.9	+7	+7	+2

Figure 3-9 Maximum Temperature for Shearwater

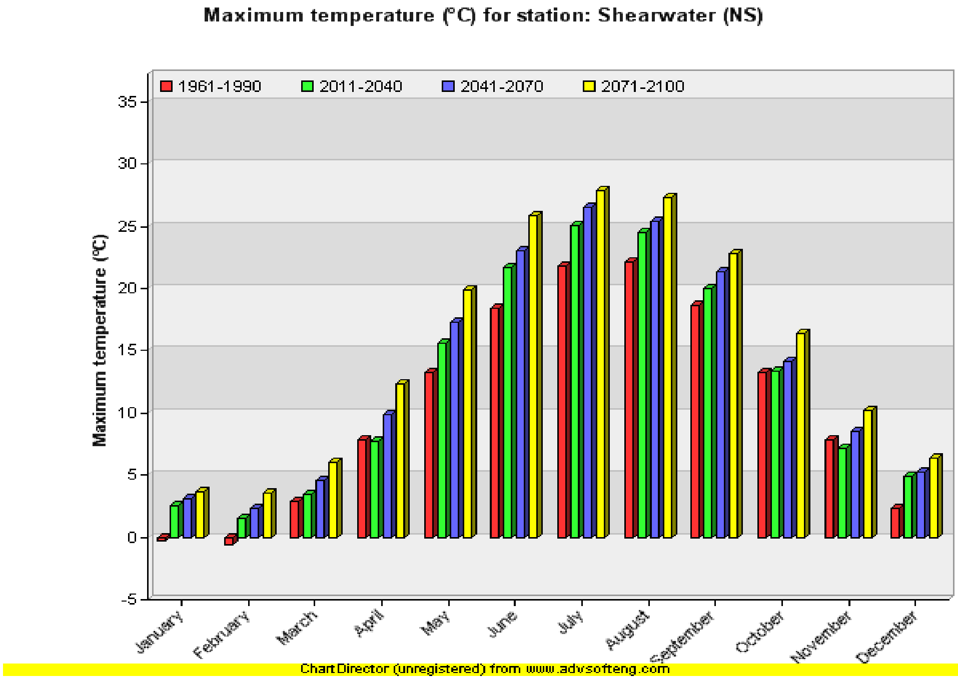
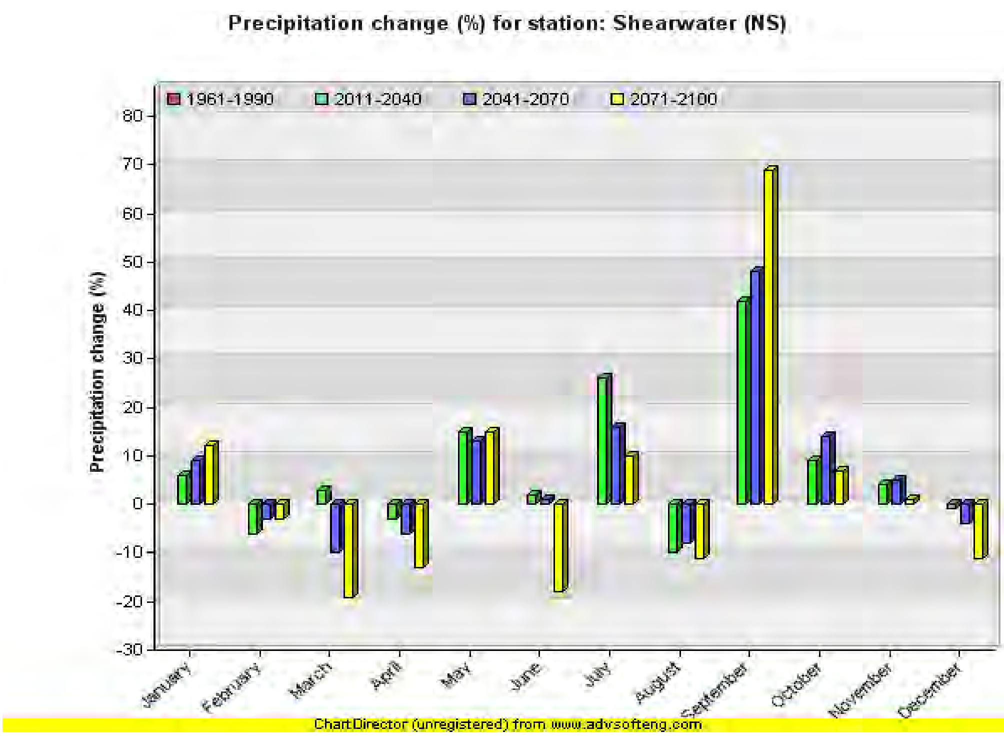


Figure 3-10 Precipitation Change at Shearwater



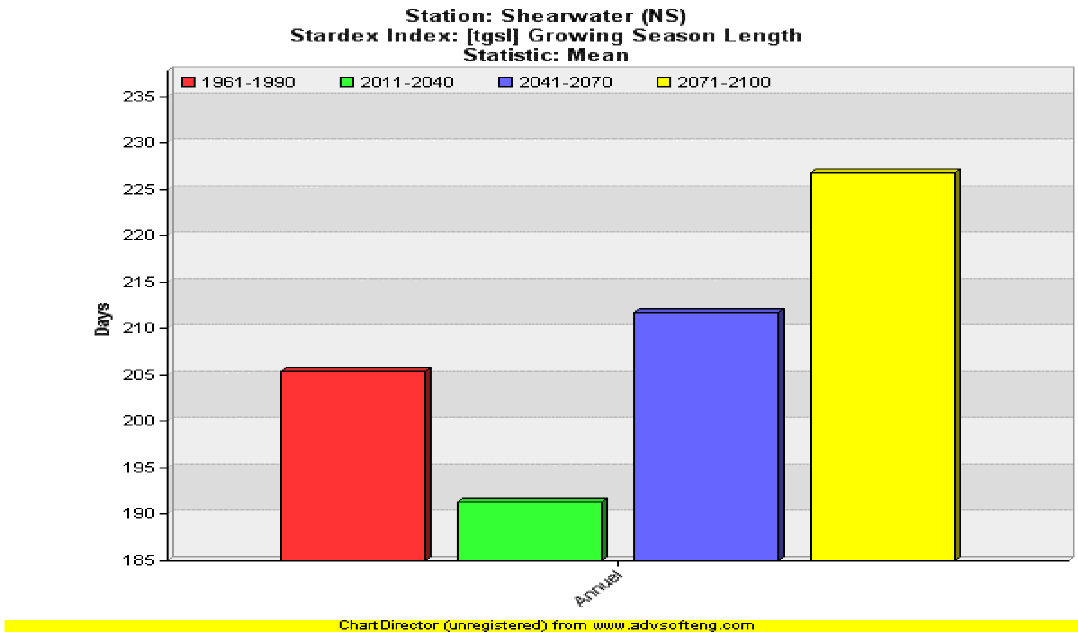


Figure 3-11 Growing Season Length Projections

As seen in Table 3-1 and Figures 3-9 and 3-10, changes to temperature and precipitation amounts can vary, however the precipitation amounts alone do not provide information about the characteristic of precipitation. For example, an increase of 7% in annual precipitation amount is not advantageous to agriculture if the precipitation falls in one or two events a year. Therefore it is just as important to understand the shift in precipitation pattern by season, as it is to know the amount of annual precipitation change. For example, Figure 3-12 shows an increase in 3 day rainfall amounts, suggesting the increase in annual precipitation may occur during an extreme event rather than distributed throughout the year.

These data were further refined by Environment Canada to provide an understanding of the spatial distribution of these projections across HRM to identify potential areas of concern for future planning. This information was transferred to GIS data format and is available to HRM users through HRM's intranet and in hard copy form in Appendix B. Mapping was developed for the following indicators broken down by 3 tri-decadal periods from 2011 – 2100:

- February minimum temperatures;
- July maximum temperatures;
- greatest three and five day rainfall event on a seasonal basis; and
- heat wave duration.

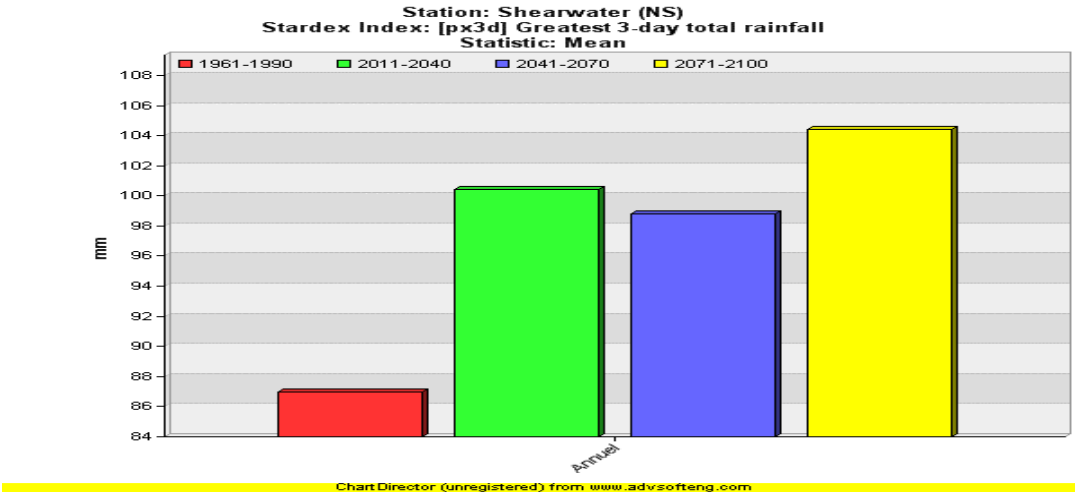


Figure 3-12 3-day Rainfall Projections

In summary, the mapping indicates that:

Minimum temperatures (February) are projected to range from 3.0 – 3.5 ^{o}C above the 1960-1990 average of –15^{o}C by 2040 and 6.0–6.5 ^{o} C above the average by 2100. Maximum temperatures (July) will also increase by the same ranges from a current average of 21.6^{o} C with the maximum July average temperature increasing to 28.1^{o} C by 2100. The degree of change is projected to be greatest inland, and more moderate along the coast. In parallel with the increase in temperature, the growing season duration will increase by an average of 13 days by 2040 to 177 days and an average of 20 days or 184 days in total by 2100.

Heat wave duration is also projected to increase. Between 2011 and 2040 heat wave duration is projected to increase by between 7 and 12 days over the current average of 5.6 days. By 2100, the modeling indicates that heat wave duration will increase to over 70 days per year. These heat waves are projected to longer in the south and west portions of the HRM (Halifax to Panuke Lake).

At present the maximum 3- and 5-day rainfall events are 73.27 mm and 85.48 mm respectively. These events will increase to 93.27 mm and 115.48 mm respectively by 2100.

3.3 Sea Level Rise

Sea levels are rising along most coasts in Atlantic Canada, in part an effect of post-glacial subsidence and also global sea-level rise (National Atlas of Canada, 2004). Much of Atlantic Canada's extensive shoreline, especially in the Maritime Provinces, is at moderate-to-high risk of impacts from rising sea levels. Coastal areas will also be vulnerable to changes in sea ice, winter storms and storm surges.

Projected sea level rise is based on the theory that a warming atmosphere will transfer that heat to the oceans, expanding the oceans as they warm. As well, as shown in Figure 3-13, melt of mountain glaciers and the Greenland ice sheet will add to that sea level rise. The range provided (9 to 88 cm) is in response to the range of emission scenarios as described earlier. The "best estimate" of 40 cm rise comes from the "Business As Usual" scenario, the average change expected to 2100.

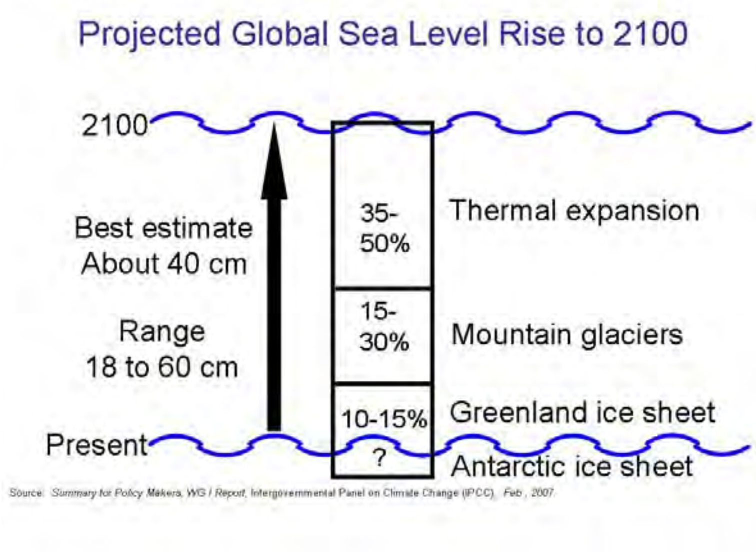


Figure 3-13 Projected Global Sea Level Rise to 2100

3.3.1 Sea-level Rise in HRM

This sea-level rise is readily apparent in the tidal record for Halifax where sea-level has risen approximately 15 cm since 1920 (Figure 3-14). A sea-level rise of up to 88 cm represents a significant increase; however, in areas sensitive to shore line erosion such as the Eastern Shore (Figure 3-15), such as increase will exacerbate an already high erosion[25] environment. In the built up areas along the coast, this sea-level rise, combined with storm surge, can result in significant inundation of built assets and natural resources along the coast.

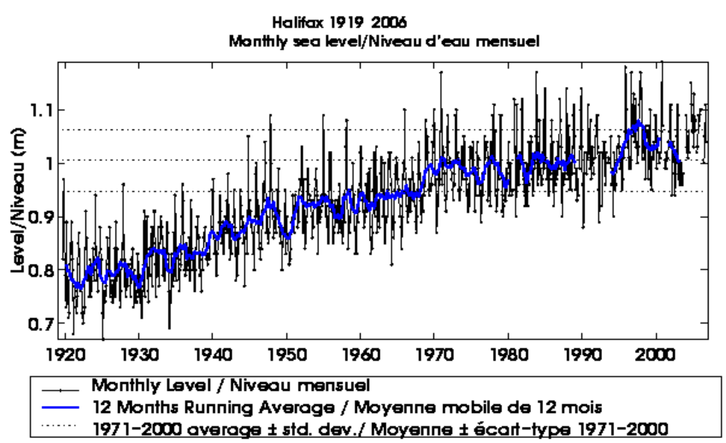


Figure 3-14 Monthly Sea Level - Halifax

[25] Taylor, R. B., J. Shaw, D. L. Forbes and D. Frobel, 1996. Eastern Shore of Nova Scotia Coastal Response to Sea-Level Rise and Human Interference. Field Trip Guidebook. Geological Survey of Canada. Open File Report 3244 46.pp.

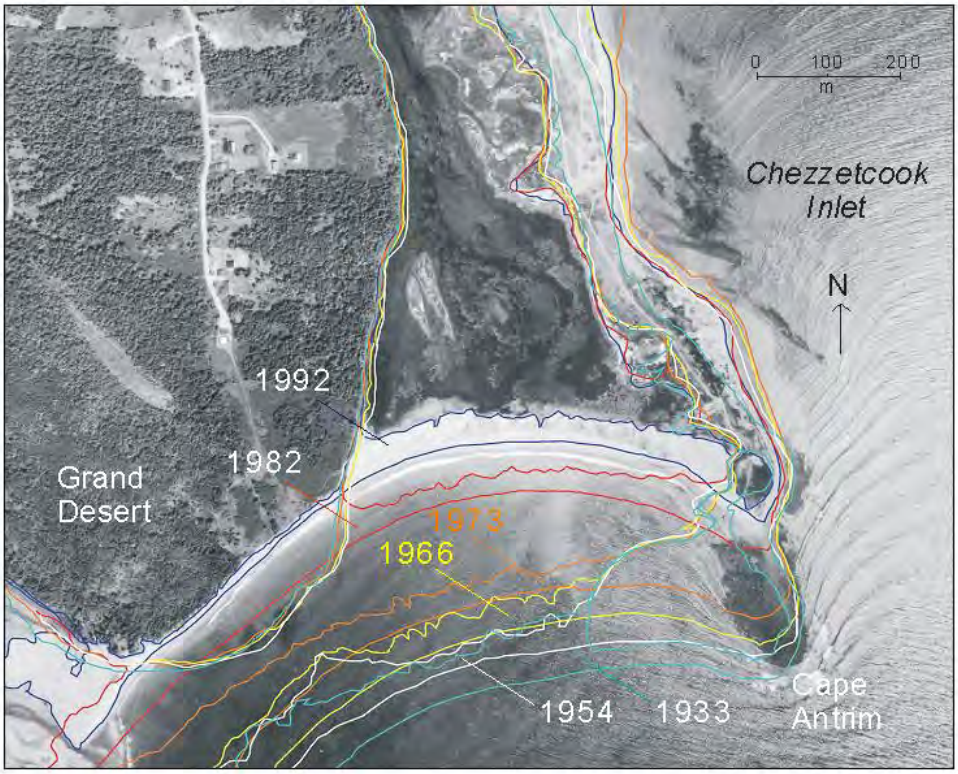


Figure 3-15 Shoreline Changes (1933-1992) at the Southeast Entrance to Chezzetcook Inlet

Inundation events due the combination of sea-level rise and storm surge events were modeled for Halifax Harbour[26] using the Water Modeler software developed by the Applied Geomatics Research Group of the College of Geographic Sciences. Based on a sea-level rise rate of 0.8 cm/yr and assuming an orthometric level of 1.201 m, water level is expected to reach 1.601 within the next 50 years. The modelling indicates that water levels will reach at 1.752 m at least once in the next 50 years with an estimated return period of 15 years. There is a 10% probably that water levels will reach 2.786 m and a 1% probability of water levels reaching 3.341 m.

Within 100 years, the model calculated that a water level of 2.001 m will be reached and a water level of 2.170 m will happen at least once in the next 100 years with an estimated return period of 87 years. There is a 10% probably that water levels will reach 3.225 m and a 1% probability

[26] Halifax Harbour is the only area in HRM with topographic mapping at a suitable scale, e.g., 1 m contour intervals to accurately demonstrate sea-level rise mapping.

of water levels reaching 3.780 m. Mapping providing a visual representation for selected areas of Halifax Harbour are provided in Appendix C.

3.4 Extreme Events in HRM

Of greatest concern to HRM residents is our vulnerability to extreme events. Two elements are important when determining that vulnerability:

- are extreme events increasing in frequency and intensity; and
- are we now more vulnerable due to our infrastructure planning?

Extreme events such as heat waves, droughts, flash floods, are increasing worldwide. Climate models are projecting those events to continue to increase. For example, in Greenwood, Nova Scotia, downscaled projections of extreme precipitation events indicate that 100 year events will increase in frequency to become 50 year events by 2100 (Figure 3-16).

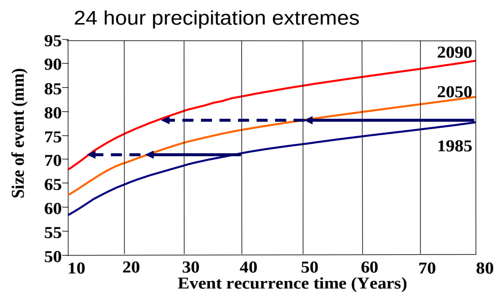


Figure 3-16 Increase In Frequency of Extreme Events

Such extreme precipitation events would mean a larger fraction of water moving into lakes, streams and estuaries, affecting estuarine processes in the coastal zone. Similarly, freshwater resources and wetlands in the region could be seriously impacted by changes in precipitation. Heavy rainfall brings an increased erosion of exposed soils and localized flooding and increased risk of contamination of drinking water supplies by surface water. Heavy rainfall can also result in a smaller fraction of that water moving into groundwater recharge. Timing of precipitation is also critical to freshwater resources, as rain during a mid-winter thaw, when the ground is frozen could essentially be lost to the terrestrial hydrologic system[27] .

Current projections indicate an increase in hurricane intensity over the next 100 years, suggesting stronger wind speeds in the hurricanes that we experience. However, it is yet to be determined whether more hurricanes will occur in the Atlantic Basin. Nor has it been determined whether Nova Scotia will get more landfall hurricanes. Research on these issues is currently underway. A summary of projected climate change impacts for Nova Scotia for tri-decadal periods 2020, 2050, and 2080 is provided in Table 3-2. Mapping showing the key climate change parameters (minimum and maximum temperature, three day total rainfall, five day total rainfall, growing season duration, frost season duration, and heat wave duration) for these periods are provided in Appendix B.

[27] Environment Canada. 1997. Canada Country Study, Volume VI – Climate Change and Vulnerability in Atlantic Canada.

Table 3-2 Summary of Projected Climate Change Impacts for Halifax Regional Municipality for Tri-decadal Periods 2020, 2050 and 2080

Climate Variable	**Mean Change**	**Variability / Frequency**	**Extreme Value**	**Knowledge Gap**
Periods	**2020s/2050s/2080s**	**2020s/2050s/2080s**	**2020s/2050s/2080s**	
Maximum Temperature	+1.8/+3.2/+5.3 (increase from 61-90 normals)	Hot days per year. (days above 30ºC) 23/34/48	Number of heat waves (days above 35ºC). 2.4/6/16.9	
Minimum Temperature	+1.1/+2.7/+4.0 (increase from 61-90 normals)	Cold days per year. (days below -10ºC) 11/8/5	Not Available.	
Season Length	Frost free season (days per year) 199.3/214.9/236.9	Surprises possible. (Late hard frost in spring, early hard frost in fall)	Not Applicable	Specific changes related to geographical differences need to be developed
Precipitation Amount	% change amount +12/+12/+10	100 year amount becoming 50 year amount	Potential Max Precipitation (PMP) increasing.	Return periods vary by location and need to be validated.
Precipitation Intensity	Percent change in intensity <2mm -36% 2-25mm +12% >25mm +20%	Max number consecutive dry days 10.7/10.6/11.8	Max 120-hr (5 day) precipitation (mm) 98.4/98.1/99.1	
Period	**By 2080s**	**By 2080s**	**By 2080s**	
Sea Level	40 cm rise globally	Not Available	60 cm globally	Regional variations on mean and extreme amount unknown.
Synoptic Storms	Not Applicable	Increase in intense storms. Decrease in weak storms. (North of 30N)	Not Applicable.	Specific number and intensity of future storms over HRM unknown.
Tropical Cyclones	Increase in peak wind speed	Unknown	Not Applicable.	Increase in frequency unknown.
Ozone (Smog)	Unknown	Increase in production of smog with increase in maximum temperature.	Not Available.	Projections of ozone production increase unavailable.
Cloud Cover	Values vary widely from model to model globally.	Unknown	Not Available.	Specifics of cloud cover change unknown.
Fog	Not Available.	Frequency of occurrence may increase with increased storm activity.	Not Available.	Specifics of frequency change over HRM unknown.
Winds	See Tropical Cyclone above			
Waves	Increase in mean Significant Wave amount over North Atlantic (0.5-1.0M by 2080s).	Increase in Significant Wave occurrence (return period of 20 year wave height reducing to 8-16yrs).	Not Available.	Need more specifics regionally.
Ice Storms (ZR)	Most recent work for Ontario and Quebec	Increase in frequency expected by 2050	Not Available.	Specifics of frequency change in HRM unknown.

4.0 Risks of Climate Change Impacts in HRM

Step 3 – Identify Climate Change Impacts and Risks

This step undertakes a qualitative, or if data is available, quantitative assessment of the risks to HRM by looking at the likelihood of an event and the consequences resulting from the event. These are to be assessed for impacts on HRM's Business Unit and Assets under its direct control, in addition to impacts on environmental, social and economic elements within HRM's jurisdiction or scope of influence.

4.1 Introduction

In order to understand what the potential impacts from climate change on the the activities of HRM's business units, and the biophysical and socio-economic attributes of HRM, the context or setting described in Section 2 is in effect overlain by the projected climate changes provided in the preceding section to make projections on how the impacts from climate change will be manifested and on what biophysical or socio-economic attribute or business unit. To provide HRM with what the key impacts are projected to be, the authors relied on a number of sources including published reports and discussions with scientists from: Environment Canada; Natural Resources Canada; the Climate-Change Impacts and Adaptation Research Network (C-CIARN) Atlantic Region, and Environment Canada's National Water Resources Institute (NWRI).

4.2 Biophysical and Socio-Economic Impacts of Climate Change in HRM

The projected increase in temperature, sea-level rise, extreme events and increased storm surge elevations will potentially impact several key elements of HRM's biophysical and socio-economic fabric and as a result will directly or indirectly impact many of HRM's business units. As detailed research on the impacts of climate change specific to HRM are at present limited the project team undertook a qualitative review of the potential impacts on eight key biophysical and socio-economic components:

- Coastal Zones;
- Communities, Infrastructure, and Transportation;
- Water Resources;
- Human Health;
- Fisheries and Marine Resources;
- Forestry;
- Agriculture; and
- Environment.

The following tables provide a summary of the projected impacts on all affected sectors and the business units potentially effected.

4.2.1 Coastal Zones

Concern	Issue	Business Units Affected
Change in Natural Erosion, Migration, and Deposition Patterns (incl. Beach Dunes) from Extreme Events, Precipitation, Wind, Sea Level and Storm Surge Events.	Rising sea level likely to expose coastlines to increase damage from wave action and intensify rates of erosion. Current projections are for wave heights and wave-energy to increase as a direct result of global warming. Coastal ice is likely to become thinner and less extensive, thereby exposing coastal areas to winter storm waves more often than today, increasing coastal erosion and storm damage. Potential for increased variability in shoreline dynamics with potential changes in shoreline advance or erosion, and resultant impact on distribution of beach sediment and sand budget.	Community Development Halifax Regional Water Commission Infrastructure and Asset Management
Changes in Coastal Flooding Patterns from Extreme Events, Precipitation and Sea Level.	Sea level will rise over the next century with the result that storm surges in HRM are likely to inundate areas never before flooded. Sea-level rise and storm surge likely to result in more frequent inundation of low-lying coastal lands.	Community Development Transportation and Public Works Fire and Emergency Services Infrastructure and Asset Management
Changes to Coastal Ecosystems and Biodiversity from Extreme Events, Precipitation, Wind, Sea Level and Storm Surge Events.	The most sensitive coasts in HRM are low-lying, with salt marshes, barrier beaches, and lagoons. These areas are likely to experience such effects as increased erosion, rapid migration of beaches, and flooding of coastal freshwater marshes. The viability of sensitive coastal wetlands and associated ecosystems likely to be threatened.	Not applicable – Federal and Provincial jurisdication

4.2.2 Communities, Infrastructure and Transportation

Concern	Issue	Business Units Affected
Change in Ports Operations from Changes in Sea Level.	Potential positive impact on commercial shipping due to changes in access by deeper draft vessels from increases in water level in Halifax Harbour. Potential negative impact on shipping traffic may result from changes in ice patterns affecting viability of year-round Northwest Passage as a principal shipping route. Increased incidents of damage to ports infrastructure due to extreme events.	Not applicable – Halifax Port Authority jurisdiction
Impact on Infrastructure from Extreme Events, Precipitation (Rain and Snow), Wind, Sea Level Rise and Storm Surge.	Possible intensified damage and disruption to an increased range and distribution of coastal infrastructure, essential services, communications. Possible increased incidents of storm sewers and sanitary systems unable to deal with more frequent, high-intensity rainfall and storms. Changes in distribution and range of river and coastal ice, compounded by break-up and extreme events, will likely increase damage to river and coastal infrastructure. Buried municipal infrastructure in coastal areas at risk of being inundated or damaged by sea-level rise. Likely increased incidents of sewer failure in coastal areas as a result of rising sea levels and more intense storm events. Possible increased damage and disruption to vulnerable critical services, utilities and other infrastructure including power outages and disruption of communications.	Halifax Regional Water Commission Fire and Emergency Services Finance Infrastructure and Asset Management
Impacts on Operation of Infrastructure from Wind and Precipitation (Rain and Snow),	Projected increased insurance costs associated with damage to vulnerable infrastructure and buildings.	Finance Transportation and Public Works Infrastructure and Asset Management

Concern	Issue	Business Units Affected
Temperature, and Extreme Events.	Anticipated increased costs for road maintenance related to pavement softening and traffic-related rutting, as well as the migration of liquid asphalt. Potential for increased cracking and deterioration of pavements related to increased number of freeze-thaw cycles.	
Impact on Land Use	Increased uncertainty in settlement patterns and urban planning due to climate variability, sea level rise and impacts from extreme events. Some low-lying communities in HRM will be flooded more frequently and the floods will become more severe. Anticipated increased economic and social 'costs' associated with adaptation measures necessary to protect vulnerable coastal communities. Potential for increased risks from forest fires in the urban/rural fringe.	Community Development Finance Fire and Emergency Services Legal Services
Change in Water Based Recreational Activities from Change in Temperature, Precipitation, and Sea Level.	Projected sea level rise highly likely to reduce or relocate existing recreational beaches. Potential direct and indirect effects on tourism through beach loss, impacted infrastructure, and ecosystem alteration or degradation.	Infrastructure and Asset Management

4.2.3 Water Resources

Concern	Issue	Business Units Affected
Change in Surface Water Supply and Quality for Communities' Health and Economy, from Precipitation (i.e., Seasonal Patterns and Run-off Rates).	Potential for increased variability in the quality and quantity of municipal water resources. Possible increased variability in water supply, affecting energy production (hydropower), and agriculture. Variation in rainfall and run-off intensity may impact management of water supply and water control dams. Potential for increased incidents of aquatic pollution associated with runoff and flooding.	Halifax Regional Water Commission Infrastructure and Asset Management
Change in Ground Water Supply and Quality for Communities' Health and Economy, from Precipitation (i.e., Seasonal Patterns and Run-off Rates).	Potential for increased incidents and distribution of environmental and water contamination primarily related to well-head management. Changes in temperature and precipitation likely to alter recharge to groundwater aquifers, causing shifts in water table levels and water supply.	Not applicable – NSEL jurisdiction
Change in Water Quality through Salt-Water Intrusion from Sea Level Rise and Extreme Events.	Possible increased incidents of salt-water intrusion in coastal aquifers affecting potable and agricultural/ horticultural groundwater supplies.	Not applicable – NSEL jurisdiction but becomes applicable to HRWC if water needs to be piped.
Change in Surface and Groundwater Supply and Quality on Aquatic Life from Precipitation (i.e., Seasonal Patterns and Run-off Rates).	Periods of intense rainfall followed by dryer conditions can lead to reduction in overall surface water flows. This impact can also lead to reduction of groundwater flow to watercourses and wetlands.	Not applicable – DFO jurisdiction
Change in Surface and Groundwater Supply and Quality on Agriculture from Precipitation (i.e., Seasonal Patterns and Run-off Rates).	Projected climate change likely to alter snow and rainfall patterns, resulting in less frequent, but heavier, precipitation earlier than present (April rather than May). Intense, heavy rainfall leads to more runoff and less groundwater recharge Longer and warmer summers likely to result in more drought and greater need	Also applies to HRM parklands.

Concern	Issue	Business Units Affected
	for irrigation. Longer and warmer summers and droughts likely to increase the demand on groundwater and surface water resources to support agriculture.	

4.2.4 Human Health

Concern	Issue	Business Units Affected
Impacts on the Use and Capacity of Public Health System from Increased Incidents of Extreme Events.	Stress and over-loading of the adaptive capacity of public health infrastructure, from the cumulative effects of extreme events, injuries, break-down in essential services such as electrical power and communications, and introduction of diseases.	Fire and Emergency Services
Change in Incidence, Distribution and Severity of Vector and Flood Borne Disease from Combination of Changes in Temperature, Precipitation, and Extreme Events.	Incidents and distribution of vector-borne diseases (e.g., Lyme disease, West Nile virus). The number and location of local incidents involving West Nile virus in birds is anticipated to spread with continuing climate change. Incidents and distribution of temperature-, rainfall- and humidity-sensitive vector-borne and food-borne diseases.	Communications Fire and Emergency Services
Increase in Respiratory Disorders due to Increased Incidents of Air Pollution from Smog and Temperature Rise.	Possible increased incidents and distribution of respiratory disorders associated with increases in temperature and air pollution as there is a strong connection between higher daily temperatures and the potential for smog formation. Local air pollution is exacerbated by long-range transport of pollutants from New England, the Midwest, and central Canada.	Not applicable – provincial jurisdiction
Change in Illness, Stress, Injury and Casualty Rates from Change in Hot and Cold Thermal Extremes.	Health impact of thermal extremes (death and illness in vulnerable sectors of the community including the elderly, frail and ill). Extreme events such as heat waves are projected to be more numerous in HRM. Health impacts (deaths, injuries, infectious diseases, stress-related disorders, adverse health effects associated with social disruption,) associated with extreme weather events and other natural hazards.	Community Development Fire and Emergency Services Communications
Eye and Skin Disorders from Change in Ultra Violet (UV) Radiation.	Increased incidents of skin cancer and cataracts in the eyes due to changes in levels of ultra-violet radiation.	Not applicable – provincial jurisdiction

Concern	Issue	Business Units Affected
Impact on Public Health by Food-Borne Diseases Attributed to Changes in Temperature.	Possible increased incidence of food poisoning and intestinal tract ailments associated with spoiled food in summer temperatures. Seafood affected by increased levels of pollution associated with run-off events of increased severity. Anticipated increased incidence in toxic algae blooms from change in sea level, temperature, and sediment in precipitation runoff.	Not applicable – provincial jurisdiction

4.2.5 Fisheries and Marine Resources

Concern	Issue	Business Unit Affected
Change in Marine Resources and Sustainable Harvest	Change in habitat, salinity, and food chain from change in sea level, temperature, and sediment in runoff has the potential to affect the commercial viability of certain fish stocks (crab, lobster, fresh water fin fish, other salt water fin fish, and other salt water shell fish). Changing temperatures likely to be a factor in the distribution and population abundance of some species, however, fish stocks are influenced by many factors and a relationship between climate change and marine species cannot be easily determined based on current research. Possible increased incidence of biotoxins associated with ocean warming and reduced resilience of natural ecosystems from pollution, with associated increase in contamination of fish and shellfish. Changes in temperature and reduced resilience of coastal ecosystems likely to affect the viability of aquaculture species being grown.	Not applicable – Federal and provincial jurisdiction
Change in Fisheries and Marine Insurance Payouts from Extreme Events, Sea Level and Storm Surge.	Anticipated increased insurance costs associated with damage to marine transport and fisheries infrastructure.	Not applicable – responsibility of private sector

4.2.6 Forestry

Concern	Issue	Business Units Affected
Change in Long-Term Planting Selections and Harvests from Temperature, Precipitation, and Season.	Projected increased variation in harvesting processes (e.g., maple sugar). Possible increased social disruption to forest dependent communities as harvests or species change.	Not applicable – provincial jurisdiction
Change in Forest Fire Potential from Temperature, Precipitation and Wind.	Anticipated increase incidents and range of forest fires due to changes in temperature and precipitation bringing about extended hot dry conditions.	Community Development Fire and Emergency Services Legal Services
Change in Sustainable Forest and Wildlife Habitat from Temperature, Precipitation, Season, and Sea Level.	Potential for increased variability in forest structure, composition, productivity, and regeneration. Warmer and more humid climate could increase the numbers of local and exotic forest pests. Periods of midwinter thaw may become more frequent and extended leading to root damage of some species.	Not applicable – provincial jurisdiction
Change in Pest Populations from Extreme Events, Temperature and Precipitation.	Potential for increased variability in incidents and location of pest, and on the natural disturbance regime, pest cycle, and rate of infestation. Anticipated increased number of extreme climatic events likely to make ecosystems more vulnerable to a greater number of pests. Possible increased risk of invasive species, especially as winter temperatures rise. Potential changes in range and distribution of invasive species. Changes in precipitation and temperature significantly affect the impacts from invasive species.	Infrastructure and Asset Management
Change in Forestry Insurance Payouts and Blow Downs from Extreme Events.	"Blow down" (of forests leading to an increased fire hazard) may increase with storms that are more frequent and intense. Anticipated increased insurance costs associated with damage to forestry resources and infrastructure.	Infrastructure and Asset Management

4.2.7 Agriculture

Concern	Issue	Business Units Affected
Change in Long-term Crop Planting Decisions from Temperature, Precipitation and Season.	Longer, warmer growing season likely to improve yields of warm weather crops (corn, grapes), however, this is dependent on heat stress tolerance of crops, availability of water for irrigation.	Not applicable – provincial jurisdiction
Change in Crop Heat Unit, Degree-Day, and Hardiness Zone Type Values from Temperature, Precipitation and Season.	Possible changes to the diversity and types of crops able to be grown. Losses from winter kill of forage and fruit likely to be less.	Not applicable – provincial jurisdiction
Change in Pest, Mould, Disease, Weeds, from Temperature, Precipitation and Season.	Changes in seasonal weather patterns likely to affect the incidents and distribution of plant pests and diseases. Warmer weather in winter and growing season projected to allow more generations of pests to develop. It may also allow for the over-wintering of insect larvae normally killed by cold winter temperatures.	Infrastructure and Asset Management
Change in Grass and Hay Potential For Animal Use from Temperature, Precipitation and Season	Anticipated positive changes in fodder production patterns due to longer growing season but this may be offset by longer dry periods.	Not applicable – provincial jurisdiction
Change in Farm Insurance Payouts from Extreme Events, Sea Level and Storm Surge.	Trend towards more extreme weather events (frequency and intensity), likely to result in damage to crop and livestock operations from storms, hail, floods, and droughts.	Not applicable – federal and provincial jurisdiction

4.2.8 Environment

Concern	Issue	Business Units Affected
Change in Abundance and Distribution of Wildlife Populations from Temperature, Precipitation, and Season.	Possible changes in the distribution, range and number of birds and other wildlife depend on habitat affected by climate change. Up to a certain point, living organisms can adapt to natural stresses such as new climatic conditions. However, the capacity to adapt varies from species to species. More resistant species may survive, others will have to migrate if they can, whereas still others will be extripated and be replaced by different species that are better adapted to the new conditions. The results of recent studies show that changes in summer climatic conditions would likely cause rapid advances or retreats of certain populations as their habitats shift or are disturbed. Mild winters will enhances the reproductive capacities of some species, leading to a gradual northward expansion of their populations. Anticipated changes in indigenous biodiversity. Projected increased stress on native species due to invasion/migration of alien species without natural controls	Not applicable – federal and provincial jurisdiction
Change in Abundance and Distribution of Isolated Populations and Ecosystems from Temperature, Precipitation, Season, and Sea Level.	Projected increased stress on isolated wildlife populations and ecosystems, such as protected areas that are ecosystems “islands”, which will likely threaten the sustainability of the species or ecosystem.	Not applicable – federal and provincial jurisdiction
Change in the Migration of Species (i.e., Coastal Water-Fowl) from Temperature, Precipitation, Season, and Sea Level.	Anticipated changes in river flow - earlier break-up, stronger spring freshet, and reduced summer flow - could impact some waterfowl. Anticipated alteration in the migration patterns of species, particularly waterfowl due to changes in coastal wetlands from temperature, precipitation, season, and sea level.	Not applicable – federal and provincial jurisdiction

4.3 Impacts of Climate Change on HRM Business Units

With the above understanding of how climate change may affect the socio-economic and environmental aspects of HRM, we are able to further refine the implications to HRM's Business Units. Table 4-1 provides examples of the relevant climate change impacts and for each Business Unit. These examples can be used by all Business Units as a basis for reviewing risks and possible adaptation measures (see Section 6).

Table 4-1 Examples of Impacts of Climate Change on HRM Business Units and Functions

Business Unit	Responsibilities	Relevant Climate Change Impacts
Chief Administrative Officer	• Information, support, guidance to Regional Council • Lead and manage administrative functions • Implementation of policies and priorities of Regional Council	• Any impacts on HRM resulting from climate change are relevant to the CAO's office as climate change will affect overall operations, service delivery, insurance, and liability.
Communications	• Internal and external communications	• As communications has responsibility for both internal and external communications all climate change impacts are relevant as climate change may lead to impacts on service delivery requiring communication with the public. Increase in resources and capacity required due to additional responsibilities of Business Unit which would also assist EMS and other Business Units in providing internal information to HRM staff and the general public concerning the nature of risks and possible risk management measures.
Fire and Emergency Services	• Provision of fire, ambulance and emergency response services • Fire safety and emergency preparedness	• Coastal erosion and impacts on transportation infrastructure impacting access for emergency services and vehicles. • Similarly, coastal inundation due to storm surge may impede access for emergency services and vehicles. • Greater range of vulnerable communities (sick, elderly, young, infirm) making demands on emergency services due to increased intensity and scope of extreme events (floods, droughts, heat-waves, storms). • Increased damage and disruption of vulnerable critical utilities and infrastructure that may impact emergency communications. • Potential for increased risks from forest fires that may be combined with additional blow down due to storm events in the urban/rural fringe requiring additional resources in these areas. • Stress and over-loading of the adaptive capacity of public health infrastructure (includes HRM Emergency Services), from the cumulative effects of extreme events, injuries, break-down in essential services such as electrical power and communications, and introduction of diseases.

Business Unit	Responsibilities	Relevant Climate Change Impacts
Police Services	• Provision of services for community protection and control • Communications related to police services activities	• Coastal erosion and impacts on transportation infrastructure assess for police vehicles. • Coastal inundation due to storm surge may impede access for police vehicles. • Increased damage and disruption of vulnerable critical utilities and infrastructure that may impact police communications. • Greater demand on police services for community protection by communities affected by social disruption (looting, etc.) due to increased intensity and scope of extreme events (floods, storms).
Community Development	• Land use policy and planning • Regional policy and planning • Land use zoning • Transportation planning • Building permits and inspection • Heritage property (designation process, no management role)	• Impacts on viable land use and zoning options due to increased incidents of coastal erosion and impacts on transportation infrastructure and coastal inundation due to storm surge. • Impacts on planning and design or location of emergency service centers, and emergency services evacuation routes/measures due to increased incidents of coastal erosion and impacts on transportation infrastructure and coastal inundation due to sea level rise, storm surge and extreme events (floods, droughts, heat-waves, storms) • Increased uncertainty in settlement patterns and urban planning due to climate variability, sea level rise and impacts from extreme events. • Impacts on viable land use and zoning options due to increased risks from forest fires in the urban/rural fringe. • Greater incidents of building and infrastructure failure due to increases intensity and scope of extreme events (floods, droughts, heat-waves, storms) resulting in increased risk of exposure to litigation and added demand for improvements to building inspection services and standards.
Infrastructure and Asset Management	• Sustainable environment policy • Design and construction of roads • Management of recreational parks • Real estate • Management of business parks • Management of HRM owned/controlled buildings	• Climate change will profoundly impact all policies and programs relating to environmental sustainability. • Potential disruption to transportation infrastructure due to impacts from sea-level rise, coastal erosion, inundation and impacts from increases in intensity of extreme events (floods, storms). • Increased demand for water in recreation parks due to longer and warmer summers likely to result in more drought and greater need for irrigation. • Increased demand for biological control agents in recreational parks due to potential for increased variability in incidents and location of pest, and on the natural disturbance regime, pest cycle, and rate of infestation. • Anticipated increased insurance costs associated with damage to buildings and

Business Unit	Responsibilities	Relevant Climate Change Impacts
		infrastructure from sea-level rise, storm surge, and extreme events (flood, forest fires, storms).
Transportation and Public Works	• Waste management policy and implementation • Public transit • Street and road (HRM owned) maintenance • Snow and ice removal • Fleet services	• Potential disruption to waste collection and management services due to impacts on transportation infrastructure from coastal erosion, coastal inundation and extreme events (floods, storms and forest fires). • Increased costs for road maintenance both winter and summer to mitigate impact on pavement from frost heave and heat. • Increased variability in demand for snow and ice removal due to impacts on snow and rainfall patterns. • Greater demand on emergency service vehicles due to impacts from extreme events (floods, droughts, forest fires, heat waves, storms).
Halifax Regional Water Commission[28]	• Water and wastewater treatment and related infrastructure • Stormwater infrastructure design, construction and maintenance	• Impacts on water quality and availability due to changes in patterns, coastal erosion and impacts on water infrastructure. • Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events. • Increased damage and disruption of vulnerable critical water/wastewater utilities and infrastructure. • Impact on management of water supply and water control dams due to variation in precipitation/evaporation patterns and run-off intensity. • Possible increased incidents of salt-water intrusion in coastal aquifers due to sea-level rise and variations in precipitation patterns.
Finance	• Corporate financial management • Fiscal and tax policy	• Sea-level rise, coastal erosion/inundation and impacts from increased intensity of extreme events on HRM controlled infrastructure will result in increases to operational and capital costs. • Increased costs from litigation by third parties alleging failure by HRM to establish appropriate risk management measures (e.g. limits to development in vulnerable areas, improvements to infrastructure, improvements to building codes, etc.) • Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events may result in costs associated with repairs to damaged structures and increased costs from litigation. • Increased damage and disruption of vulnerable critical utilities and infrastructure resulting in increased costs for repair.

[28] Reflects organizational change effective April 1, 2007

Business Unit	Responsibilities	Relevant Climate Change Impacts
		• Projected increase in insurance costs for vulnerable HRM assets. • Increased costs for road maintenance both winter and summer due to impacts on pavement from frost heave and heat. • Increased variability in costs from snow and ice removal due to changes in precipitation patterns. • Anticipated increased operational economic and social 'costs' associated with adaptation measures necessary to protect vulnerable communities and infrastructure.
Business Systems and Control	• Geographic information services • HRM intranet and internet • HRM information technology • Call centre/dispatch services	• Increased demand by developers, communities and land owners for improved hazard mapping and climate risk information services. • Greater demand on call centre and dispatch staff during extreme events. • Potential for impacts on HRM's IT system due to extreme events.
Legal Services	• Writing By-Laws • Interpretation of legal statutes for staff and Council • Prosecutions and defence on matters under HRM jurisdiction • Corporate (HRM) Risk Assessment and Management	• Increased demand for by-laws that will restrict or control development in vulnerable areas. • Increased incidents of litigation by third parties alleging failure to HRM to establish appropriate risk management measures (e.g. limits to development in vulnerable areas, improvements to infrastructure, improvements to building codes, etc.) • Increased incidence of litigation from alleged failure in storm and combined sewers due to changes in precipitation patterns. • Increased incidence of litigation from alleged failure in HRM controlled infrastructure due to sea-level rise, storm surge or extreme events. • Increased incidence of litigation from alleged impacts on water quality and availability due to changes in precipitation patterns, coastal erosion and impacts on water infrastructure, and increased damage and disruption of vulnerable critical water/wastewater utilities and infrastructure. • Increased incidence of litigation from alleged increased damage and disruption of vulnerable critical utilities and infrastructure. • Projected increase in insurance claims associated with vulnerable HRM assets/operations. • Vulnerability and exposure to climate change impacts resulting in an increase in the scope and range of HRM risk assessment and management framework to satisfy "due diligence".

Step 3 – Identify Climate Change Impacts and Risks

This step undertakes a qualitative or if data is available quantitative assessment of the risks to its assets by looking at the likelihood of an event and the consequences resulting from the event. These are to be assessed for socio-economic impacts and environmental impacts.

Step 4 – Prioritize the Risks

This step involves summarizing the outputs of Step 3 in order to rank impacts in terms of overall or integrated risk to HRM's Business Unit, assets under its direct control, and associated environmental, social and economic elements.

5.0 Identification of Risks

5.1 Objective

This section of the strategy integrates information presented in the forgoing sections and using a risk assessment-based process, categorizes the vulnerability and risk of the potential impacts to assist in the prioritization of adaptation responses.

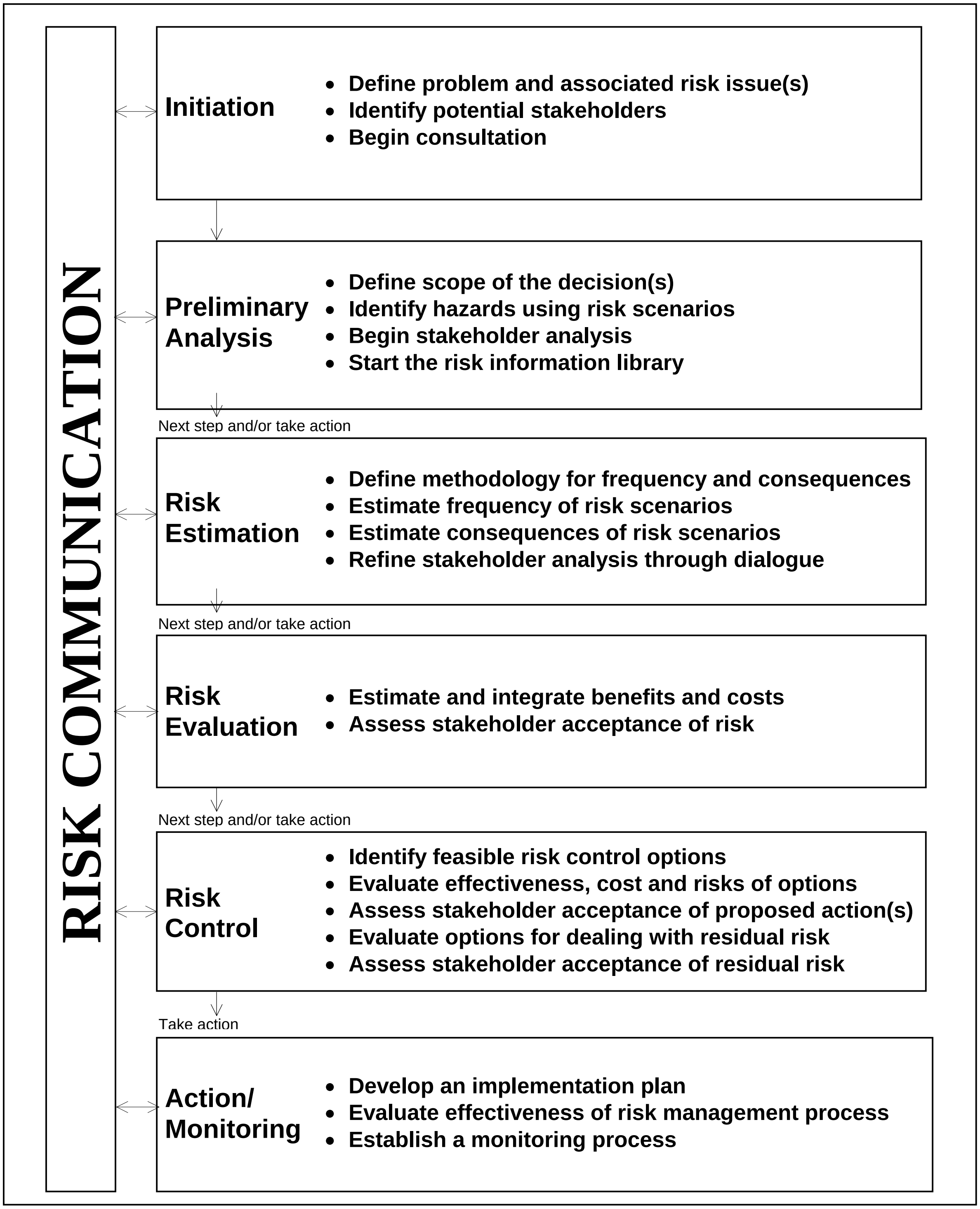
5.2 Approach

The overall approach to determining risk for this strategy was based on risk management standards published by the Canadian Standards Association, specifically: *CAN/CSA- Q634-M91 – Risk Analysis Requirements and Guidelines*, and *CAN/CSA -Q850-97 – Risk Management: Guidelines for Decision-Makers.* In these Standards, risk is defined as:

"a measure of the probability and severity of an adverse effect to health, property, or the environment"

Risk can be expressed mathematically as the product of probability of an event multiplied by consequence of the event. This approach can also be used qualitatively as well in risk assessments where numerical probabilities have not been established as in the case of most events resulting from climate change. The latter of these two approaches was employed in this application as quantitative probabilities of climate change impacts are not available for HRM. The general structure of the approach is illustrated in Figure 5-1.

Figure 5-1 Structure of a Risk-Based Process Adopted for Vulnerability Assessment



The determination of risk associated with the projected climate change impacts was undertaken for each of potential impacts described in Section 4. The probability of the impact occurring (based on the estimated frequency or likelihood of the impact occurring) and the resulting consequence (based on the estimated severity of the impact) based on current knowledge was assigned a category of Low, Medium, or High (L, M, H) where:

Low probability = the frequency of the impact occurring is improbable to unlikely.

Medium probability = current knowledge indicates that the impact is likely to occur.

High probability = the impact is highly likely or virtually certain to occur.

And

Low consequence = Minor instances of impact that would be short term and reversible.
Medium consequence = Noticeable social and environmental impact that will require additional resources for adequate response. Opportunities for reversing impacts are limited.

High consequence = Significant social, economic and environmental impact leading to reduced quality of life. Impacts not reversible.

As consequences of the impacts can have both environmental and socio-economic considerations, the categories were further subdivided and shown as follows:

For socio-economic considerations: $\mathbf{L_S}$**,** $\mathbf{M_S}$**, or** $\mathbf{H_S}$ and

For environmental considerations: $\mathbf{L_E}$**,** $\mathbf{M_E}$**, or** $\mathbf{H_E}$**.**

This approach allows for the integration of the probability and consequence for both environmental and socio-economic considerations in order to develop an overall risk for the potential impacts (Figure 5-2). The integrated risks were also assigned **L**, **M** and **H** rankings where:

Low = Risks that require no or minimal actions. Minimal actions could include public education/awareness.

Medium = Some actions controls will be required to reduce risks to low or negligible levels.

High = These risk areas will require high-priority actions to reduce risks to low or negligible levels.

These findings were subsequently carried forward in the development of adaptation options and priorities in Section 6.

Figure 5-2 Risk Assessment Matrix

		PROBABILITY		
IMPACT SEVERITY		LOW	MEDIUM	HIGH
	HIGH	M	H	H
	MEDIUM	L	M	H
	LOW	L	L	M

It is noted that the potential impacts presented in Table 5-1 were categorized only if specific research or published information was available for the preparation of this document. Where scientific data are not available or current research not conclusive, a probability, consequence and risk category has not been assigned. These potential impacts are noted by **I.** Impacts noted as having insufficient information have also been carried forward as a recommendation for further research.

Table 5-1 Risk Evaluation Tabulation

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
1. COASTAL ZONES					
a) Impacts on coastal wetlands/ecosystems					
• Sea level rise/storm surge	**H**	**H_S H_E**	**H_S H_E**	**H**	**n/a**
b) Impacts from erosion					
• Sea level rise/storm surge	**H**	**H_S H_E**	**H_S H_E**	**H**	**H**
c) Impacts from flooding					
• Sea level rise/storm surge	**H**	**H_S H_E**	**H_S H_E**	**H**	**H**
d) Impact on recreational use					
• Loss or relocation of beaches	**H**	**M_S L_E**	**M_S M_E**	**M**	**n/a**
2. COMMUNITIES/INFRASTRUCTURE/TRANSPORTATION					
e) Impacts on settlements & related coastal infrastructure					
• Sea level rise/storm surge	**H**	**H_S H_E**	**H_S H_E**	**H**	**H**
• Storm and combined sewer surcharging and failure	**M**	**M_S H_E**	**M_S H_E**	**H**	**H**
• Ice damage	**L**	**L_S L_E**	**L_S L_E**	**L**	**L**
• Disruption to critical utilities	**M**	**H_S L_E**	**H_S L_E**	**H**	**n/a**
• Increased insurance cost	**H**	**H_S L_E**	**H_S L_E**	**H**	**H**
• Increased economic and social costs associated with adaptation	**H**	**H_S L_E**	**H_S L_E**	**H**	**H**
a) Impacts on settlement patterns & land-use planning					
• Extreme events, sea level rise & storm surge	**H**	**H_S H_E**	**H_S H_E**	**H**	**H**
• Increase in areas of flooding and severity	**H**	**H_S M_E**	**H_S M_E**	**H**	**H**
• Increased risk of forest fire in urban/rural fringe	**M**	**H_S H_E**	**H_S H_E**	**H**	**H**
b) Impacts on transportation infrastructure					
• infrastructures & patterns	**M**	**H_S L_E**	**H_S L_E**	**M**	**M**
• frequency and cost of maintenance	**M**	**M_S L_E**	**M_S L_E**	**M**	**M**
• port operations	**H**	**M_S L_E**	**M_S L_E**	**M**	**n/a**
c) Impacts on buildings and building code criteria					
• Extreme events	**H**	**H_S L_E**	**H_S L_E**	**H**	**H**
3. WATER RESOURCES					
a) Impacts on the variability of quality & quantity of surface water resources					
• Potable water	**L**	**M_S M_E**	**L_S L_E**	**L**	**L**
• Agriculture	**H**	**M_S M_E**	**M_S M_E**	**H**	**n/a**
• Water chemistry	**M**	**M_S M_E**	**M_S M_E**	**M**	**M**
• Management of dams	**M**	**H_S H_E**	**H_S H_E**	**H**	**H**
b) Impacts on groundwater supplies					
• Groundwater contamination	**M**	**H_S H_E**	**H_S H_E**	**H**	**H**
• Quantity of groundwater	**M**	**M_S M_E**	**M_S M_E**	**M**	**M**
• Salt water intrusion	**H**	**M_S M_E**	**M_S M_E**	**H**	**H**

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
• Agriculture	**H**	M_S M_E	M_S M_E	**H**	**n/a**
4. HUMAN HEALTH					
a) Impacts from extreme weather events					
• Capacity of health care system	**M**	H_S L_E	H_S L_E	**M**	**M**
• Thermal extremes	**M**	H_S L_E	H_S L_E	**M**	**n/a**
• Stress related health issues	**M**	M_S L_E	M_S M_E	**M**	**n/a**
• Increased incidence of toxic algae blooms	**I**	**I**	**I**	**I**	**n/a**
b) Impacts from vector-borne disease					
• Spread of Lyme Disease, West Nile virus	**H**	H_S L_E	H_S L_E	**H**	**n/a**
c) Impacts from increased air pollution with higher temperatures					
• Increase in respiratory illnesses	**M**	M_S M_E	M_S M_E	**M**	**n/a**
• Overloading of public health system	**M**	M_S L_E	M_S L_E	**M**	**M**
d) Impacts from change in UV radiation					
• Increased incidents of skin cancer, cataracts	**M**	M_S L_E	M_S L_E	**M**	**n/a**
e) Impacts from food-borne disease					
• Increased incidence of food poisoning associated with spoiled food	**M**	M_S L_E	M_S L_E	**M**	**n/a**
• Seafood affected by increased levels of pollution from increased run-off	**I**	**I**	**I**	**I**	**n/a**
f) Overall impact to public safety	**M**	H_S L_E	H_S L_E	**H**	**H**
5. MARINE/FISHERIES					
a) Impacts on physical & chemical regime of oceans					
• Temperature	**I**	**I**	**I**	**I**	**n/a**
• Salinity	**I**	**I**	**I**	**I**	**n/a**
• Increase in biotoxins	**I**	**I**	**I**	**I**	**n/a**
b) Socio-economic impacts					
• Fisheries	**I**	**I**	**I**	**I**	**n/a**
• Tourism	**I**	**I**	**I**	**I**	**I**
6. FORESTRY					
a) Impacts on natural disturbances, pests and rate of infestation					
• Midwinter thaws	**M**	M_S L_E	M_S L_E	**M**	**M**
• Forest fires	**M**	M_S L_E	M_S L_E	**M**	**M**
• Pest invasion	**M**	M_S L_E	M_S L_E	**M**	**M**
• Blowdown from Extreme Events	**H**	M_S M_E	M_S M_E	**M**	**M**
b) Impacts on harvesting processes					
• Variation in timing and quantity	**M**	M_S L_E	M_S L_E	**M**	**n/a**
c) Impacts on forest dependant communities					
• Change in harvests or species composition	**M**	M_S L_E	M_S L_E	**L**	**n/a**
• Insurance costs	**I**	**I**	**I**	**I**	
d) Impacts on forest structure, composition, productivity & regeneration					
• Ecosystem changes	**L**	M_S L_E	M_S L_E	**L**	**L**

Item	Probability (Frequency of event)	Consequence (Impact severity)	Segregated risk	Integ-rated risk	Risk to HRM Business Units
7. AGRICULTURE					
a) Impacts on crops due to drought & changing precipitation patterns • Storm/hail/drought damage	**H**	$H_S\ L_E$	$H_S\ L_E$	**H**	**n/a**
b) Impacts due to longer growing season • Higher yields • Increased diversity • Less loss due to frost damage	**M** **M** **M**	$H_S\ L_E$ $M_S\ M_E$ $M_S\ M_E$	$H_S\ L_E$ $M_S\ M_E$ $M_S\ M_E$	**M** **M** **M**	**n/a** **n/a** **n/a**
c) Impacts from changing pest & disease regimes • Increase in pests due to warmer winters	**M**	$H_S\ L_E$	$H_S\ L_E$	**M**	**M**
8. ENVIRONMENT					
a) Impacts on terrestrial & aquatic biodiversity. • Range and distribution of species • From temp & flow changes	**M** **H**	$L_S\ M_E$ $L_S\ H_E$	$L_S\ M_E$ $M_S\ H_E$	**M** **H**	**n/a** **n/a**
b) Impacts on isolated populations & ecosystems	**M**	$L_S\ H_E$	$M_S\ H_E$	**M**	**n/a**
c) Impacts on migration of species • Break up & low summer flows	**I**	**I**	**I**	**I**	**n/a**
d) Impacts on native species due to invasion/ migration of alien species without natural controls	**M**	$M_S\ M_E$	$M_S\ M_E$	**M**	**M**

In total, the review of socio-economic and environmental impacts and risks identified and evaluated the risks for 60 broad impacts, of which 29 present risks that are under the control or influenced by one or more of HRM's business units.

High Risk

The high risk category consisted of 21 impacts (14 are applicable to HRM) that were dominated by impacts on coastal zones; infrastructure groundwater supplies, and overall public safety. These are outlined below.

Coastal zones:

- sea level rise/surges on wetlands/ecosystems
- sea level rise/surges on erosion*[29]
- sea level rise/surges on flooding*

Communities/infrastructure/transportation:

- impacts on insurance and property values*
- impacts on transportation infrastructure and patterns from extreme events*
- extreme events, sea level rise and surges on settlement patterns*

[29] *=presents risks to one or more of HRM's business units, see Section 4.

- extreme events, sea level rise and surges on infrastructure and transportation*
- extreme events on buildings and building code criteria*
- storm and combined sewer surcharging and damage*
- increase in flooding*
- increase in forest fires*
- disruption to critical utilities due to extreme events
- impacts on power usage
- increased economic and social costs to implement adaptation measures*

Water resources:
- impacts related to agriculture
- potential for contamination of groundwater*
- salt water intrusion*
- management of HRWC and private dams*

Human Health:
- increase in West Nile virus and Lyme's disease

Agriculture:
- impact due to drought and changing precipitation patterns*

Environment:
- temperature and flow changes resulting from impacts on terrestrial and aquatic biodiversity

Medium Risk
The medium risk category consisted of 25 (12 applicable to HRM) impacts that included impacts on infrastructure maintenance; health care; air quality; forestry; agriculture; aboriginal uses; and general environment considerations. These are outlined below.

Coastal zones:
- loss or relocation of beaches

Communities/infrastructure/transportation:
- port operations
- impacts on transportation infrastructure and patterns*
- impacts on frequency and cost of transportation maintenance*

Water resources:
- impacts on variability of quantity with respect to hydro generation on variability of quality and quantity with respect to hydrogeology
- impacts on variability of quality and quantity with respect to water chemistry*
- impacts on quantity of groundwater*

Human Health:
- capacity of health care system due to impacts from extreme events*
- stress related health issues
- increase in respiratory illnesses
- overloading of health care system due to increased admissions
- increased incidents of skin cancer, cataracts due to change in UV radiation

Forestry:
- impacts on natural disturbance regime, pest cycle and rate of infestation due to midwinter thaws*
- impacts on natural disturbance regime, pest cycle and rate of infestation due to increased forest fires*
- impacts on natural disturbance regime, pest cycle and rate of infestation due to pest infestations*
- impacts on natural disturbance regime, pest cycle and rate of infestation due to blowdown from extreme events*
- impacts on harvesting processes

Agriculture:
- impact due to an increase in pest and disease regimes*
- impacts on yield due to longer growing season
- impacts on diversity and types of crops grown
- decreased loss due to frost damage*

Environment:
- impacts on range and distribution of species
- impacts on isolated populations and ecosystems

- impacts resulting from invasion/migration of alien species*

Low Risk
The low risk category consisted of four impacts (three applicable to HRM) which included coastal ice damage; potable water supply; forest compositional and related ecosystem changes. These are outlined below.

Communities/infrastructure/transportation:
- impacts settlement patterns and related coastal infrastructure due to ice damage*

Water resources:
- potable water supply*

Forestry:
- change in harvests or species composition*
- ecosystem changes

Insufficient Data/More Research Required
The integrated risk of nine impacts (one applicable to HRM) was not determined due to lack of research or inconclusive findings. These impacts generally related to those of a more regional or global level such as impacts on commercial fisheries and migration patterns, and are presented below.

Human Health:
- effects on toxic algae blooms
- effects on seafood by increased levels of contaminants due to increased run-off

Marine/fisheries issues:
- impacts on the physical, chemical, and temperature regime impacts on fish migration
- impact on distribution of bio-toxins
- socio-economic impacts on commercial fisheries
- socio-economic impacts on tourism*

Forestry:
- insurance costs
- the impacts on forestry dependent communities

Environment:
- impacts on migrations of species

Evaluation of Risks for Business Units

In order to provide guidance on the impacts affecting the Business Units and to what degree, the broad risks that are relevant to HRM can be assigned based on the Business Units' roles and responsibilities as previously summarized in Tables 2-1 and 4-1. This assignment is provided in Table 5-2.

Table 5-2 Initial Risk Evaluation Tabulation for Business Units

Business Unit and Relevant Climate Change Impacts	Probability (Frequency of event)	Consequence (Impact severity)	Integ-rated risk
CHIEF ADMINISTRATIVE OFFICE			
All projected climate change impacts.	H	M to H	H
COMMUNICATIONS			
All projected climate change impacts.	H	M	M
FIRE AND EMERGENCY SERVICES			
• Coastal erosion and impacts on transportation infrastructure.	M	H	H
• Coastal inundation due to storm surge.	M	M	M
• Increased damage and disruption of vulnerable critical utilities and infrastructure.	M	H	H
• Potential for increased risks from forest fires in the urban/rural fringe.	M	H	H
• "Blow down" (of forests leading to an increased fire hazard) may increase with storms that are more frequent and intense.	L	M	M
• Stress and over-loading of the adaptive capacity of public health infrastructure, from the cumulative effects of extreme events, injuries, break-down in essential services such as electrical power and communications, and introduction of diseases.	M	H	H
• Overall impact to public safety.	M	H	H
POLICE SERVICES			
• Coastal erosion and impacts on transportation infrastructure.	M	H	H
• Coastal inundation due to storm surge.	M	M	M
• Increased damage and disruption of vulnerable critical utilities and infrastructure.	M	H	H
• Overall impact to public safety	M	H	H
COMMUNITY DEVELOPMENT			
• Coastal inundation due to storm surge.	M	H	H
• Increased uncertainty in settlement patterns and urban planning due to climate variability, sea level rise and impacts from	M	M	M

Business Unit and Relevant Climate Change Impacts	Probability (Frequency of event)	Consequence (Impact severity)	Integ-rated risk
extreme events.	H	H	H
• Potential for increased risks from forest fires in the urban/rural fringe.	M	H	H
INFRASTRUCTURE AND ASSET MANAGEMENT			
• Coastal erosion and impacts on transportation infrastructure.	M	H	H
• As Infrastructure and Asset Management develops policy related to environmental sustainability and climate change can have an impact on HRM's environmental sustainability, all climate impacts are relevant.	H	M to H	H
• Coastal erosion and impacts on transportation infrastructure.	M	H	H
• Longer and warmer summers likely to result in more drought and greater need for irrigation.	M	M	M
• Potential for increased variability in incidents and location of pest, and on the natural disturbance regime, pest cycle, and rate of infestation.	H	H	H
• Anticipated increased insurance costs associated with damage to infrastructure.	L	L	L
• Ice damage to structures.	L	L	L
TRANSPORTATION AND PUBLIC WORKS			
• Coastal inundation due to storm surge.	M	M	M
• Increased costs for road maintenance both winter and summer to mitigate impact on pavement from frost heave and heat.	M	M	M
• Projected climate change likely to alter snow and rainfall patterns, resulting in less frequent, but heavier, precipitation earlier than present (April rather than May).	M	M	M
	M	M	M
HALIFAX REGIONAL WATER COMMISSION			
• Coastal erosion and impacts on transportation infrastructure.	M	H	H
• Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events.	M	H	H
• Increased damage and disruption of vulnerable critical utilities and infrastructure.	M	H	H
	M	H	H
• Variation in rainfall and run-off intensity may impact management of water supply and water control dams.	H	M	H

Business Unit and Relevant Climate Change Impacts	Probability (Frequency of event)	Consequence (Impact severity)	Integ-rated risk
• Possible increased incidents of salt-water intrusion in coastal aquifers affecting potable and agricultural/ horticultural groundwater supplies. • Impacts on surface water resources	**L**	**L**	**L**
FINANCE			
• Coastal erosion and impacts on transportation infrastructure.	**M**	**H**	**H**
• Coastal inundation due to storm surge.	**M**	**M**	**M**
• Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events.	**M**	**H**	**H**
• Increased damage and disruption of vulnerable critical utilities and infrastructure.	**M**	**H**	**H**
• Projected increase in insurance costs for HRM assets.	**H**	**H**	**H**
• Increased costs for road maintenance both winter and summer to mitigate impact on pavement from frost heave and heat.	**M**	**M**	**M**
• Anticipated increased economic and social 'costs' associated with adaptation measures necessary to protect vulnerable coastal communities.	**H**	**H**	**H**
BUSINESS SYSTEMS & CONTROL INFORMATION MANAGEMENT			
• Additional burden on call centre and dispatch staff.	**M**	**M**	**M**
LEGAL SERVICES			
• Coastal erosion and impacts on transportation infrastructure.	**M**	**H**	**H**
• Coastal inundation due to storm surge.	**M**	**M**	**M**
• Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events.	**M**	**H**	**H**
• Increased damage and disruption of vulnerable critical utilities and infrastructure.	**M**	**H**	**H**
• Projected increase in insurance costs for HRM assets.	**H**	**H**	**H**

Step 5 – Identify the Options to Manage the Risks

HRM's Business Units review and identifies potential options to manage the impacts in the proceeding steps with emphasis on those items listed as high risk or priorities.

6.0 Climate Change Adaptation Options for HRM

6.1 Introduction

In an attempt to identify potential adaptation options for assign priorities for action, a two stage approach was undertaken. As a first step, the impacts with a medium or high integrated risk and therefore viewed as high priority items were tabulated by sector. The second step involved testing and refining these options and priorities with HRM staff through project workshops. The outcomes of these workshops were then tabulated by Business Unit to provide guidance on options available and resources required. The workshops also provided HRM staff the opportunity to discuss over arching priorities that would need to be addressed prior to implementing specific actions (see Section 7).

6.2 Identification of Adaptation Options

Relevant adaptation options for each high risk impact identified in Section 5 were assembled and then assessed in terms of area of a) responsibility (e.g. HRM; provincial; federal; private sector); or a combination of the parties and b) the requirements, information or resources needed to implement the option (Table 6-1). This screening was completed to more clearly define those actions HRM are directly responsible for and more readily implemented versus those options that would involve other parties and therefore longer lead time to develop an effective approach. The table provides strategic direction and guidance on adaptation responses. Specific actions are to be developed within the scope of HRM priorities and budgets and can be adjusted as new scientific information and adaptation responses come to light.

Table 6-1 Adaptation Responses and Requirements

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
Chief Administrative Officer	• Any impacts on HRM resulting from climate change are relevant to the CAO's office as climate change will affect overall operations, service delivery, insurance, and liability.	• The CAO must provide direction to staff to implement the consideration of climate change in business unit planning e.g. through risk assessment approaches. It also must communicate the implications of climate change to Regional Council. • Increased collaboration with federal and provincial governments to develop complimentary climate change adaptation programs and to provide necessary modeling data. • Set policy that requires all business units to incorporate climate change in risk assessment undertaken as part of annual business plan development.	• Facilitate increase in capacity and resources required by Business Units to adequately manage risks. • Provide guidance information and tools for staff to implement policy direction on climate change adaptation and risk management approaches. • Incorporation of climate change risk assessment into business unit integrated risk assessments. • Dedicated personal to facilitate coordination of appropriate risk management measures with Provincial and federal governments. Union of Nova Scotia Municipalities Federation of Canadian Municipalities.	• Provincial and federal governments, Union of Nova Scotia Municipalities, Federation of Canadian Municipalities.
Communications	• As communications has responsibility for both internal and external communications all climate change impacts are relevant as climate	• Increased awareness and dissemination of information on climate change and adaptation measures. • Improve quality and quantity of information available on climate	• Additional resources may be required for research and preparation of text and web resources, and to provide improved quality and quantity of information	• EC and NRCan for climate change modeling and sea-level rise/inundation modeling.

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	change may lead to impacts on service delivery requiring communication with the public. Business Unit would also assist EMS and other Business Units in providing internal information to HRM staff.	change risk, and extend delivery to vulnerable communities.	available on climate change risk. • Information to be provided to vulnerable communities through HRM Communications including Naturally Green and HRM website.	
Fire and Emergency Services	• Coastal erosion and impacts on transportation infrastructure impacting access for emergency services and vehicles. • Similarly, coastal inundation due to storm surge may impede access for emergency services and vehicles. • Greater range of vulnerable communities (sick, elderly, young, infirm) making demands on emergency services due to increased intensity and scope of extreme events (floods, droughts, heat-waves, storms) • Increased damage and disruption of vulnerable critical utilities and infrastructure that may impact emergency	• Development of contingency planning to address loss of transportation and/or communication infrastructure. Impact of increased intensity/frequency of extreme events need to be factored in with regards to human resources. • Expand emergency management and contingency planning at community level, and assist in the establishment of community preparedness plans. • Increased resources and capabilities to address forest fires in the urban/rural fringe, especially in unserviced areas. • Need to identify and map vulnerable sectors of the community to allow emergency service providers to be able to respond on a priority basis to those sectors.	• Intergovernmental collaboration to incorporate climate change in EMO system. • Data from Climate SMART project and follow on studies (if funded). Improved topographic mapping, e.g. LiDAR to delineate zones of vulnerability. GIS database. • Improved hazard mapping, e.g. LiDAR to delineate zones of vulnerability and prioritize protection/relocation. • Assess costs of expropriation in vulnerable areas. Encourage land owners to donate lands for conservation under existing Revenue Canada tax programs.	• EMO NS; Public Safety and Emergency Preparedness Canada; NSTPW • EC and NRCan for climate change modeling and sea-level rise/inundation modeling. • Capital Health District; NS Dept. of Health

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	communications. • Potential for increased risks from forest fires that may be combined with additional blow down due to storm events in the urban/rural fringe requiring additional resources in these areas. • Increased demand on emergency services from stress and over-loading of the adaptive capacity of public health infrastructure (includes HRM Emergency Services), from the cumulative effects of extreme events, injuries, break-down in essential services such as electrical power and communications, and introduction of diseases.	• An inventory and the development of vulnerability maps of coastal ecosystems, communities, infrastructure and buildings at risk from climate change impacts. • The establishment of appropriate adaptation and risk reduction measures including protection, abandonment, compensation, and legal issues for coastal property and private residences facing increased erosion. • An improved understanding of the adaptive capacity of the health response service in HRM to address increased outbreaks of diseases and illnesses associated with climate change. • Forest risk assessment for new developments. Review fire protection requirements and update as required.	• Community Risk Management Guide disseminated to vulnerable communities.	
Police Services	• Coastal erosion and impacts on transportation infrastructure impacting access for police vehicles. • Similarly, coastal inundation due to storm surge may impede access	• In collaboration with Fire and Emergency Services, develop contingency planning to address loss of transportation and/or communication infrastructure. • Impact of increased intensity/frequency of extreme events need to be factored in	• Possible increase in police resources, capacity, vehicles and infrastructure.	• EMO NS; Public Safety and Emergency Preparedness Canada; NSTPW

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	for police vehicles. • Increased damage and disruption of vulnerable critical utilities and infrastructure that may impact police communications. • Greater demand on police services for community protection by communities affected by social disruption (looting, etc.) due to increased intensity and scope of extreme events (floods, storms)	with regards to human resources and delivery of police services.		
Community Development	• Impacts on viable land use and zoning options due to increased incidents of coastal erosion and impacts on transportation infrastructure and coastal inundation due to storm surge. • Impacts on planning and design or location of emergency services centers, and emergency services evacuation routes/measures due to increase incidents of coastal erosion and	• Revised vulnerability mapping will be required to identify the areas unsuitable for development due to flooding or coastal inundation risks. • The evaluation of the cost of converting privately owned coastal land back to public land in most vulnerable areas compared to the costs of fortification and/or compensation. • Local planning advisory committees, community groups and the general public need to take a pro-active role in identifying ecosystems,	• Data from Climate SMART project and follow on studies (if funded). Improved topographic mapping, e.g. LiDAR to delineate zones of vulnerability. GIS database. • Improved topographic mapping, e.g. LiDAR to delineate zones of vulnerability and prioritize protection/relocation. • Better understanding of groundwater carrying capacity needed in areas proposed for development.	• EC and NRCan for climate change modeling and sea-level rise/inundation modeling.

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	impacts on transportation infrastructure and coastal inundation due to sea-level rise, storm surge and extreme events (floods, droughts, heat-waves, storms) • Increased uncertainty in settlement patterns and urban planning due to climate variability, sea level rise and impacts from extreme events. • Impacts on viable land use and zoning options due to increased risks from forest fires in the urban/rural fringe.	identifying ecosystems, buildings, infrastructure and essential services that are vulnerable to climate change impacts, and establish appropriate adaptation measures to reduce risks. • Planning regulation (i.e. By-laws and polcies) to limit development in high risk areas. Setbacks. • Forest fire assessments should be conducted for new developments in urban/rural fringe. These assessments must include consideration that forest fire risks will increase.	• Enforcement of proposed setbacks. Updating of setback requirements as vulnerability data improves. • Incorporation of climate change risk assessment into business unit integrated risk assessments.	
Infrastructure and Asset Management	• Climate change will profoundly impact all policies and programs relating to environmental sustainability. • Greater incidents of building and infrastructure failure due to increased intensity and scope of extreme events (floods, droughts, heat-waves, storms) resulting in increased risk of exposure to litigation and added demand for improvements to	• In collaboration with the CAO work with federal and provincial governments to develop and implement appropriate climate change risk management policies. • Appropriate adaptation risk assessment and risk management measures incorporated into municipal physical planning processes and guidance provided to assist developers in assessing possible risks. • Additional liaison with similarly sized municipalities, in	• Information to be provided to community level through HRM Communications including Naturally Green and HRM website. • Incorporation of climate change risk assessment into business unit integrated risk assessments. • Vulnerability assessment to determine species and park areas at risk. • HRM needs to investigate appropriate insurance approaches for vulnerable coastal communities and	• EC and NRCan for climate change modeling and sea-level rise/inundation modeling. • EMO NS; Public Safety and Emergency Preparedness Canada; NSTPW • Insurance community

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	building inspections services and standards. • Potential disruption to waste collection and management services due to impacts on transportation infrastructure from coastal erosion, coastal inundation and extreme events (floods, storms, events (floods, storms, forest fires) • Increased demand for water recreation parks due to longer and warmer summers likely to result in more drought and greater need for irrigation. • Increased demand for biological control agents in recreational parks due to potential for increased variability in incidents and location of pests, and on the natural disturbance regime, pest cycle, and rate of infestation. • Anticipated increased insurance costs associated with damage to buildings and	sized municipalities, in particular coastal municipalities to share knowledge. • Parks may need to modify species mix to be compatible with project climate changes (longer dry periods, increased temperatures, pest infestations), investigate biological control options for pest management, and assess capacity for improved irrigation options. • Need for additional insurance coverage and development of measures to reduce insurable risk from climate change impacts.	coastal communities and infrastructure. • Apply findings of research on the impacts of climate change on terrestrial an aquatic ecosystems as this information becomes available.	

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	infrastructure from sea-level rise, storm surge, and extreme events (floods, forest fires, storms).			
Transportation and Public Works	• Potential disruption to transportation infrastructure due to impacts from sea-level rise, coastal erosion, inundation and impacts from increases in intensity of extreme events (floods, storms) • Increased costs for road maintenance both winter and summer to mitigate impact on pavement from frost heave and heat. • Increased variability in demand for snow and ice removal due to impacts on snow and rainfall patterns. • Greater demand on emergency service vehicles due to impacts from extreme events (floods, droughts, forest fires, heat waves, storms).	• Develop contingency planning for impacts on transportation infrastructure in collaboration with Fire and Emergency and Police Services. • An inventory and the development of vulnerability maps of communities, infrastructure and buildings at risk from climate change impacts. • Will require additional resources to address increased deterioration of roads. • Appropriate adaptation risk assessment and risk management measures incorporated into municipal physical planning and waste management processes. • Increases in vehicle fleet to meet anticipated risks.	• Improved hazard mapping to delineate zones of vulnerability and prioritize protection/relocation. • Additional resources to address increased deterioration of roads. • Data from Climate SMART project and follow on studies (if funded). • Incorporation of climate change risk assessment into business unit integrated risk assessments.	

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
Halifax Regional Water Commission[30]	• Impacts on water quality and availability due to coastal erosion and impacts on water infrastructure. • Increased incidence of storm and combined sewers unable to accommodate more intense rainfall events. • Increased damage and disruption of vulnerable critical water/wastewater utilities and infrastructure. • Impact on management of water supply and water control dams due to variation in precipitation/evaporation patterns and run-off intensity. • Possible increased incidents of salt-water intrusion in coastal aquifers due to sea-level rise and variations in precipitation patterns.	• Development of contingency plans to maintain water and sewer service in vulnerable areas. • An inventory and the development of vulnerability maps of communities and water resources/infrastructure at risk from climate change impacts. • Revise design criteria to include climate change projections as well as traditional IDF curves. • Management of dams and overflows to be reviewed against climate change projections. • HRWC may be required to provide municipal services to outlying coastal communities ahead of planned growth.	• Data from Climate SMART project and follow on studies (if funded). • Improved hazard mapping to delineate zones of vulnerability and prioritize protection/relocation. • Better understanding of groundwater carrying capacity needed in areas proposed for development. • Vulnerability assessment and associated climate model outputs targeted to water use in the region. • Downscaled precipitation modeling and associated hydrological modeling. • Incorporation of climate change risk assessment into business unit integrated risk assessments.	• EC and NRCan for climate change modeling and sea-level rise/inundation modeling.
Finance	• Sea-level rise, coastal erosion/inundation and impacts from increased	• Budgeting to include provision for contingency funding in the anticipation of more intense	• Assess costs of expropriation in vulnerable areas. Encourage land	• EC and NRCan for climate change modeling and sea-level rise/inundation

[30] Reflects organizational change effective April 1, 2007

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	intensity of extreme events on HRM controlled infrastructure will result in increases to operational and capital costs. • Increased costs from litigation by third parties alleging failure by HRM to establish appropriate risk management measures (e.g. limits to development in vulnerable areas, improvements to infrastructure, improvements to building codes, etc.) • Increased incidence of storm and combined sewers unable to accommodate more intense rainfall may result in costs associated with repairs to damaged structures and increased from litigation. • Increased damage and disruption of vulnerable critical utilities and infrastructure resulting in increased costs for repair. • Projected increase in	events causing damage. • Provision for increases to insurance costs in the short term, but engage insurance community to develop appropriate risk reduction measures and insurance coverage that address climate change insurance costs for HRM. • Provision for increases in infrastructure costs. • Provision for increases in litigation costs. • Provision for increases to snow removal, road maintenance, and other operational costs affected by climate change risks. • Review of taxation and fees. Possible increases to address increased cost of services.	owners to donate lands for conservation under existing Revenue Canada tax programs. Incorporation of climate change risk assessment into business unit integrated risk assessments. HRM needs to investigate appropriate insurance approaches for vulnerable coastal communities and infrastructure.	modeling.

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	insurance costs for vulnerable HRM assets. • Increased costs for road maintenance both winter and summer due to impacts on pavement from frost heave and heat. • Increased variability in costs for snow and ice removal due to changes in precipitation patterns. • Anticipated increased operational economic and social 'costs' associated with adaptation measures necessary to protect vulnerable coastal communities and infrastructure.			
Business Systems and Control	• Increased demand by developers, communities and land owners for improved hazard mapping and climate risk information services. • Greater demand on call centre and dispatch staff during extreme events. • Potential for impacts on HRM's IT system due to extreme events.	• Call centre and dispatch staff will need to be aware of HRM's contingency planning and have plans for addressing calls dealing with climate change. • Additional human resources to be on-call during extreme events.	• Improved hazard mapping to delineate zones of vulnerability	

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
Legal Services	• Increased demand for by-laws that will restrict or control development in vulnerable areas. • Increased incidents of litigation by third parties alleging failure by HRM to establish appropriate risk management measures (e.g. limits to development in vulnerable areas, improvements to infrastructure, improvements to building codes, etc.) • Increased incidence of litigation from alleged failure in storm and combined sewers due to changes in precipitation patterns. • Increased incidence of litigation from alleged failure in HRM controlled infrastructure due to sea-level rise, storm surge or extreme events. • Increased incidence of litigation from alleged impacts on water quality and availability due to	• Oversee incorporation of climate change risk assessment across all Business Units. • Development of additional by-laws to enable HRM to be more resilient to climate change e.g. coastal setbacks, undergrounding of electrical utilities. • Additional legal staff to address additional claims that are anticipated due to climate change.	• Additional legal staff to address claims that are anticipated due to climate change. • Assess costs of expropriation in vulnerable areas. Encourage land owners to donate lands for conservation under existing Revenue Canada tax programs. • Incorporation of climate change risk assessment into business unit integrated risk assessments. • HRM needs to investigate appropriate insurance approaches for vulnerable coastal communities and infrastructure.	• EC and NRCan for climate change modeling and sea-level rise/inundation modeling.

Business Unit	Relevant Climate Change Impacts	Adaptation Responses	Requirements	Other Responsible Entities
	changes in precipitation patterns, coastal erosion and impacts on water infrastructure, and increased damage and disruption of vulnerable critical water/wastewater utilities and infrastructure. • Increased incidence of litigation from increased damage and disruption of vulnerable critical utilities and infrastructure. • Projected increase in insurance litigation associated with vulnerable HRM assets/operations. • Vulnerability and exposure to climate change impacts resulting in an increase in the scope and range of HRM risk assessment and management framework to satisfy “due diligence”			

Step 6 – Identify the Resources, Barriers and Timeframes
HRM's Business Units take the options identified in Step 5 and determines the resources (technical and financial) needed to implement the measures, the timeframe in which they should occur, and the possible barriers to implementing the measures.

7.0 Identification of Priorities for Action

In order to refine the types of adaptation options that could be implemented and to prioritize the options, the project team held two workshops and a number of individual meetings with HRM staff. These sessions provided opportunities for the project team to update HRM staff on the latest climate change projections affecting HRM, review possible adaptation options, review the resources required and the potential barriers in moving forward. These sessions raised a number of key issues, including resources and barriers; and priorities relating to the establishment of an effective risk management regime for identified climate change impacts in HRM. An overarching theme in the feedback received during the workshops is that there is general agreement on the need to implement adaptation measures to maintain HRM as a healthy, sustainable and vibrant community, however, before the measures could be implemented, there are a number of enablers that need to be in place or are implemented concurrently with the adaptation measures. The key enablers that were identified by staff were:

- innovative and responsive funding;
- community outreach and HRM inreach;
- hazard and risk mapping;
- integration of climate change as a risk into business plans;
- take a life-cycle approach to decision making;
- improved intergovernmental collaboration, communication and coordination; and
- tools to assist in decision making.

The following sections provide a description of these key enablers and discuss resources required, suggested timeframes and potential barriers.

7.1.1 Innovative and Responsive Funding

How to fund the variety of actions that need to be taken to adapt to climate change in HRM was a key concern to all who participated in the project as adaptation measures such as changes in design criteria are expected to increase costs to all HRM stakeholders over the business-as-usual case. Increased frequency and intensity of storm events may also result in HRM budget overruns as allowance for these events is not generally factored into the budget process. As well, the insurance industry has been assessing its risk for climate change and this may have consequences in terms of higher costs or lack of coverage for certain events for municipalities deemed to be at risk. Identifying and attracting funding is seen as an on-going process that should start within the next business planning cycle.

Recommended Action

Funding to develop risk management tools and implement adaptation measures is a primary barrier to the establishment of an effective risk management regime for identified climate change impacts in HRM. Funding for adaptation measures is primarily the responsibility of all three levels of government as each level has the jurisdictional control and responsibilities for mitigating the high risk impacts summarized in Section 6.2. Within HRM, there is a need to establish a reserve fund that will allow HRM to prepare for and respond to extreme events. This fund would not necessarily be directed to solely hard assets such as generators or snow removal equipment but could also be used for additional community outreach as well as co-funding for mapping and on-going climate modeling specific to HRM. There is a recognized need for HRM to be better able to track and allocate costs related to extreme events to support requests for post-event relief funding from the provincial and federal government.

One source of funding may be provincial and federal governments, however, there is currently a lack of policy direction at both levels of government to be able to provide funding for adaptation with the exception of the recently renewed Climate Change Impacts and Adaptation Programme and FCM. Both of these sources only provide 50% of the funding required for specific projects.

Another source of funding available to HRM are municipal taxes, fees, and levies. Increases in taxes, fees, and levies would need to be accompanied by sustained community outreach and education as residents and businesses will not necessarily see immediate or concrete action attributable to the increase in the short term.

Some of the financial burden should also be shared by residents and businesses in HRM through emergency preparedness and risk reduction as preparedness can reduce HRM's response costs. Guidance on measures communities and individuals can take to adapt to climate change and be prepared for extreme events is available on the HRM website at http://www.halifax.ca/climate/index.html. HRM can and has taken a lead role through its EMO and Naturally Green. As with any message, this needs to be continually reinforced beyond this project.

Addressing funding requirements is an on-going activity carried out by key HRM staff but with the addition of climate change considerations from the perspective of both mitigation and adaptation will likely require at least one full-time equivalent (FTE) in staffing.

7.1.2 Enhance Community Outreach and HRM Inreach

In contrast to public and HRM knowledge of GHGs and means to reduce GHG emissions, relatively little attention has been focussed on dealing with the risks from climate change impacts despite the potentially significant effects the impacts will have the some sectors in HRM. This lack of attention to the risks/impacts and how to adapt was most recently recognized at the federal level as a major deficiency in the federal departments' approach to climate change[31]. In the early months of 2007, impacts from climate change have become more prominent with the public with the release of the Intergovernmental Panel on Climate Change's *Climate Change 2007: Impacts, Adaptation and Vulnerability – Summary for Policy Makers,* which highlighted the impacts of climate change that are projected to occur despite measures to reduce GHGs.

Recommended Action

In order to affect change at the municipal level, there needs to be clear direction from Regional Council that HRM's Business Units need to address climate change in business planning and within operational activities. In order to do that, Regional Council needs to be informed of the risks, measures to manage the risks and an understanding of the costs. This document provides the information necessary for Regional Council to gauge the risks to HRM and the general actions necessary. The costs of the actions can only be assessed qualitatively at this point as specific actions need to be developed by the HRM's Business Units with the support of the tools provided in this report and additional data as they become available.

As the broader HRM community informs Regional Council on directions that should be taken, it is equally important that the community understand how they can reduce GHGs and also to identify the risks facing residents and businesses from climate change and what measures can be taken to minimize the risks. To date, three primary vehicles have been used to communicate risks and adaptation measures: the HRM website (see link in Section 6.3.1); the *Community Guide to Climate Change and Emergency Preparedness*; and the Naturally Green newsletter (http://www.halifax.ca/environment/index.html). Additional information and communication can be deployed via cable television advertising and home or environmental related events in HRM. Climate change impacts occur in two manners: impacts that slowly onset such as sea-level rise or the movement of pests or diseases; and impacts that occur quickly and dramatically such as a hurricane. For impacts that appear to be slow in fully manifesting themselves, the public and other stakeholders may not observe a change until it is too late to adapt. For rapid onset impacts which are much less frequent, the urgency of preparedness tends to wane during the period between events. As a result, public information needs to be an ongoing effort in order to affect recognition of the issue and behavioural change.

Apart from staffing and funding requirements summarized in 7.1.1 above, no other barriers to implementing this priority are foreseen.

7.1.3 Hazard and Risk Mapping

A key tool to enable HRM to develop appropriate plans, policy and by-laws to manage risks from climate change impacts is the development of mapping that would identify areas at risk in HRM. While some high resolution information is available on a regional scale, mapping at a scale to inform policy and decision making was not available. In the course of this project, GIS

[31] 2006 Report of the Commissioner of the Environment and Sustainable Development (http://www.oag-bvg.gc.ca/domino/reports.nsf/html/c2006menu_e.html)

compatible mapping was developed by Environment Canada to provide HRM with the distribution of key climatic indicators across the region (see Appendix B). In addition, digital elevation modeling in sufficient detail was available for the area surrounding Halifax Harbour to enable mapping of areas susceptible to sea-level rise and storm surge events (Appendix C). The GIS mapping in this report is now available to HRM GIS users for use in planning.

Land use regulation is one of the few areas where HRM Business Units have significant degree of control over managing risks from climate change impacts. However, it was noted that in order to implement some measures (e.g., coastal setbacks), this may in result in potentially negative impacts on land values that will be challenged. As a result, HRM requires strong scientific data on which to base such planning decisions.

<u>Recommended Action</u>

It is well recognized within HRM that the municipality will require more detailed mapping that can be provided by the existing digital elevation models for most of the municipality. The use of LIDAR[32] mapping coupled with coastal inundation modelling can improve the basis for planning decisions such as coastal set backs in vulnerable or high risks areas. Acquiring and processing LIDAR data is costly and to this point sufficient funds have not been available to map the entire municipality.

In the meantime, more precise digital elevation models should be developed for the entire region. Currently only the Halifax Harbour has a contour interval small enough (1 m or less) to accurately project areas at risk from inundation resulting from sea-level rise and storm surge associated with climate change. This information is key to providing recommendations for areas such as the Eastern Shore identified by Natural Resources Canada as having a high risk to damage from coastal inundation. Improved mapping coupled with modeling software such as Coastal DSS® developed in part by the Applied Geomatics Research Group of the Nova Scotia Community College, will lead to planning decisions that include improved predictions of climate change impacts and associated risks.

This mapping can be taken one step further by overlaying HRM's asset inventory and by doing so an estimation of potential damage and direct economic costs can be made.

HRM should continue to work with Environment Canada to identify, develop and refine mapping for key climate change parameters such as temperature, precipitation, and heat wave duration. Environment Canada continues to develop meteorological hazard mapping across Canada and this will be publicly available as the regions are completed. For example of the mapping produced see: www.hazards.ca.

[32] Light Detection and Ranging (LIDAR) is a technology that uses a light transmitted from an aircraft to the ground, the time it takes for the light beam to echo back determines the ground elevation. LIDAR provides highly precise elevation data of ground features.

In addition to mapping related to inundation and climatic indicators, risk or hazard mapping needs to include identification of evacuation routes and alternates as getting people out of peninsular Halifax which is susceptible to a number of pinch points that restrict ease of evacuation in times of emergency.

7.1.4 Integrate Climate Change as a Risk Consideration in Business Plans

As part of its annual business plan cycle, HRM's business units evaluate the potential risks to their operations from a variety of threats. Climate change has not been considered in the risk assessment in part due to lack of available information and awareness, and the lack of appropriate risk management tools. Given the potential economic, social and environmental costs resulting from climate change impacts, climate change needs to be evaluated as another threat to the operation of the business units, in other words, consideration of climate change needs to be integrated into the process. A number of jurisdictions, (e.g., United Kingdom, Australia, Caribbean countries) have developed protocols for evaluating the risks on which the risk management strategy described in this report is based.

This Strategy has provided an initial assessment of risks to HRM Business Units, and a pilot exercise has been undertaken with HRM's Community Development Unit to evaluate key steps in the process to "mainstream" climate change risks management into the unit's business cycle. Lessons learned and key steps resulting from the pilot exercise are provided in Appendix D.

<u>Recommended Action</u>

To assist HRM in implementing the risk assessment at the Business Unit level, the project team developed a generic risk assessment protocol that can be used by all business units and follows the outline presented in Section 1. Sections 2 through 6 of this report provide the results of an overall risk and vulnerability assessment for HRM. The information and protocols outlined serve as the primary reference tool for Business Units to integrate climate change in business planning. Clearly, each unit will have to further evaluate risks and risk reduction measures specific to the unit. To understand what a single unit's assessment may entail, the approach was tested with a focus group consisting of senior planners from the Community Development department to assess its functionality in an HRM business unit setting. As previously stated, summary report documenting the generic protocol with the results of the focus group exercise is provided in Appendix D.

In addition, the evaluation of some climate change risks has been constrained by the lack of data on which sound risk-based decisions can be made. Through the course of this project, these data or tools were identified by HRM staff including: risk mapping and engineering design criteria.

While more work is required as the amount of climate change impact data grows, the tools developed as part of this project (Appendices B, C, and E) represent a first generation of data sets or tools that can be used to facilitate risk assessment/management within the Business Units.

7.1.5 Include Climate Change with Life-Cycle Assessment

Including climate change adaptation measures for development, infrastructure, and buildings may result in an increase in up-front costs for HRM as design criteria will change in a more conservative direction to make facilities more resilient to climate change. Financial and planning decisions, however, are often made on a short term, e.g., budget cycle, basis and do not necessarily incorporate the long term costs of operations and maintenance.

Recommended Action

Typically, cost/benefit assessments examine strictly economic costs and benefits. When considering climate change however, longer term economic benefits (e.g., reduced maintenance) and broader social benefits must also be considered in the assessment. Many methods of this full cost accounting or triple bottom line approach to decision making are available. To demonstrate the utility of this broader perspective, the project team examined the incremental costs and benefits of burying electrical utilities underground in new subdivisions. The results of this assessment are provided in Appendix E. Cost/benefit analysis of climate change risks should become a standard part of the operational and financial budgeting process for all HRM Business Units.

7.1.6 Continue to Enhance Intergovernmental Collaboration, Communication and Coordination

It was recognized that adaptation measures described in the preceding sections cannot be undertaken by HRM alone due to jurisdictional issues and financial considerations. It was also noted that during the course of the project there was little overall policy direction related to climate change adaptation at either the federal or provincial government levels and that it is these two levels of government who have the most legislative responsibility (see Table 2-3). The weakness in intergovernmental collaboration and coordination of climate change activities was seen as a significant barrier to making progress on climate change issues.

Recommended Action

HRM should encourage federal and provincial governments to develop strategies; policies, and ultimately, legislation for addressing climate change impacts. This effort can be supported by on-going strategic planning being undertaken by the Nova Scotia Department of Energy as well as the findings of the IPCC Fourth Assessment.

Similarly, emergency response in HRM involves all three levels of government with the majority of the resources (personnel and equipment) within provincial and federal jurisdictions. While emergency response measures are in place and continually reviewed by all three levels of government, it is noted that risks associated with climate change impacts are not currently an integral part of the emergency planning process. Consideration of the projected increase in intensity and frequency of extreme events resulting from climate change and the resulting resources needs to be evaluated. In addition, it is recognized that the EMOs need to have information on the location of vulnerable people. This is seen as an important emergency response issue regardless of the impacts from climate change.

7.1.7 Update Design Criteria for Infrastructure

A key concern raised during the project is that design criteria for infrastructure such as storm sewers, culverts, bridges and dams need to be updated to reflect what the climate change models are projecting for HRM in terms of storm event intensity and frequency as current criteria rely on hindcasting and data sets that do not include the most recent meterological data, which shows an increase in storm intensity and frequency. This information is seen as critical to make appropriate planning decisions and to justify the increase in cost that will accompany the change in the criteria.

Recommended Action:

Based on modeling developed for this project, return periods for extreme events appear to be shifting by a factor of 2 so that what was a 1 in 100 year event is being seen on a 1 in 50 year frequency. EC has developed a projection of extreme precipitation return periods out to the 2080s for use in developing new design criteria:

PERIOD	10 YEARS	50 YEARS	100 YEARS
HISTORICAL	102.1mm	135.1mm	149.1mm
2020's	148.9mm	202.6mm	225.4mm
2050's	130.1mm	165.8mm	180.8mm
2080's	132.8mm	175.6mm	193.7mm

In addition, precipitation Intensity-Duration-Frequency (IDF) charts related to precipitation are in the process of being updated with the latest observations for sites across Canada. As these data are finalized they will be made available to municipal engineers. In addition to work being completed by Environment Canada, the Canadian Council of Professional Engineers, through the Public Infrastructure Engineering Vulnerability Committee, is assessing the vulnerability of Canada’s infrastructure to climate change and will likely provide further guidance on incorporating climate change in engineering design.

8.0 Measuring Progress

Tracking performance towards an organization's objectives enables them to regularly evaluate whether the status of the progress, successes, and areas for improvement. Performance measurement is intended to provide an objective evaluation for staff and HRM Council. Annually, through its business planning process, HRM Business Units evaluate success in reaching the year's objectives and set objectives for the following fiscal year. The objectives can consist of on-going goals, that is objectives the Business Unit needs to meet to maintain a certain standard of service year to year and project specific objectives.

The priorities outlined in this strategy cross-cut several business units, however, as climate change falls under the Healthy Sustainable Vibrant Community theme, and adaptation to climate change is identified as part of Environmental Management Services' Strategic Goal #3 for the 2007-2010 planning period, the responsibility for measuring progress best fits with the Sustainable Environment Management Office of EMS. Table 8-1 lists recommended performance indicators for the priority areas discussed in Section 7.

Table 8-1 Priorities and Performance Indicators

Priority	Performance Indicators
Innovative and Responsive Funding	• Increase in funding earmarked for programs to enable implementation of adaptation measures. • Reduction in budget over-runs from extreme events. • Establishment of emergency expenditure tracking system to enhance recovery of costs from the provincial and/or federal governments.
Improve Community Outreach	• Number of articles in Naturally Green devoted to climate change. • % of residents aware of resources, emergency preparedness, and adaptation measures.
Improve HRM Inreach	• Availability of climate change data on HRM Intranet. • % of staff aware of resources, priorities, and adaptation measures. • Council approval of Risk Management Strategy.
Hazard and Risk Mapping	• % of HRM mapped with LIDAR or improved digital elevation models. • Mapping to identify areas susceptible to storm surge. • Mapping and designation of flood zones. • % of HRM assessed for forest fire hazard. • Availability of HRM specific climate change modelling.
Integration of Climate Change in Business Plans	• % of Business Units addressing climate change in plans. • Integration of climate change risk in business unit risk assessment. • Identification of funds to implement adaptation measures, as applicable.
Life-Cycle Assessment Approach	• % implementation of full cost accounting in cost/benefit assessments and asset design or recommendations.
Improved Intergovernmental Collaboration and Coordination	• % alignment of HRM, provincial and federal government climate change priorities and programs. • Demonstrated coordination between HRM and provincial and federal government on climate change adaptation.
Update Design Criteria for Infrastructure	• Availability of HRM specific climate change data related to engineering design. • Development of new design criteria and standards that considers climate change impacts.

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Appendix A
Emission Scenarios

Appendix A
Emission Scenarios
(taken from CCIS Website)

In order to determine how climate may change in the future we need to know how the concentrations of those atmospheric components which affect the Earth's energy balance may change. Gases such as water vapour, carbon dioxide, methane and nitrous oxide (the greenhouse gases) absorb long-wave (heat) radiation emitted from the Earth's surface and re-emit this energy, ultimately resulting in raised surface temperatures. Whilst these greenhouse gases occur naturally, human activities since the beginning of the industrial revolution have resulted in large increases in the atmospheric concentrations of these gases and it is now widely accepted that this has affected global climate.

Trying to determine how atmospheric composition may change in the future is fraught with uncertainty since it is necessary to make assumptions about how both the natural and anthropogenic emissions of these greenhouse gases will change which, in turn, is dependent on assumptions regarding population growth, economic activity, energy use, land use change, etc.

For the IPCC Third Assessment Report (IPCC, 2001), a new set of emissions scenarios was commissioned to replace the six IS92 emissions scenarios (Leggett *et al*., 1992) detailed in the 1992 Supplement (IPCC, 1992) to the IPCC First Assessment Report (IPCC, 1990). Until recently, the IS92a scenario, a 'business-as-usual' type scenario, had been in wide use by the climate modelling and vulnerability, impacts and adaptation communities.

The IPCC Special Report on Emissions Scenarios (SRES; Nakicenovic *et al*., 2000) details 4 storylines, narratives of qualitative (e.g., political, social, cultural and educational conditions) emissions drivers. The SRES emissions scenarios are the quantitative interpretations of these qualitative storylines. Six international modelling teams (see Table 1) were involved in quantifying the SRES storylines, which resulted in the formulation of 40 alternative SRES scenarios, of which no single scenario is treated as more or less probable than others belonging to the same scenario family. In order to reduce the number of scenarios to be used in climate change studies, six marker, or illustrative, scenarios have been selected based on the consensus opinion of the modelling teams. These are A1FI, A1T and A1B from the A1 family, and A2, B1 and B2.

Table 1: Modelling Teams Involved in Quantifying the SRES Storylines

Acronym	Model Name	Institutes	References
AIM	Asian Pacific Integrated Model	National Institute for Environmental Studies (NIES), Japan	Morita *et al.* (1994)
ASF	Atmospheric Stabilisation Framework Model	ICF Consulting, USA	Lashof & Tirpak (1990); Pepper *et al.* (1998); Sankovski *et al.* (2000)
IMAGE	Integrated Model to Assess the Greenhouse Effect (used in connection with the Central Planning	National Institute for Public Health (RIVM), The Netherlands	Alcamo *et al.* (1998); de Vries *et al.* (1994, 1999, 2000); de Jong & Zalm

Acronym	Model Name	Institutes	References
	Bureau (CPB) WorldScan model)		(1991)
MARIA	Multiregional Approach for Resource and Industry Allocation	Science University of Tokyo, Japan	Mori & Takahashi (1999); Mori (2000)
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact	International Institute for Applied Systems Analysis (IIASA), Austria	Messner & Strubegger (1995); Riahi & Roehrl (2000)
MiniCAM	The Mini Climate Assessment Model	Pacific Northwest National Laboratory (PNNL), USA	Edmonds *et al.* (1994, 1996a,b)

The Six SRES Marker Scenarios

Only a brief introduction to the SRES emissions scenarios is given here. Full details can be found in the Special Report on Emissions Scenarios (Nakicenovic *et al*., 2000). (Full text for other IPCC Special Reports and also the Third Assessment Report can be found on the IPCC web site.)

A very simplistic representation of the six SRES Marker Scenarios is given in Figure 1.

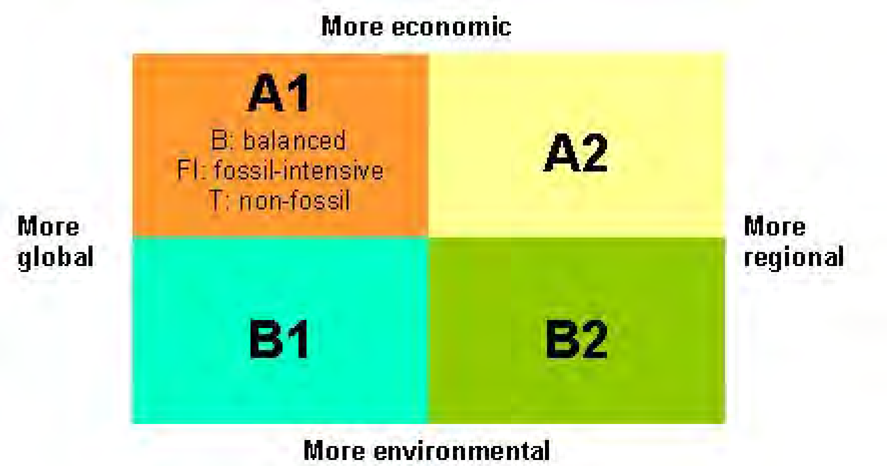


Figure 1: A schematic representation of the SRES scenario family. The A1 and A2 families have a more economic focus than B1 and B2, which are more environmental, whilst the focus of A1 and B1 is more global compared to the more regional A2 and B2.

The quantitative inputs for each scenario are, for example, regionalised measures of population, economic development and energy efficiency, the availability of various forms of energy, agricultural production and local pollution controls. Explicit policies to limit greenhouse gas emissions or to adapt to the expected global climate change are NOT included. Details of these inputs (population, energy use etc.) for each scenario can be found in Appendix VII: Data Tables of the SRES.

A1FI, A1T and A1B

The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity-building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance across all sources (A1B; where balanced is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies).

A2

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1

The B1 storyline and scenario family describes a convergent world with the same global population that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

Changes in global-mean temperature associated with each of the six marker scenarios are illustrated in Figure 2. The response of global-mean temperature to the different emissions scenarios can be determined by using a relatively simple upwelling diffusion energy balance (UD/EB) climate model, such as the one developed by Wigley and Raper (1992). This model distinguishes between land and ocean and between the hemispheres, but simulates only the underlying signal in response to external forcing and not the variability.

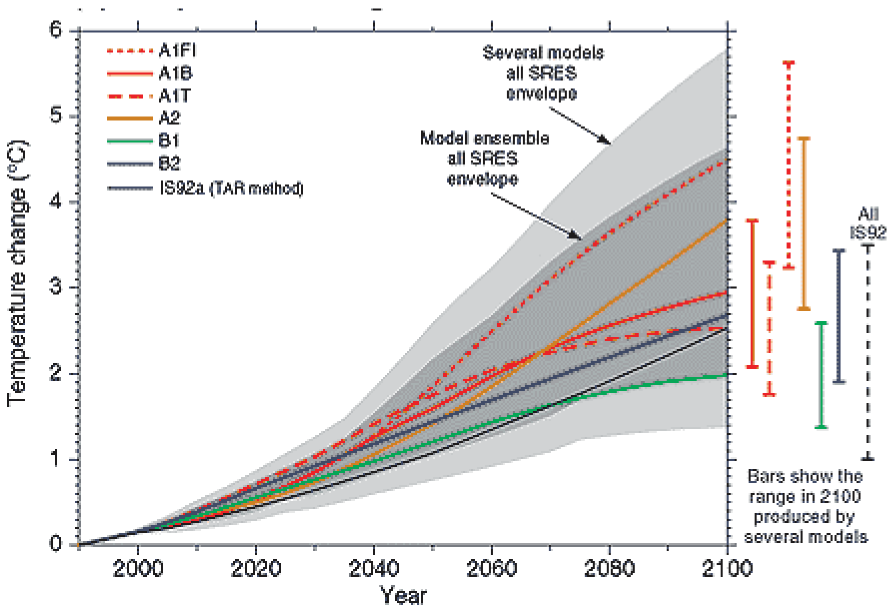


Figure 2: Global-mean temperature change (°C) associated with the six SRES marker scenarios, A1FI, A1T, A1B, A2, B1 and B2. These figures have been derived using a simple climate model. The 'several models all SRES envelope' shows the temperature projections for the simple model when tuned to a number of complex models with a range of climate sensitivities. [Source: IPCC WGI Summary for Policymakers]

IS92 Emissions Scenarios

In the 1992 Supplement (IPCC, 1992) to the IPCC First Assessment Report (IPCC, 1990), Leggett *et al.* (1992) proposed six emissions scenarios, the IS92 scenarios, which reflected the large uncertainty associated with, for example, the evolution of population and economic growth, technological advances, technology transfer and responses to environmental, economic or institutional constraints.

IS92a: a middle of the range scenario in which population rises to 11.3 billion by 2100, economic growth averages 2.3% year $^{-1}$ between 1990 and 2100 and a mix of conventional and renewable energy sources are used. Only those emissions controls internationally agreed upon and national policies enacted into law, e.g., London Amendments to the Montreal Protocol, are included.

IS92b: population rises to 11.3 billion by 2100 and the current emissions control policies are enlarged to include stated policies beyond those legally adopted, e.g., all CO_2 commitments of OECD member countries are included along with an assumption of world-wide ratification and compliance with the amended Montreal Protocol.

IS92c: economic growth averages 1.2% year^{-1} between 1990 and 2100 and population is forecast to be 6.4 billion by 2100, with population decreasing in the 21st century. As well as assuming lower growth in GNP per capita than IS92a and IS92b, low oil and gas resource availability results in higher prices which promote the expansion of nuclear and renewable energy. Lower population growth results in slower deforestation rates.

IS92d: another low scenario, but more optimistic than IS92c. The trend is towards increasing environmental protection but only actions that could be taken due to concerns about local or regional air pollution and waste disposal are included. Population is forecast to be 6.4 billion by 2100 and would be associated with lower natality, falling below the replacement rate late in the 21st century, due, for example, to improvements in per capita income or increased family planning. Low fossil fuel resource availability means that there is greater market penetration of renewable energy and safe nuclear power. A 30% environmental surcharge on fossil energy use is levied to meet the costs of more stringent local pollution controls. Greater well-being is assumed to lead to voluntary actions to halt deforestation, to adopt CFC substitutes with no radiative or other adverse effects and to recover and efficiently use the methane from coal mines and land fills.

IS92e: results in the highest CO_2 emissions. Economic growth averages 3% $year^{-1}$, between 1990 and 2100 and the population is forecast to reach 11.3 billion by 2100. Fossil resources are plentiful but, due to assumed improvements in living standards, environmental surcharges are imposed on their use. Nuclear energy is phased out by 2075 and, although CFC substitute assumptions are the same as those of IS92d, the plentiful fossil fuel resources discourage the additional used of coal mine methane for energy supply. Deforestation proceeds at the same pace as IS92a.

IS92f: falls below IS92e, has high population growth (17.6 billion by 2100), but lower assumptions of improvements in GNP per capita than IS92a. Other assumptions are high fossil fuel resource availability, increasing costs of nuclear power and less improvement in renewable energy technologies and costs.

These six emissions scenarios were considered to be equally likely.

Figure 3 illustrates the global-mean temperature change associated with the six IS92 scenarios.

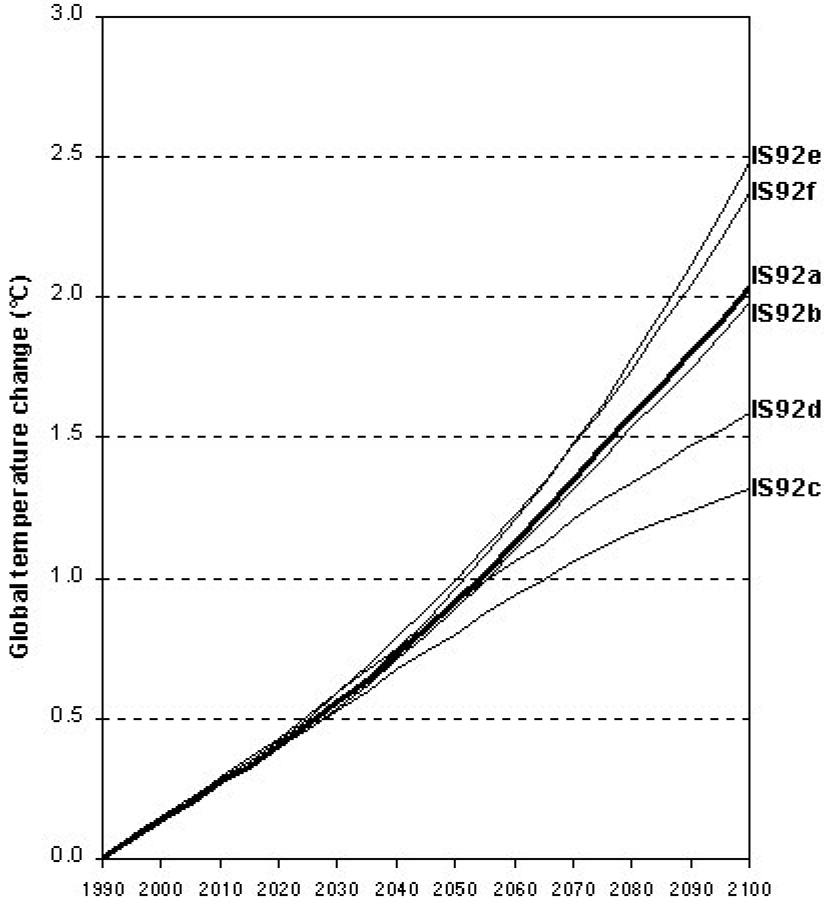
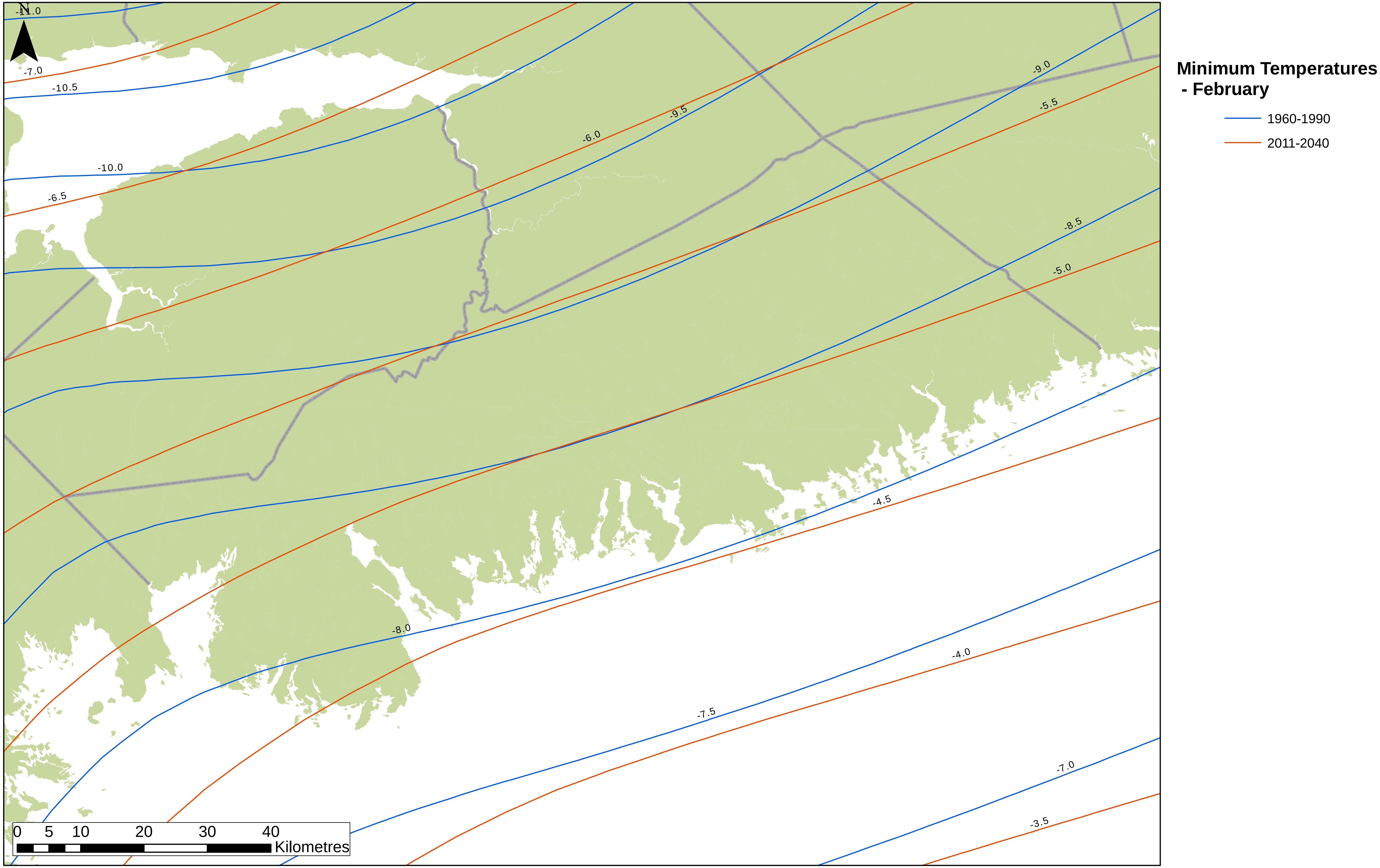
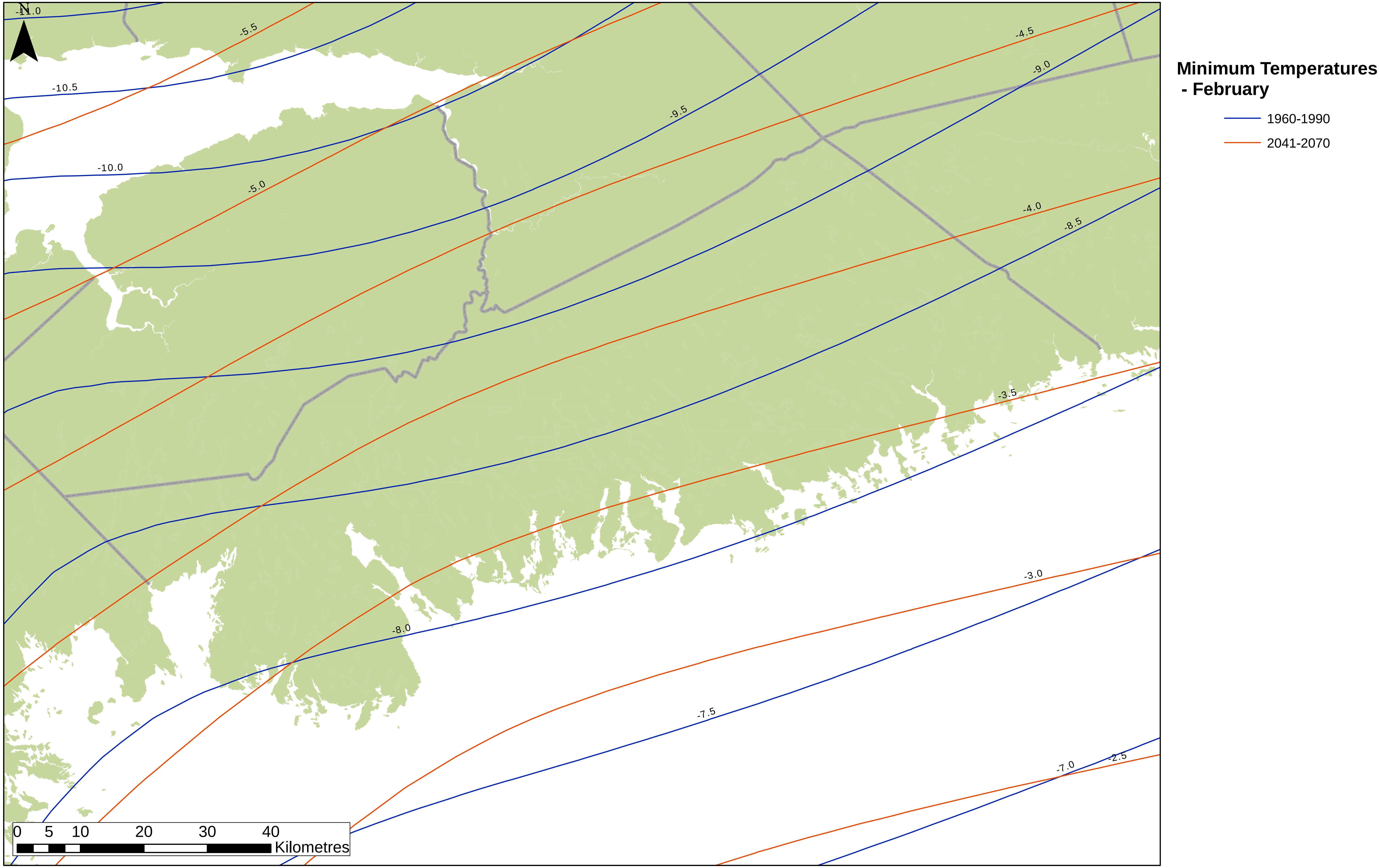


Figure 3: Global-mean temperature change (°C) associated with the IS92 emissions scenarios. IS92a is shown in bold.

Appendix B
Tri-Decadal Climate Change Mapping



N
Minimum Temperatures
- February
1960-1990
2011-2040
-11.0
-7.0
-10.5
-10.0
-6.5
-6.0
-9.5
-9.0
-5.5
-8.5
-5.0
-4.5
-8.0
-4.0
-7.5
-7.0
-3.5
0 5 10 20 30 40
Kilometres


N
-11.0
-10.5
-10.0
-5.5
-5.0
-4.5
-9.0
-9.5
-4.0
-8.5
-3.5
-3.0
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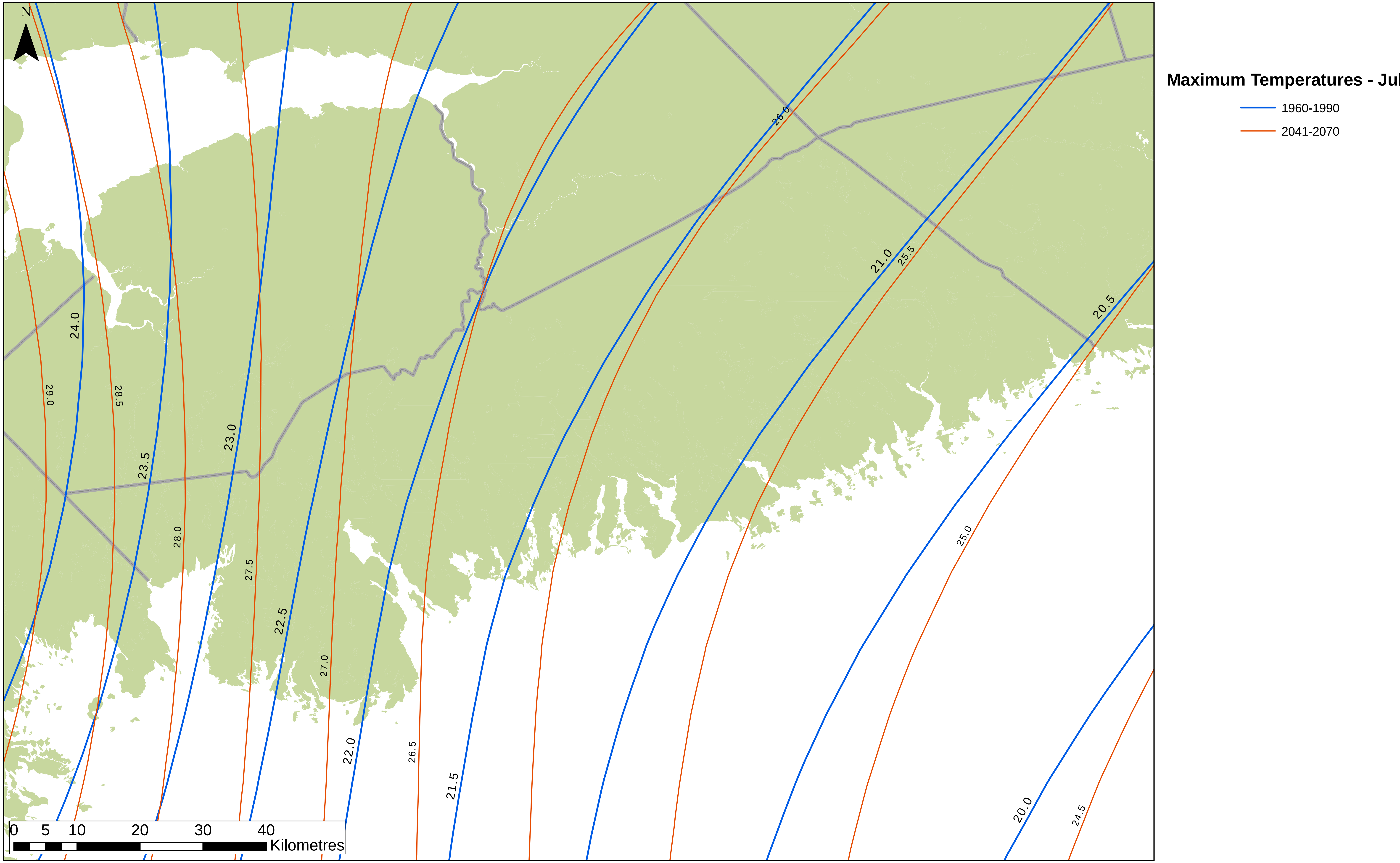
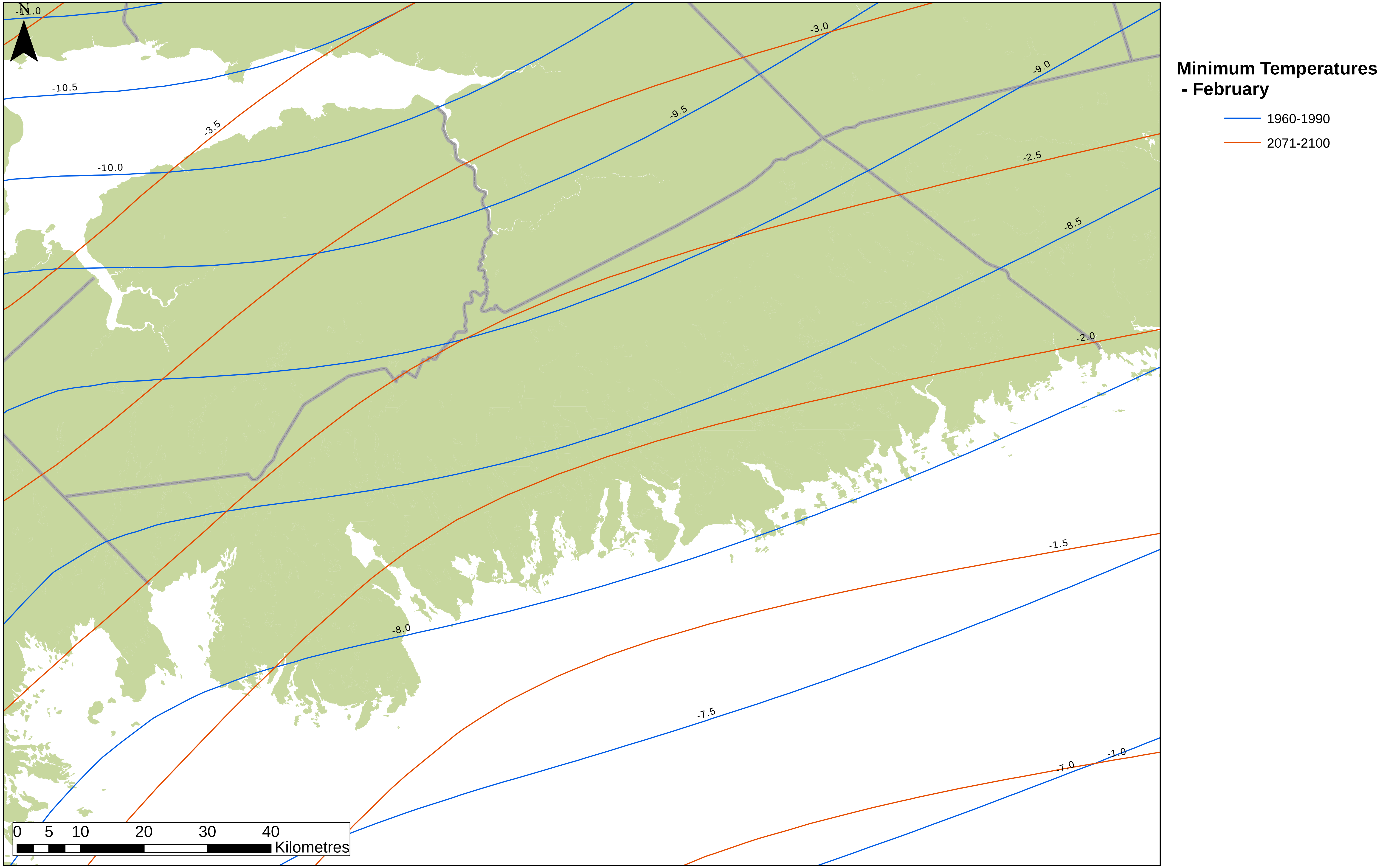
-2.5
0 5 10 20 30 40
Kilometres
Minimum Temperatures - February
1960-1990
2041-2070



Maximum Temperatures - July
1960-1990
2041-2070
N
0 5 10 20 30 40
Kilometres
24.0
23.5
23.0
22.5
22.0
21.5
21.0
20.5
20.0
29.0
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5



Minimum Temperatures - February
1960-1990
2071-2100
N
-11.0
-10.5
-10.0
-9.5
-9.0
-8.5
-8.0
-7.5
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-3.0
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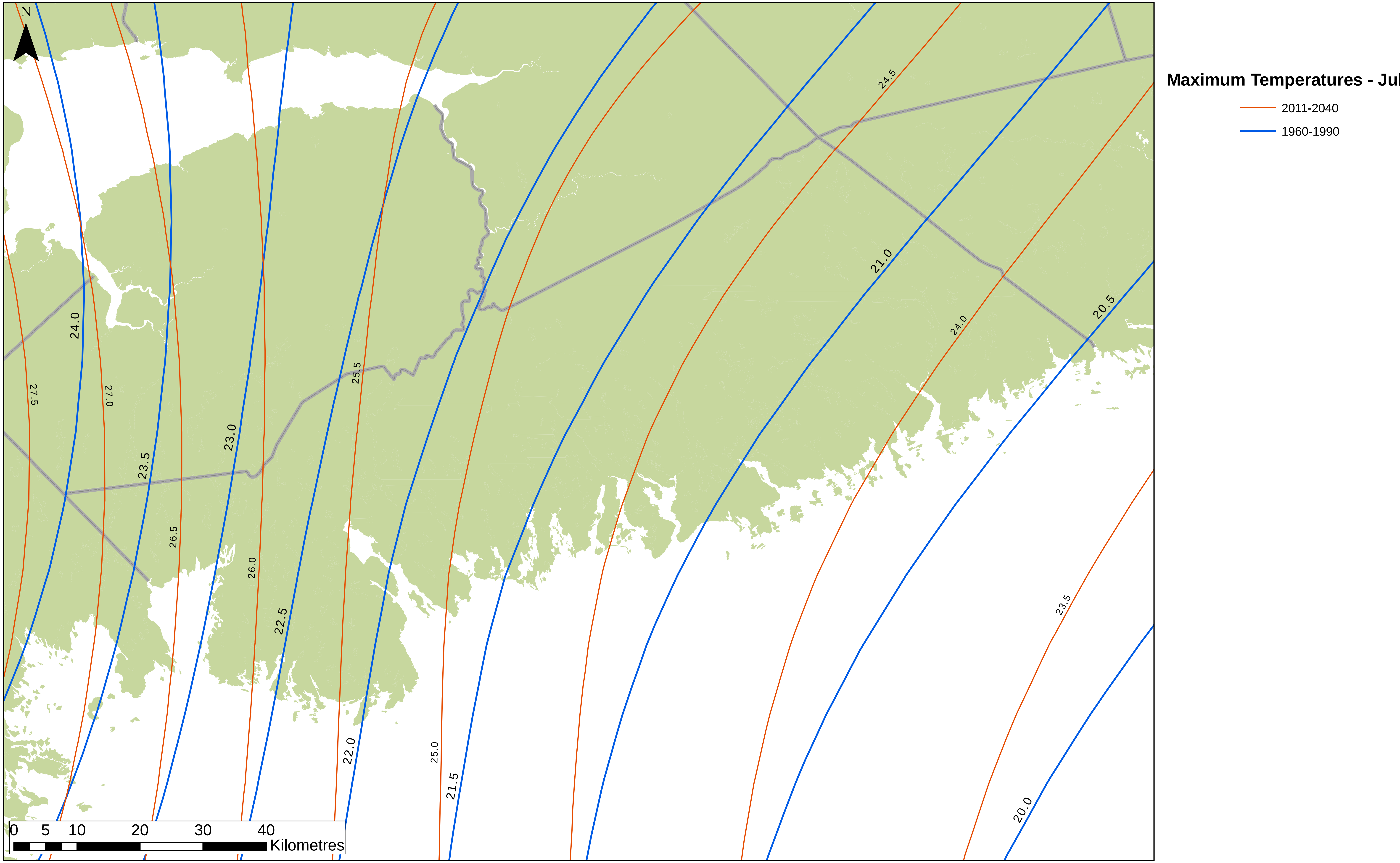
-2.0
-1.5
-1.0
0 5 10 20 30 40
Kilometres



N
Maximum Temperatures - July
2011-2040
1960-1990
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
23.5
24.0
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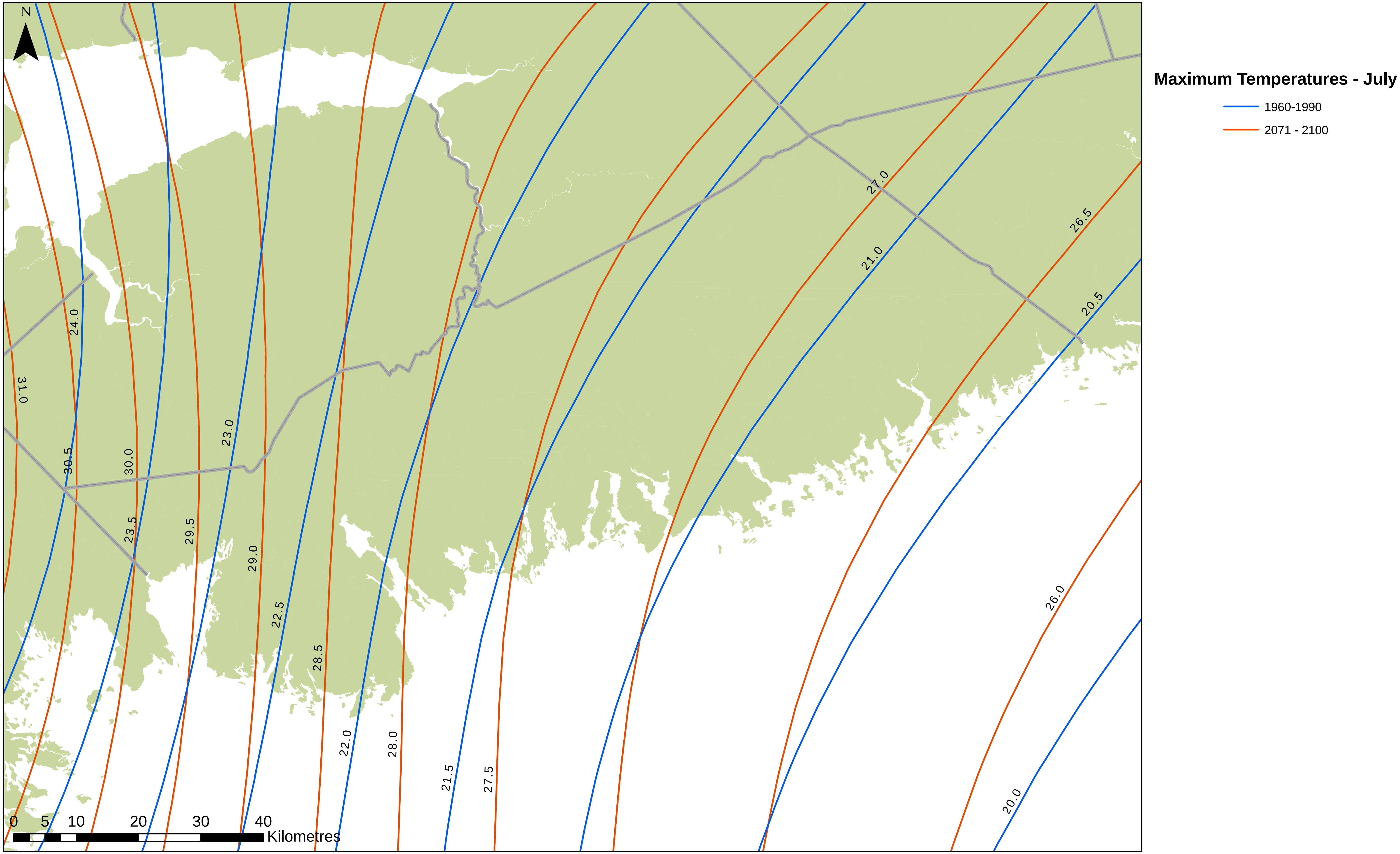
21.5
21.0
20.5
20.0
0 5 10 20 30 40
Kilometres



N
Maximum Temperatures - July
1960-1990
2071 - 2100
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30.5
30.0
29.5
29.0
28.5
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27.0
26.5
26.0
24.0
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21.5
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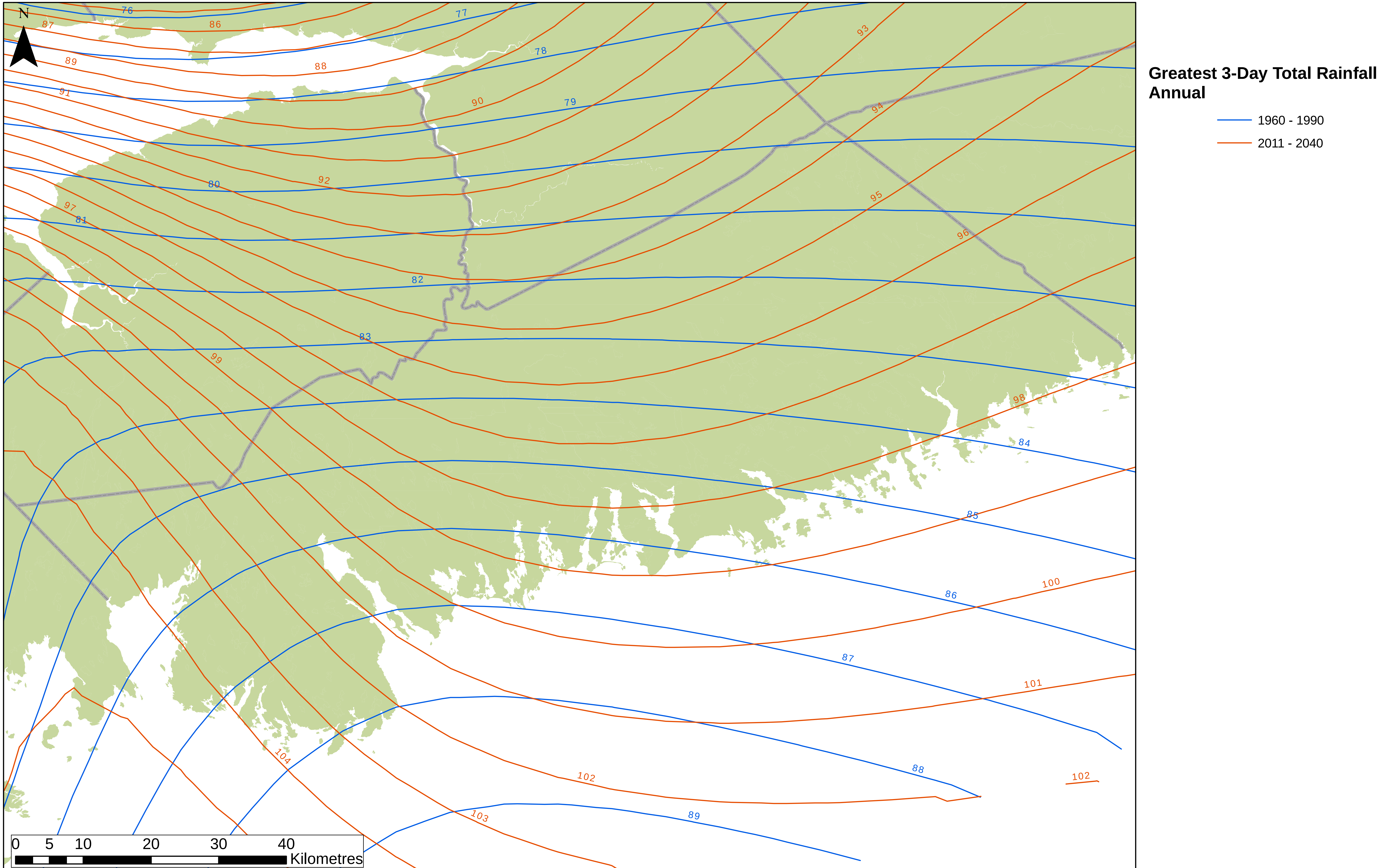
20.5
20.0
0 5 10 20 30 40
Kilometres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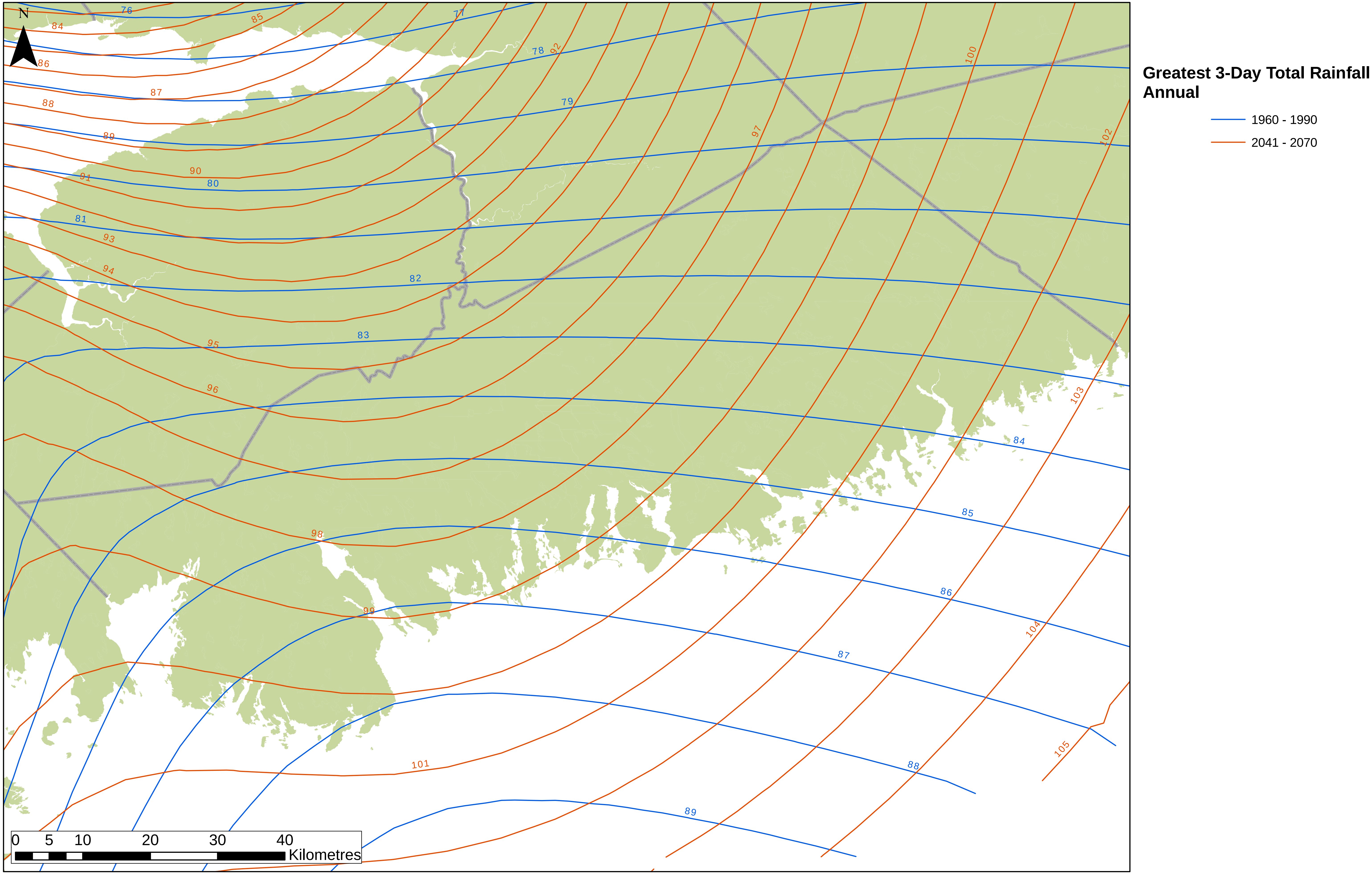
Greatest 3-Day Total Rainfall - Annual
1960 - 1990
2011 - 2040
0 5 10 20 30 40
Kilometres



N
Greatest 3-Day Total Rainfall - Annual
1960 - 1990
2041 - 2070
0 5 10 20 30 40
Kilometres
76
77
78
79
80
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82
83
84
85
86
87
88
89
84
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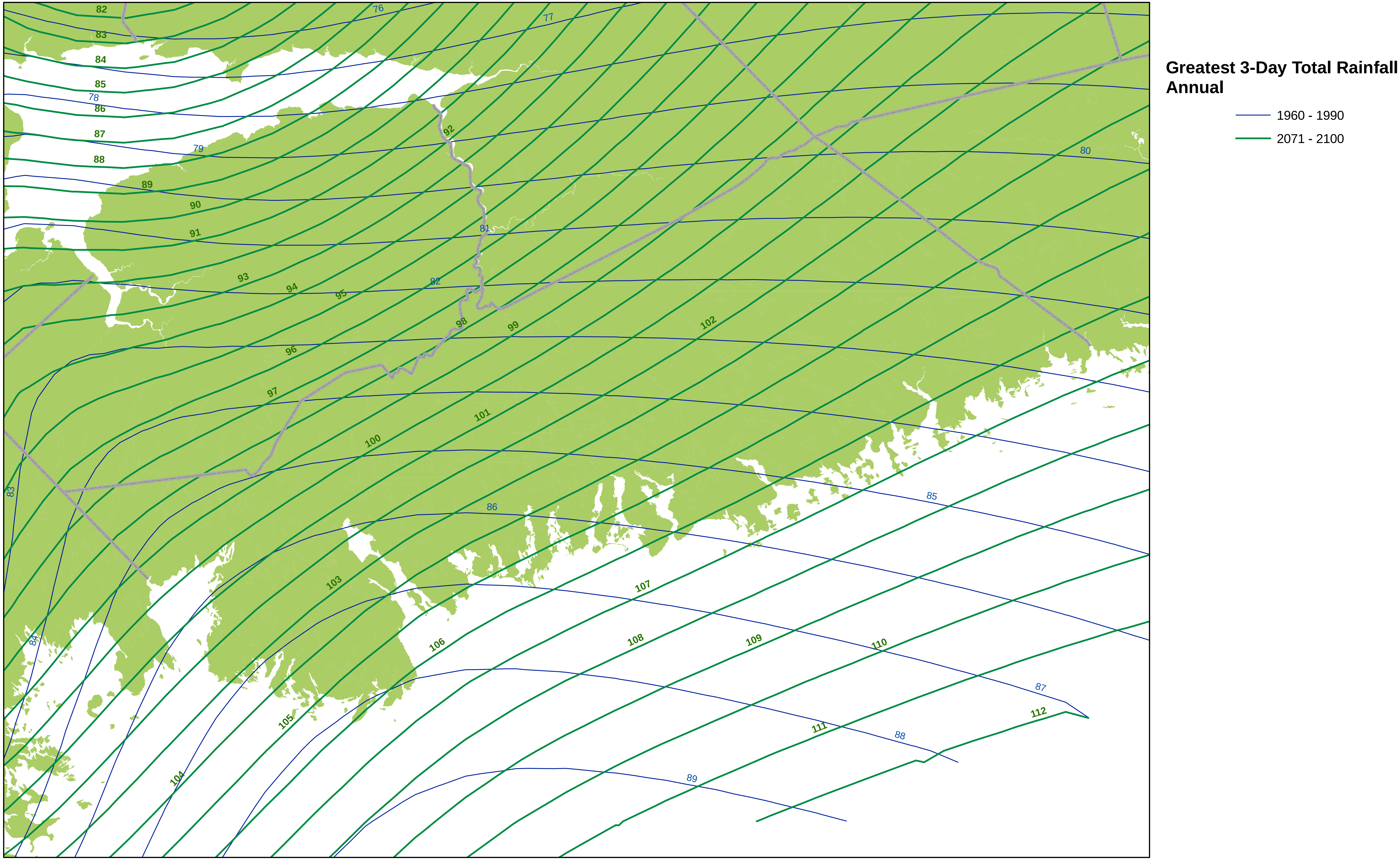
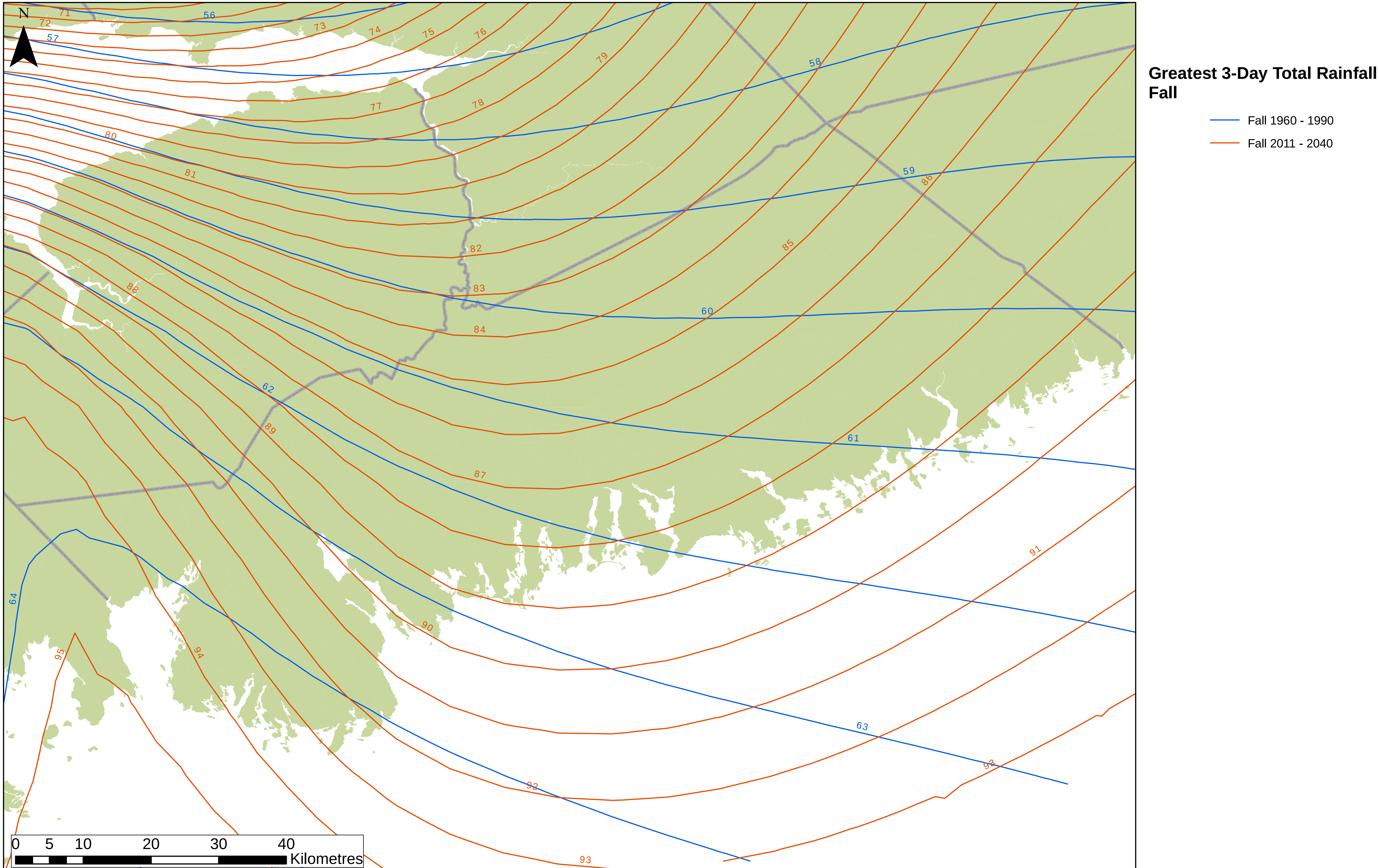
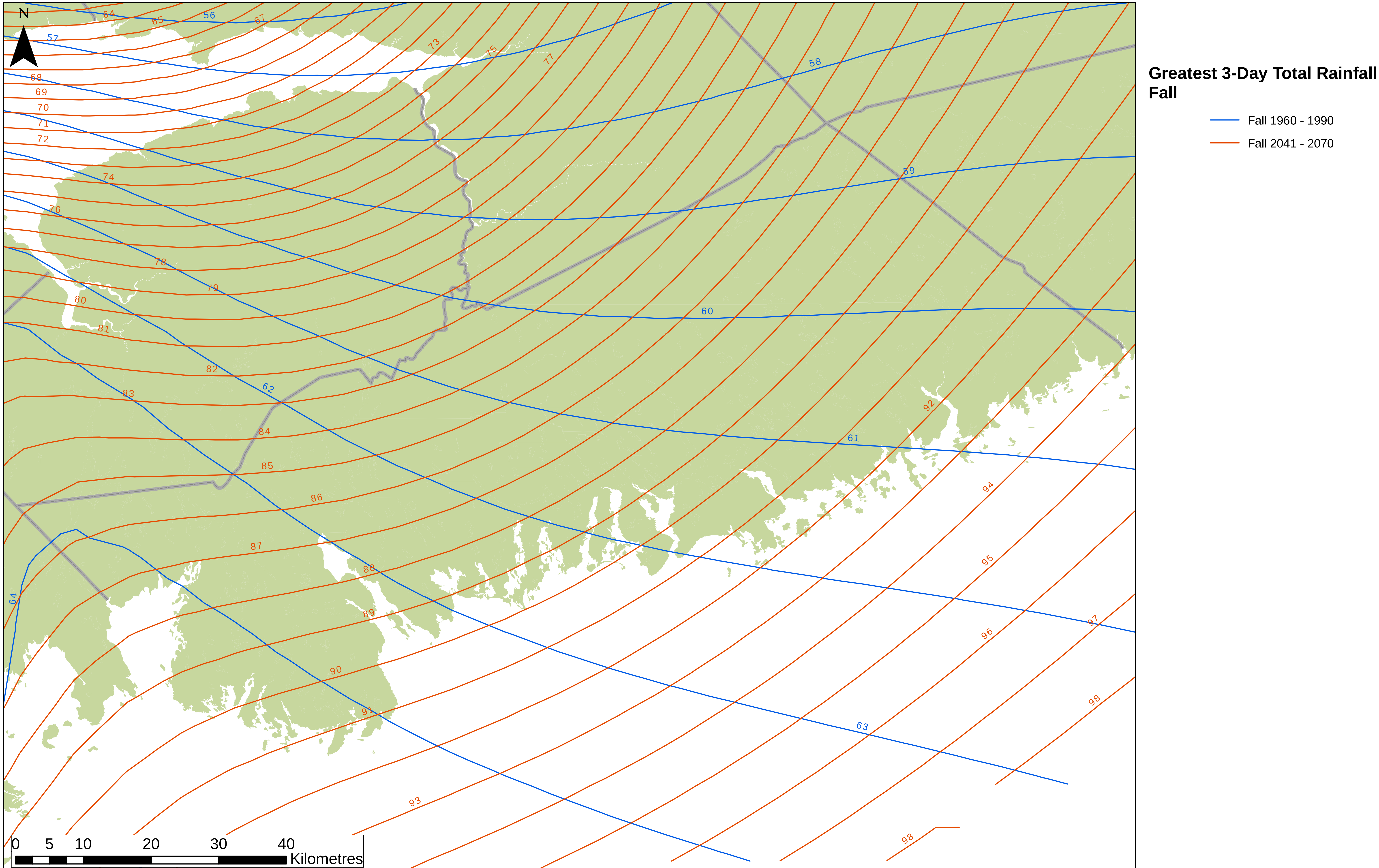
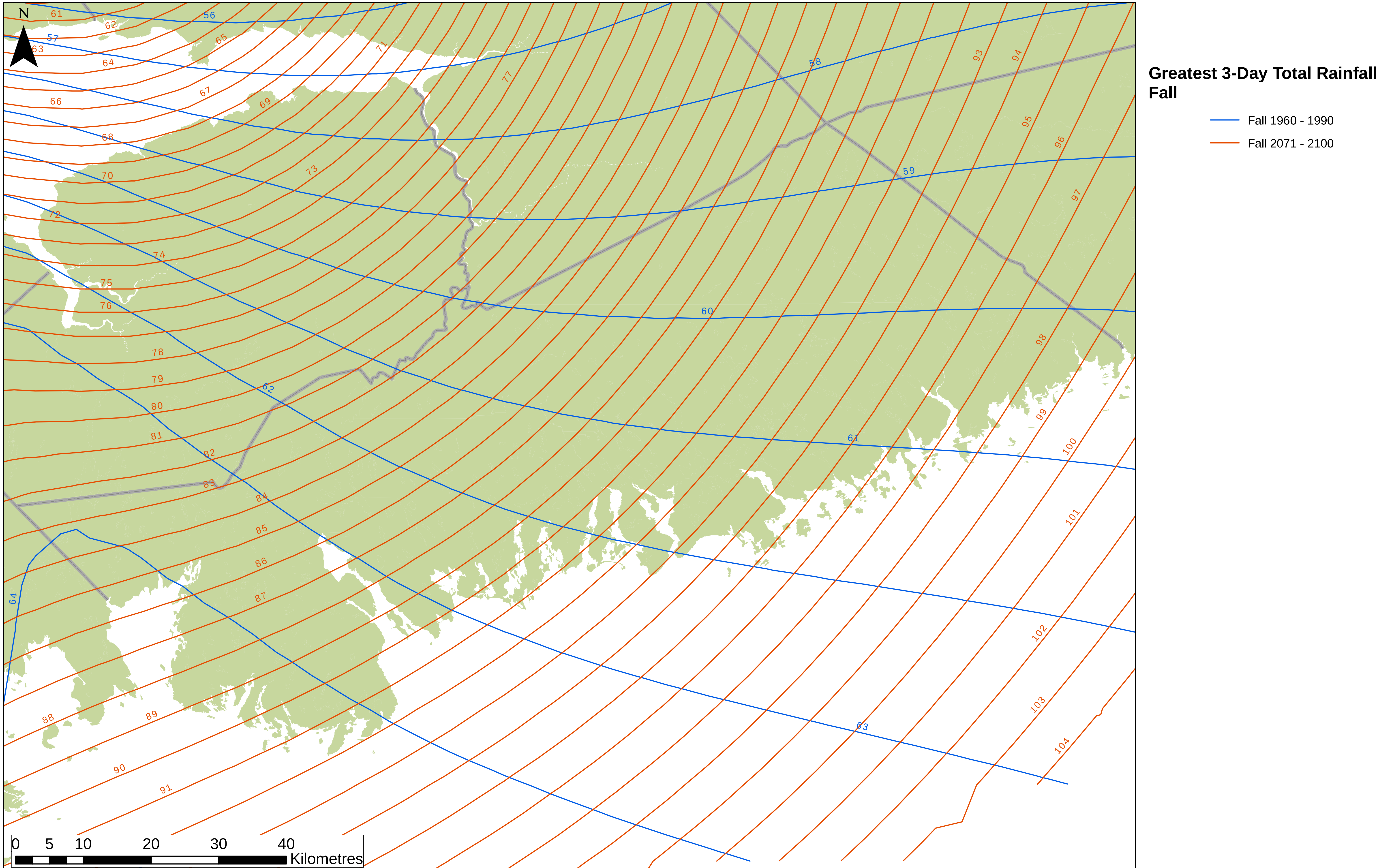


Greatest 3-Day Total Rainfall - Annual
1960 - 1990
2071 - 2100

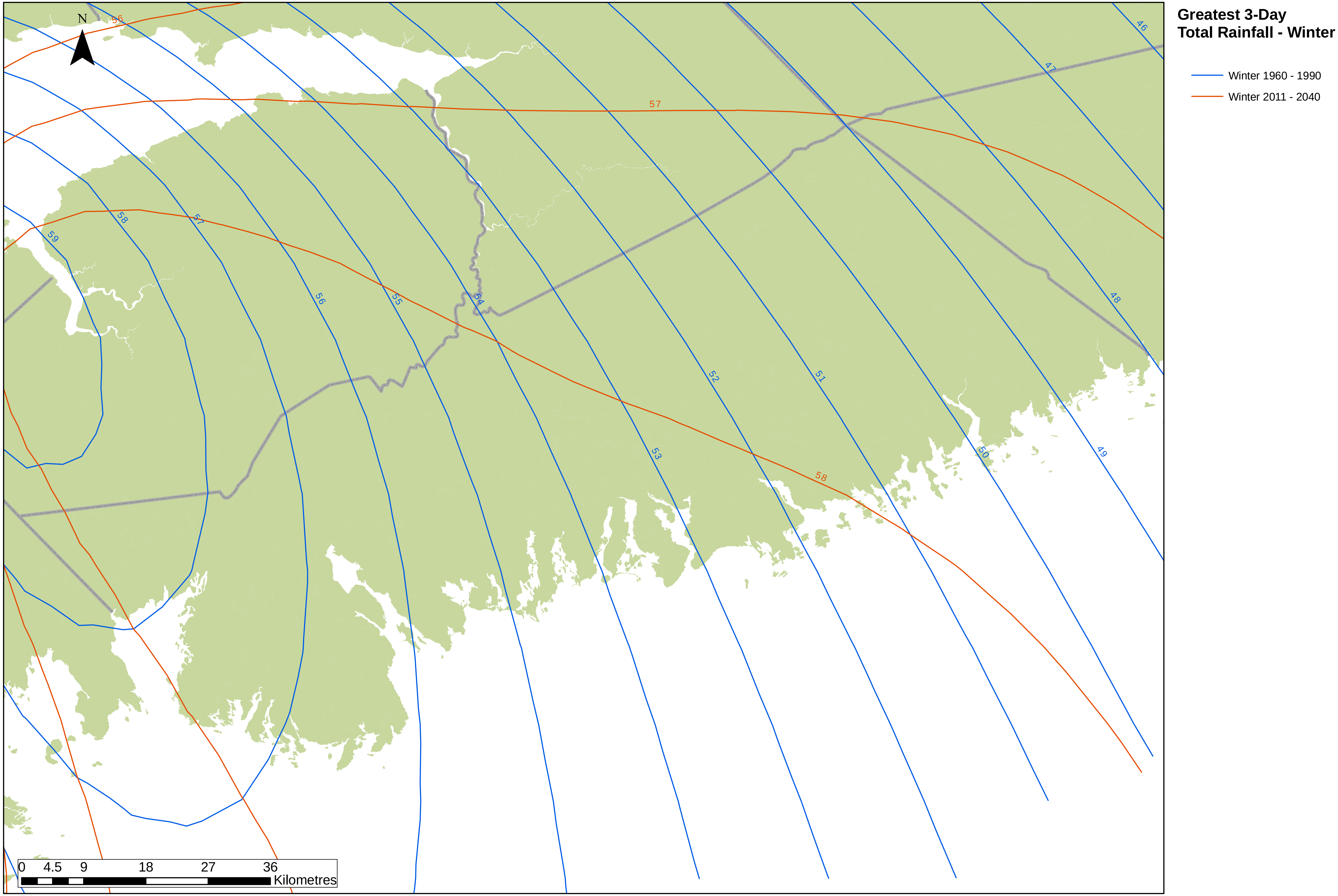


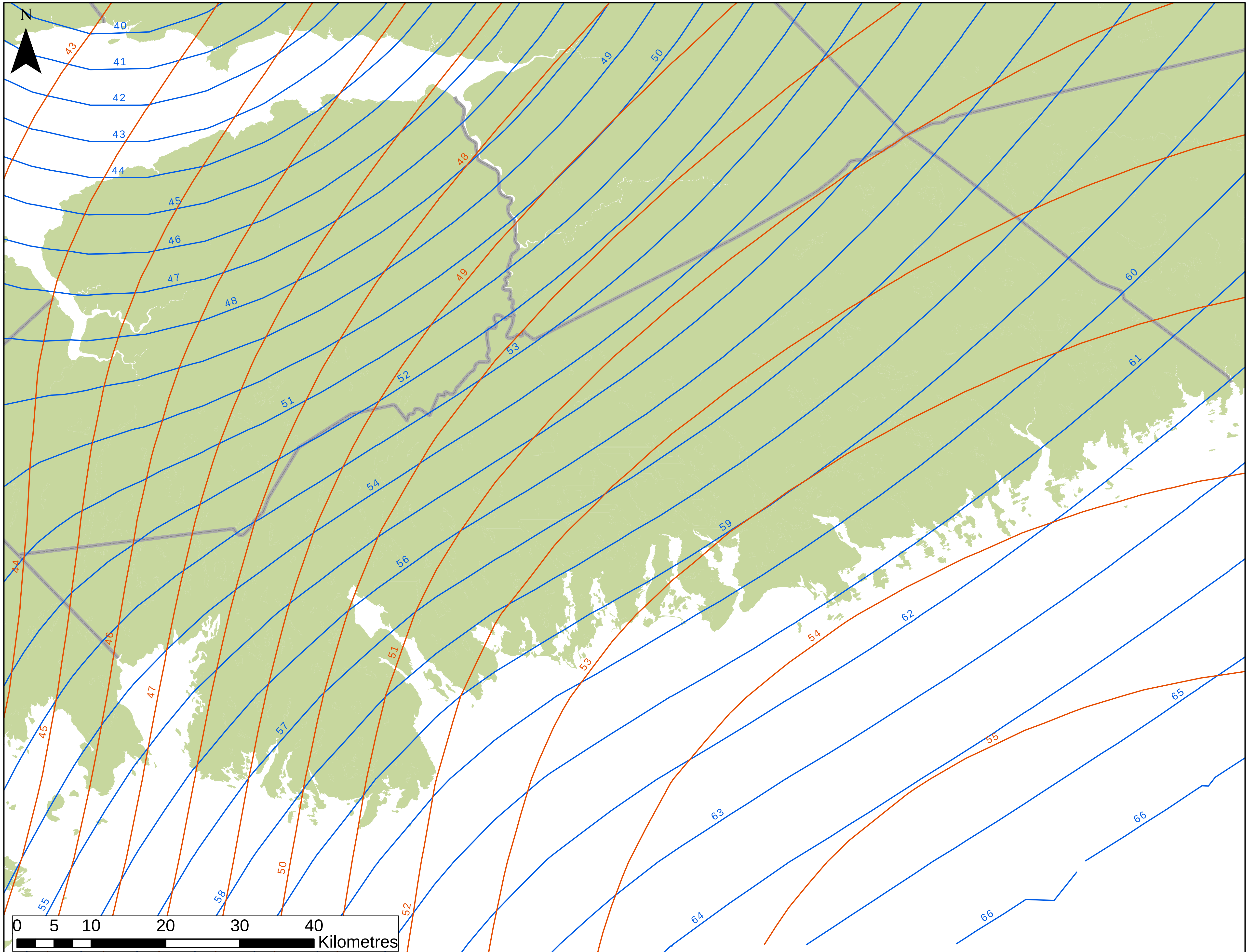
N
Greatest 3-Day Total Rainfall - Fall
Fall 1960 - 1990
Fall 2011 - 2040
0 5 10 20 30 40
Kilometres


N
0 5 10 20 30 40
Kilometres
Greatest 3-Day Total Rainfall - Fall
Fall 1960 - 1990
Fall 2041 - 2070


N
0 5 10 20 30 40 Kilometres
Greatest 3-Day Total Rainfall - Fall
Fall 1960 - 1990
Fall 2071 - 2100

Greatest 3-Day Total Rainfall - Winter

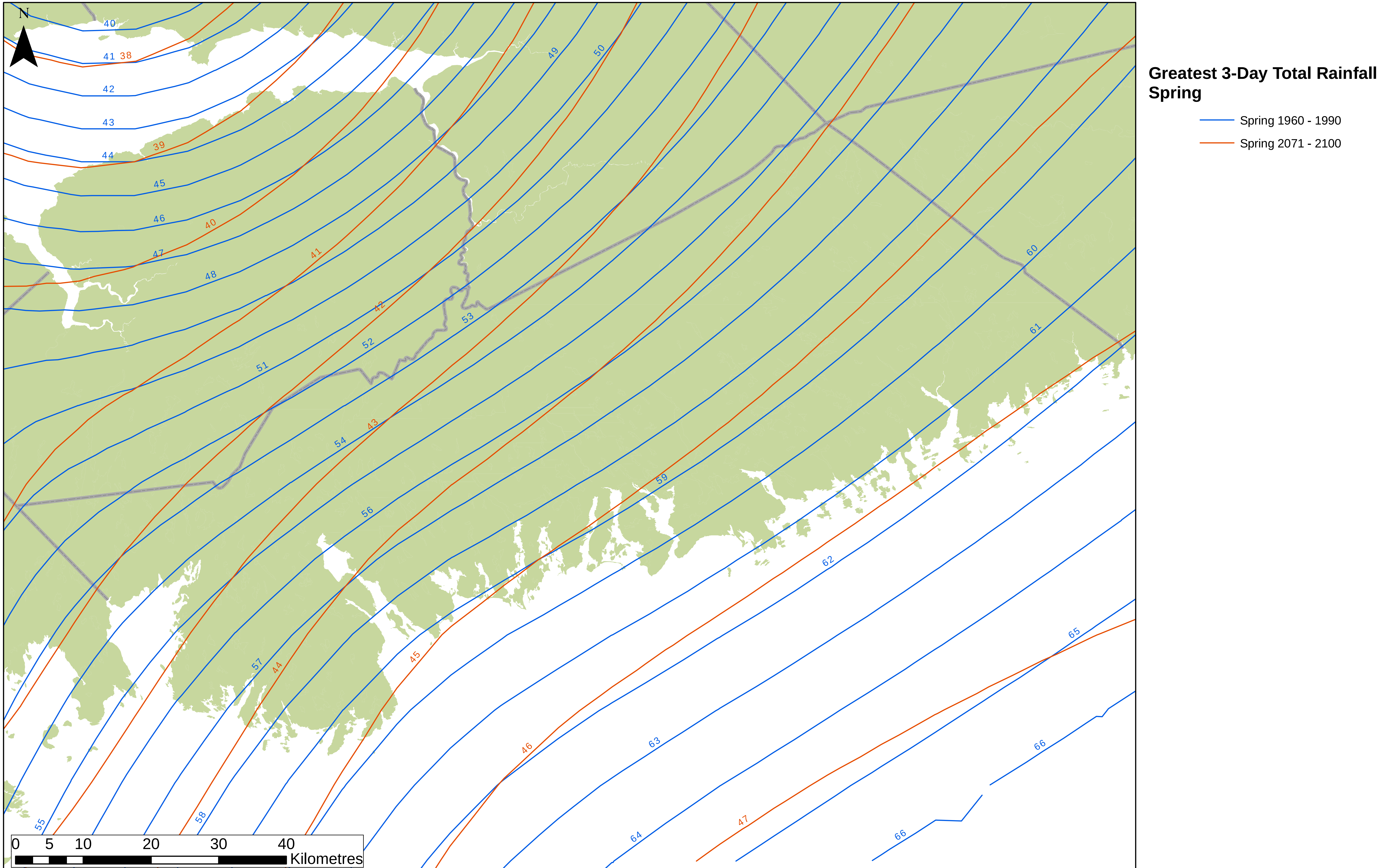




Greatest 3-Day Total Rainfall - Spring

Spring 1960 - 1990

Spring 2041 - 2070


N
40
41
38
42
43
39
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41
48
49
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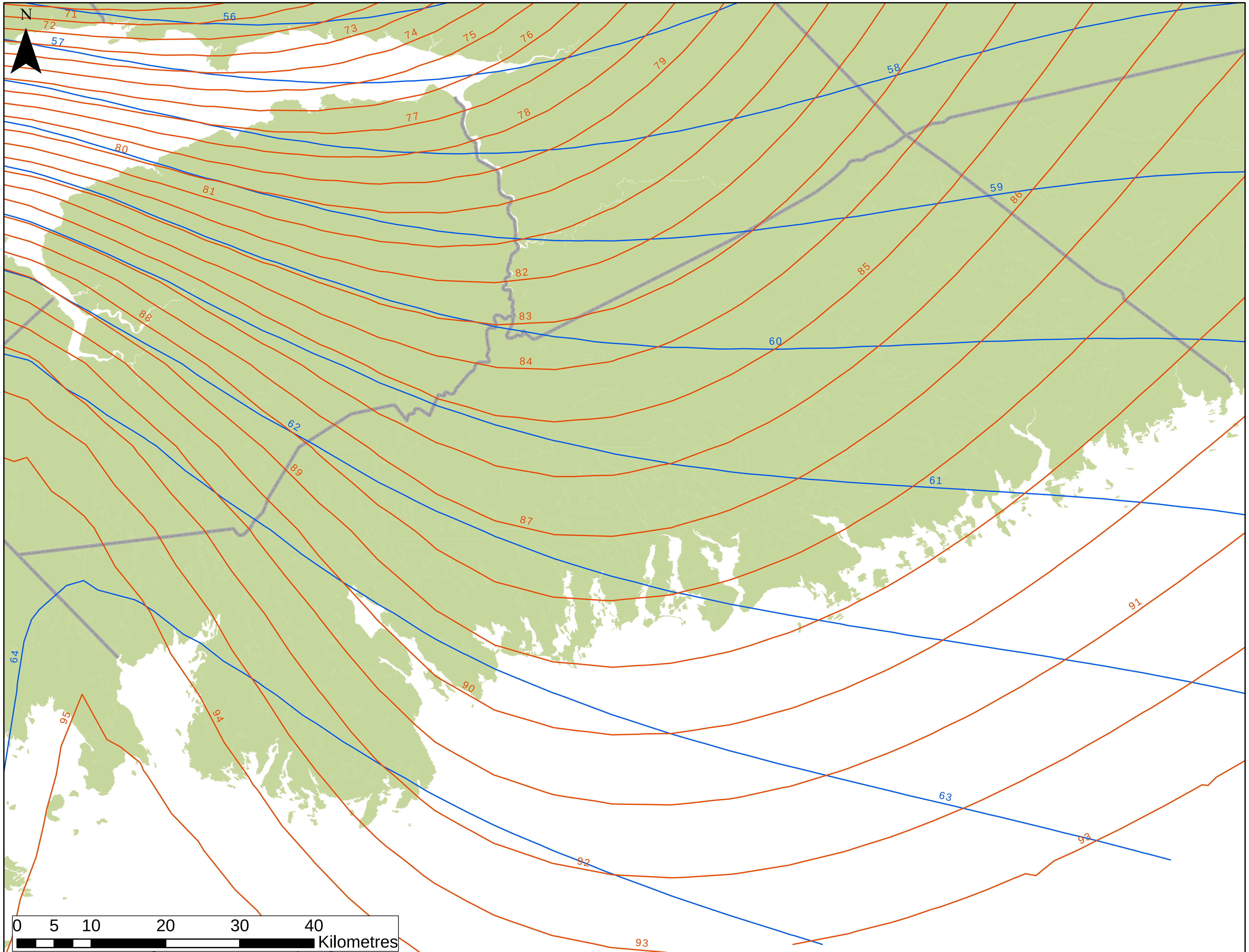
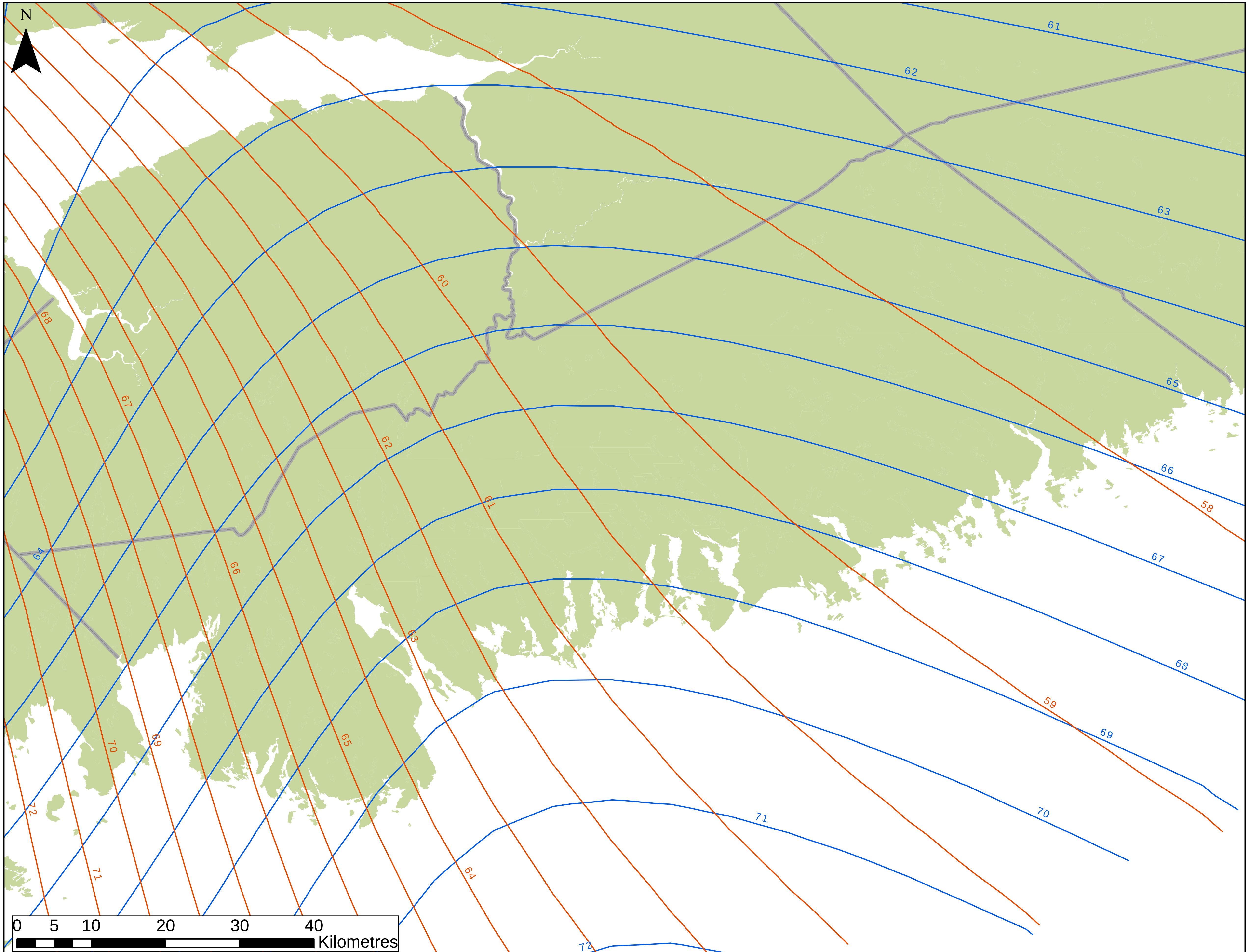
51
43
54
60
61
59
56
62
57
44
45
46
63
65
55
58
64
47
66
66
0 5 10 20 30 40
Kilometres
Greatest 3-Day Total Rainfall - Spring
Spring 1960 - 1990
Spring 2071 - 2100



Greatest 3-Day Total Rainfall - Summer

Fall 1960 - 1990

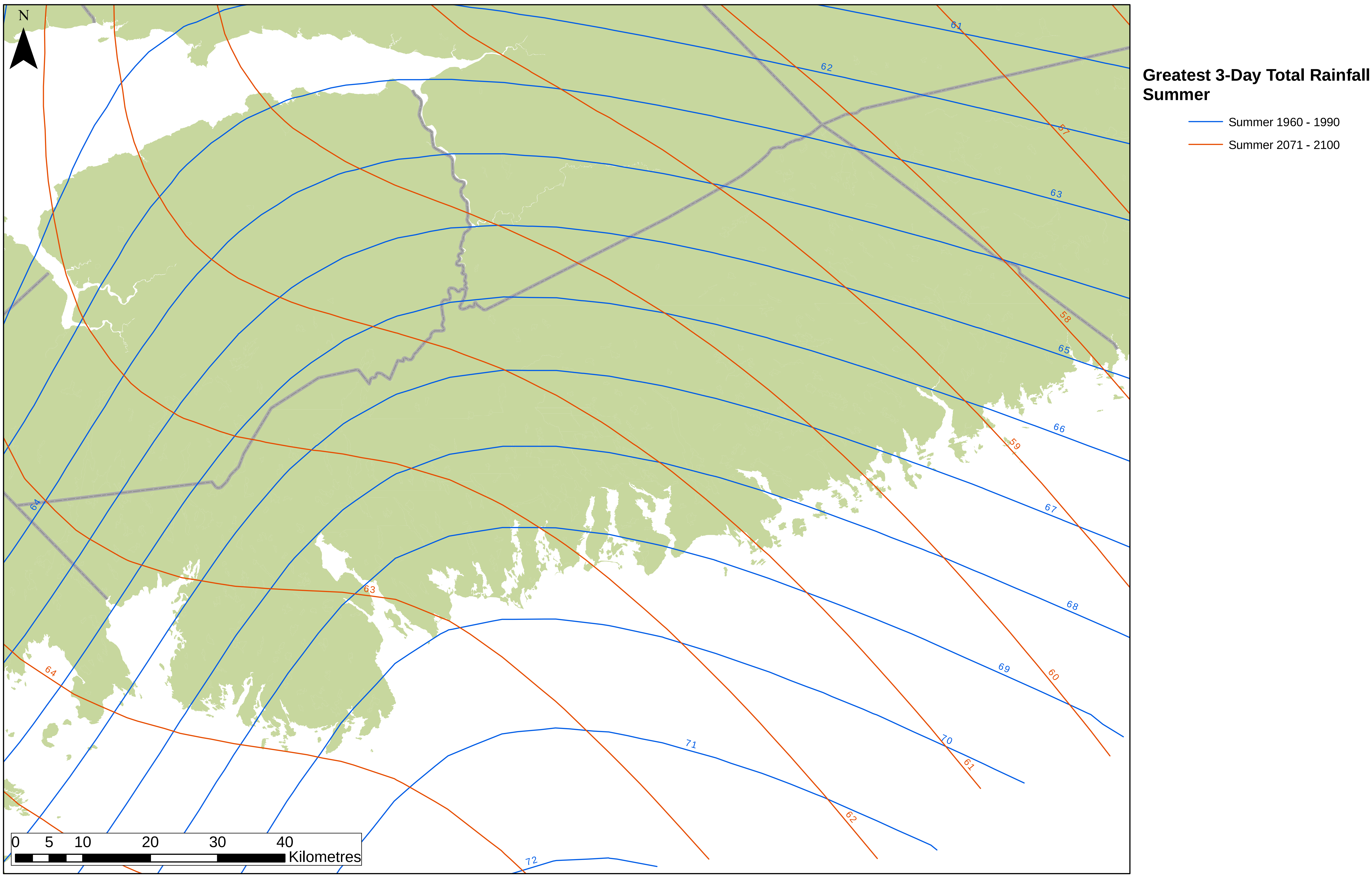
Fall 2011 - 2040



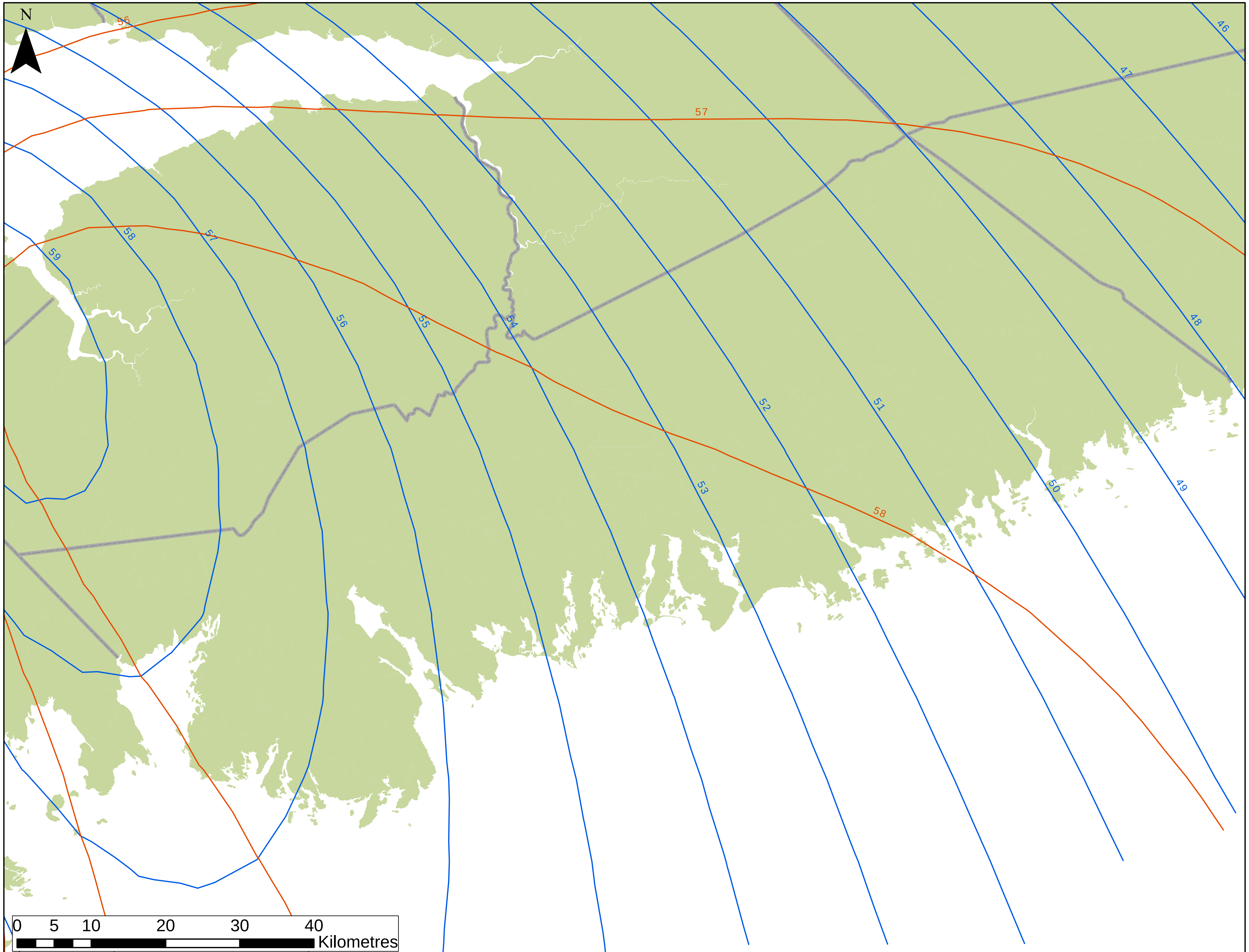
Greatest 3-Day Total Rainfall - Summer

Summer 1960 - 1990

Summer 2041 - 2070



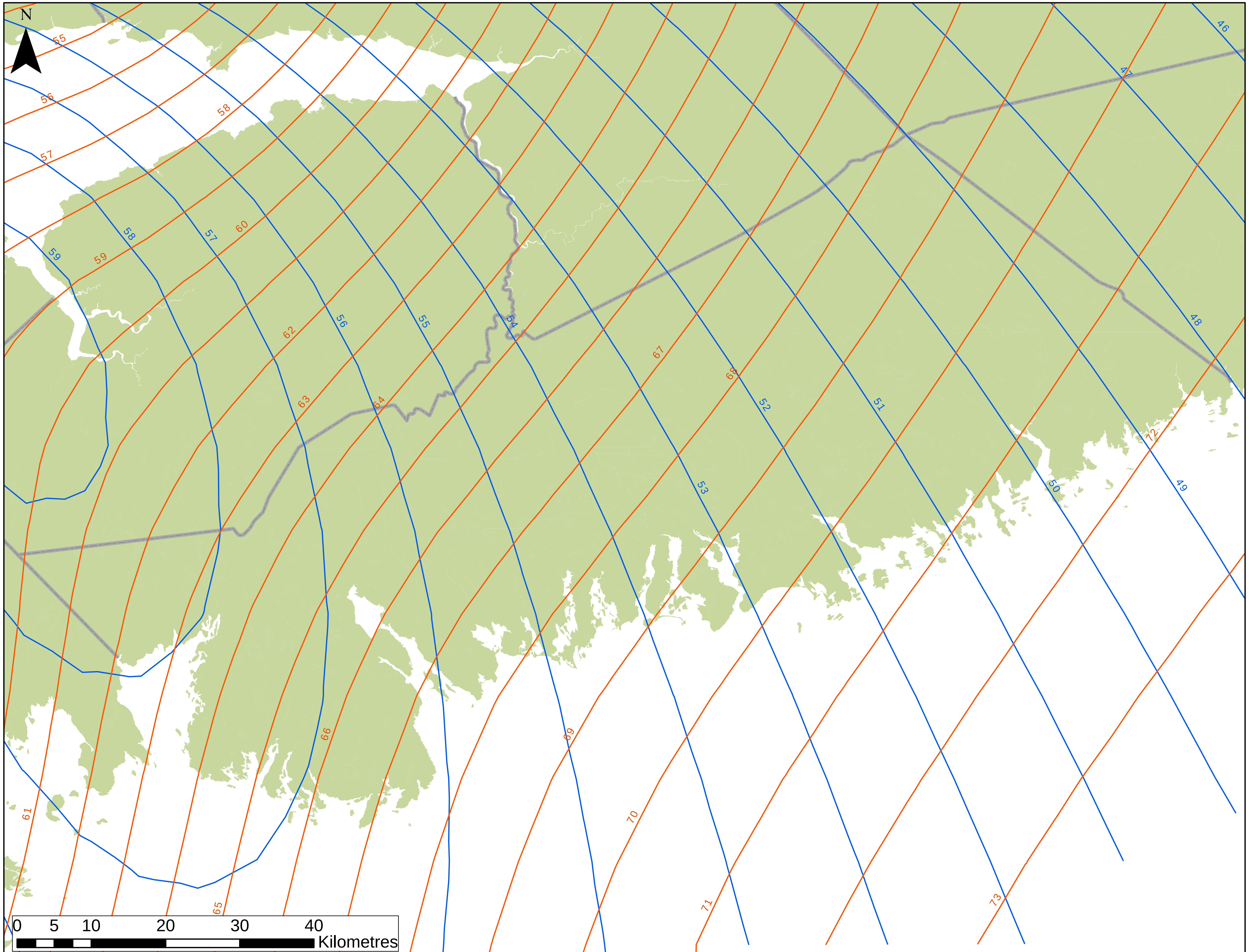
N
Greatest 3-Day Total Rainfall - Summer
Summer 1960 - 1990
Summer 2071 - 2100
61
62
63
64
65
66
67
68
69
70
71
72
57
58
59
60
61
62
63
64
0
5
10
20
30
40
Kilometres



Greatest 3-Day Total Rainfall - Winter

Winter 1960 - 1990

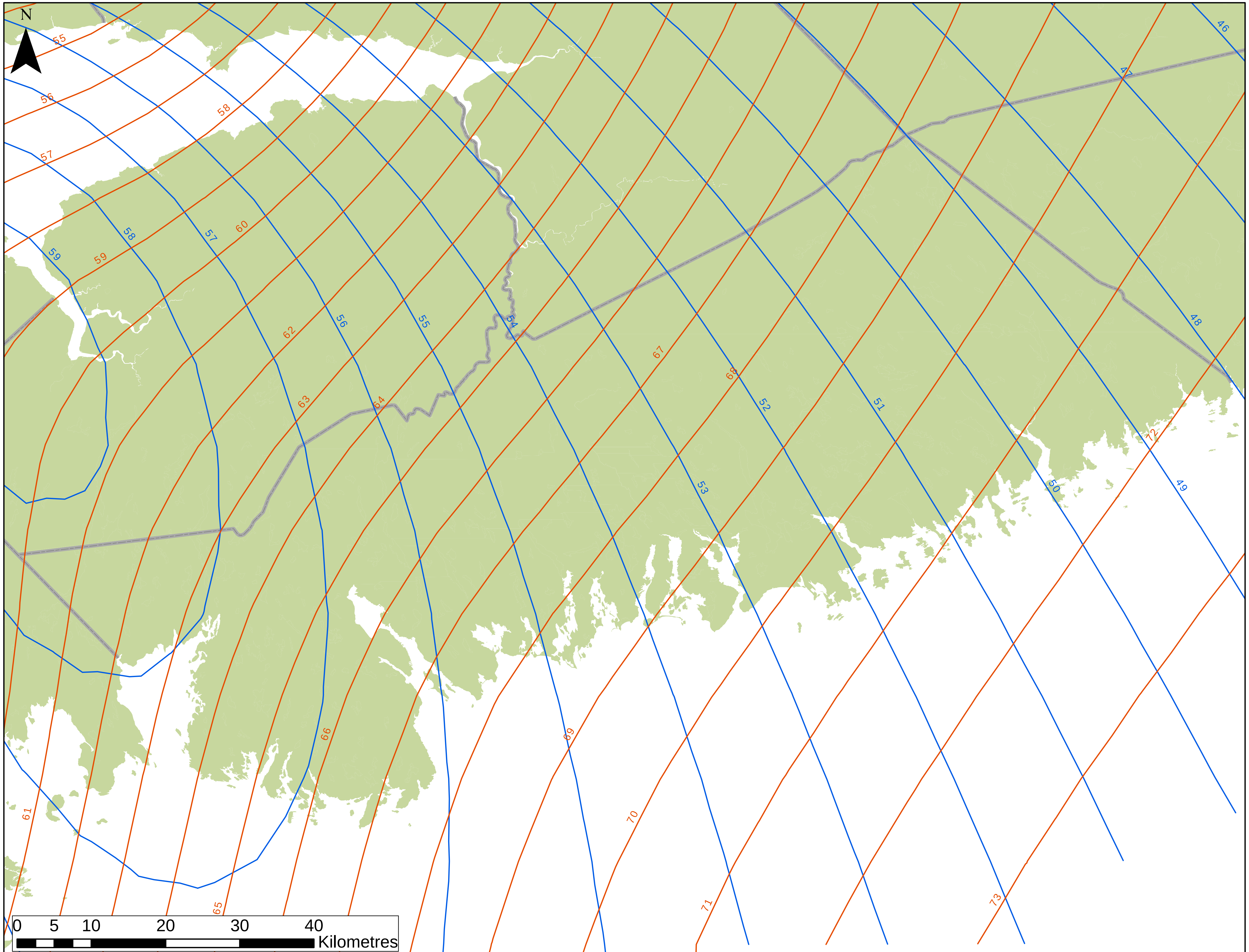
Winter 2011 - 2040



Greatest 3-Day Total Rainfall - Winter

Winter 1960 - 1990

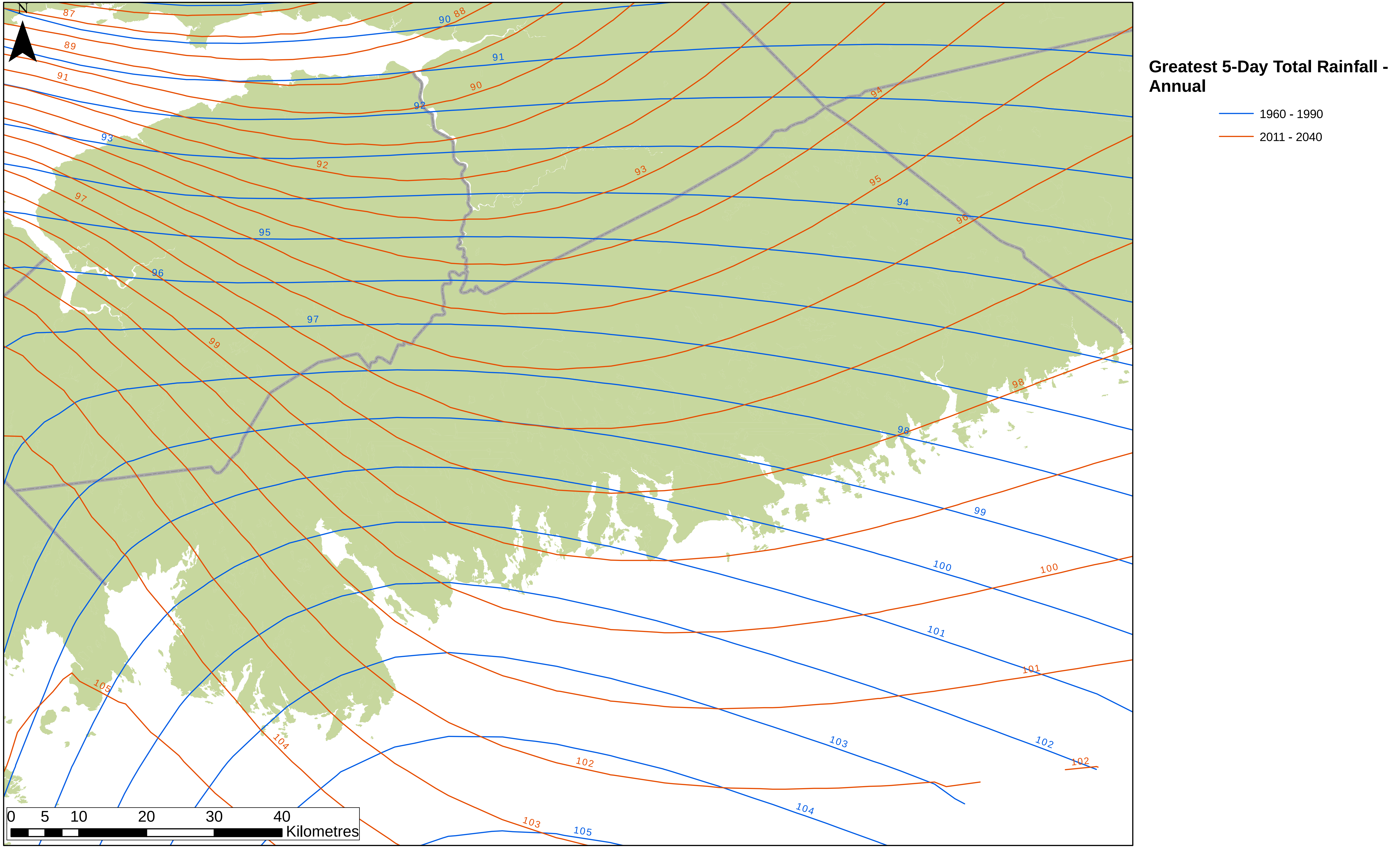
Winter 2041 - 2070

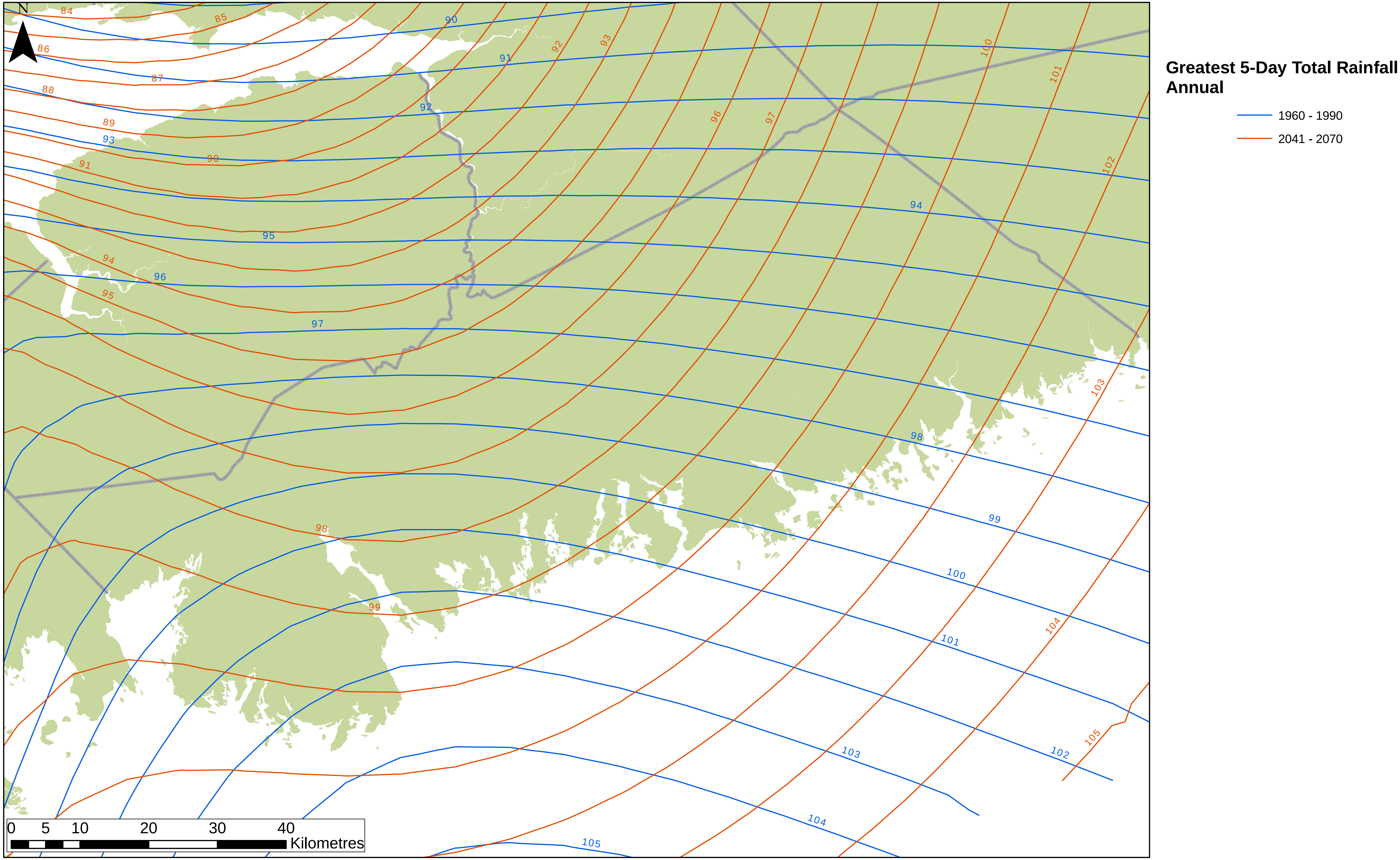


Greatest 3-Day Total Rainfall - Winter

Winter 1960 - 1990

Winter 2071 - 2100


Greatest 5-Day Total Rainfall - Annual
1960 - 1990
2011 - 2040
N
0 5 10 20 30 40
Kilometres


Greatest 5-Day Total Rainfall - Annual
1960 - 1990
2041 - 2070
N
0 5 10 20 30 40
Kilometres
84
85
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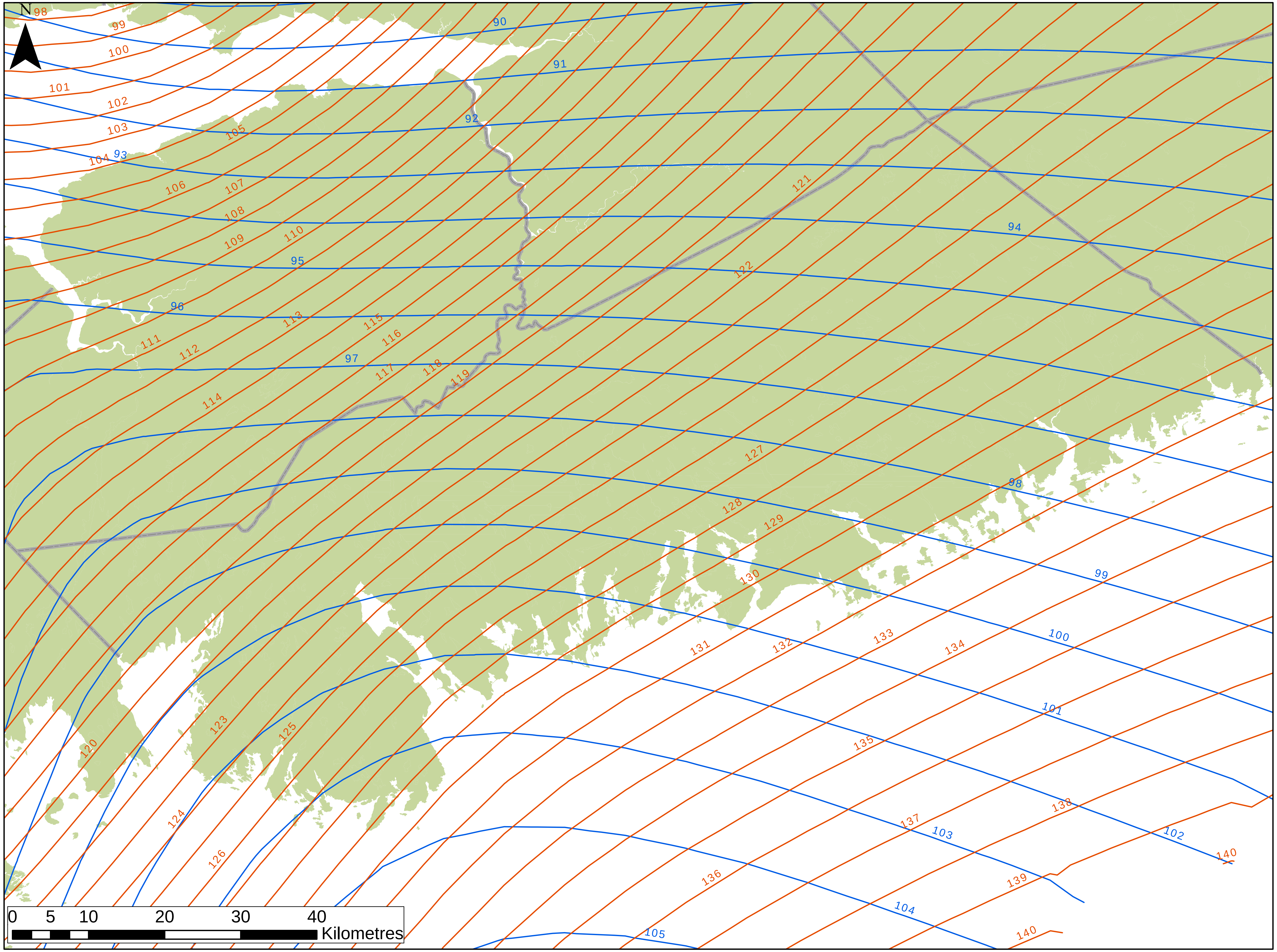
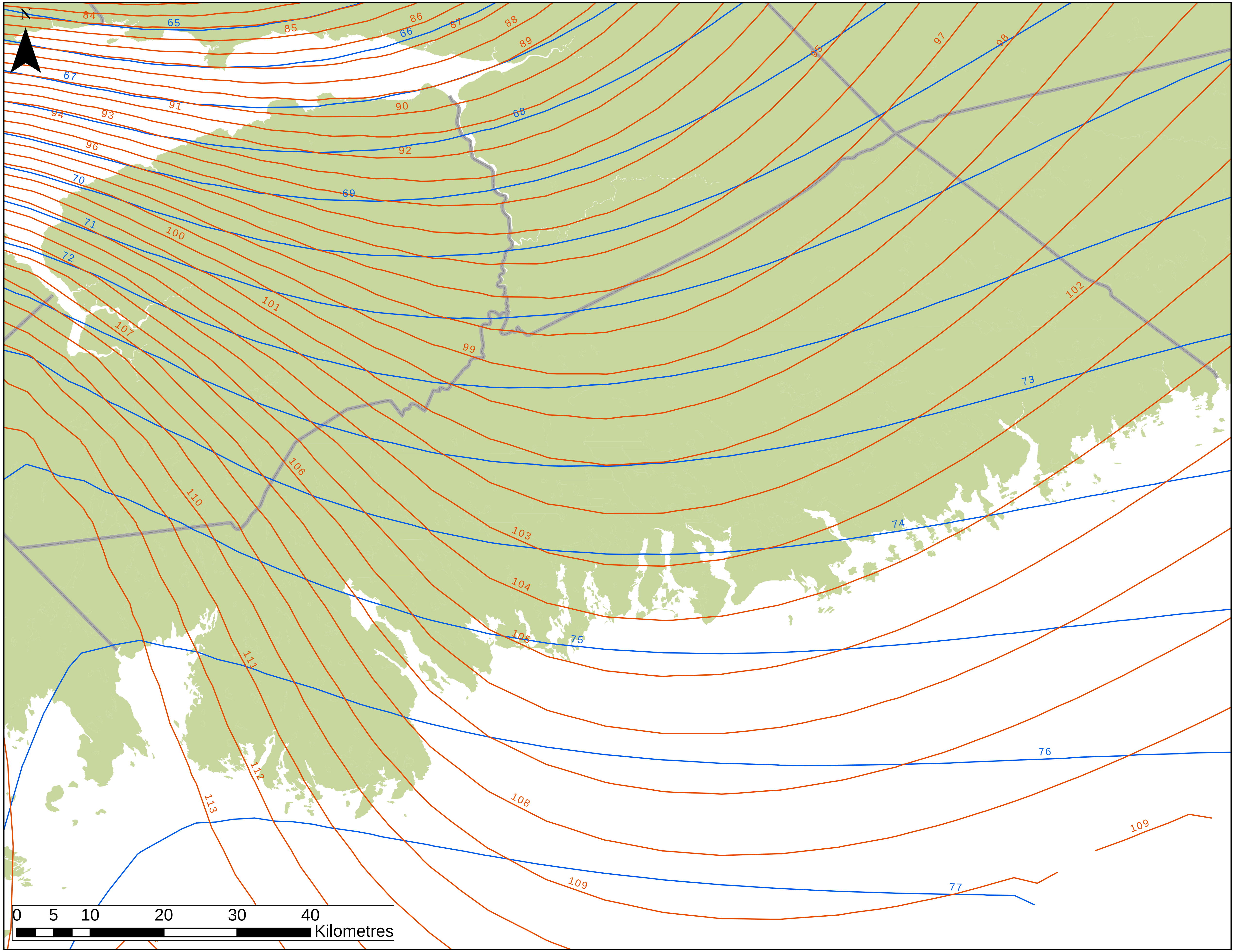
101
102
103
104
105



Greatest 5-Day Total Rainfall - Annual

1960 - 1990

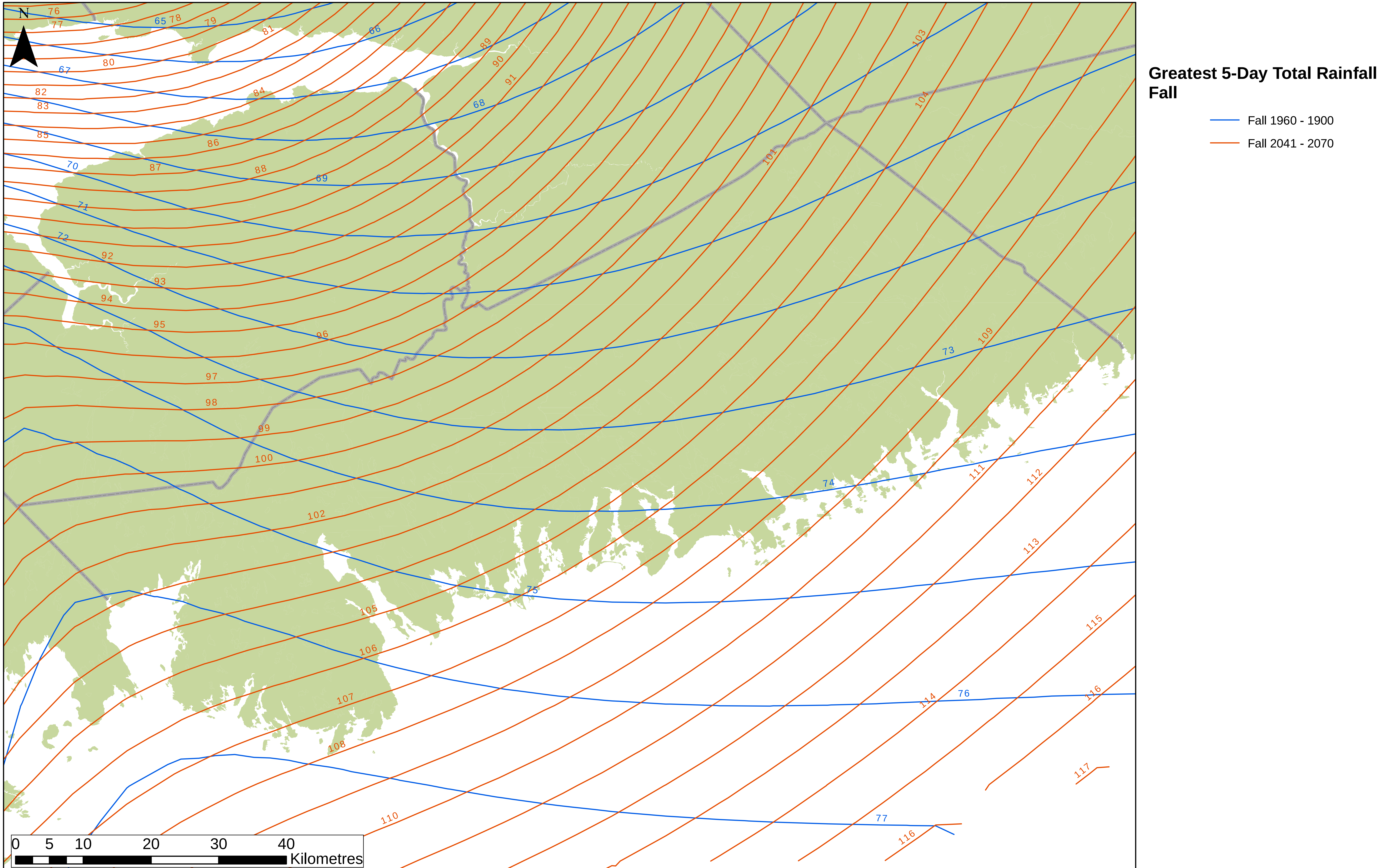
2071 - 2100



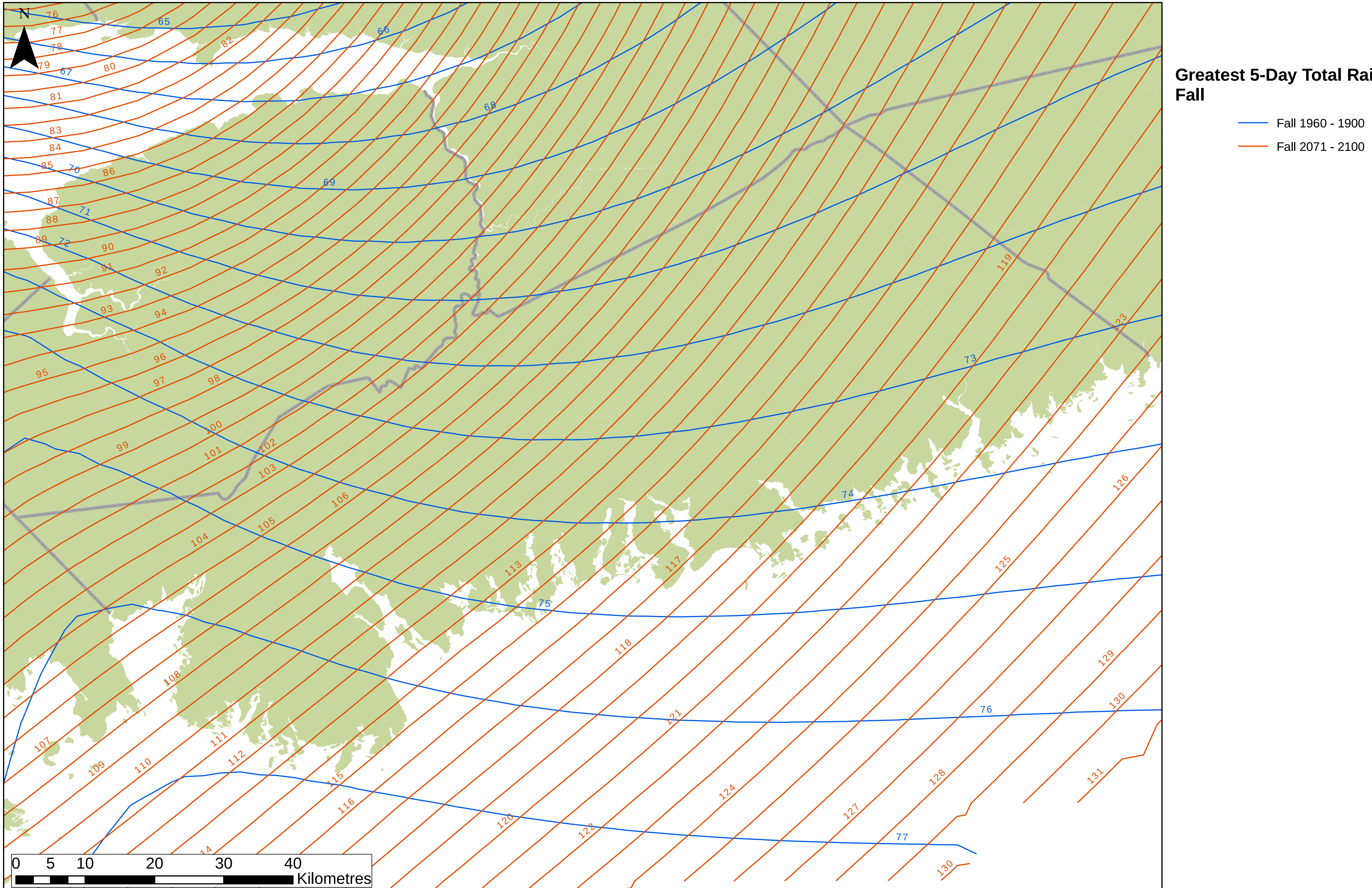
Greatest 5-Day Total Rainfall - Fall

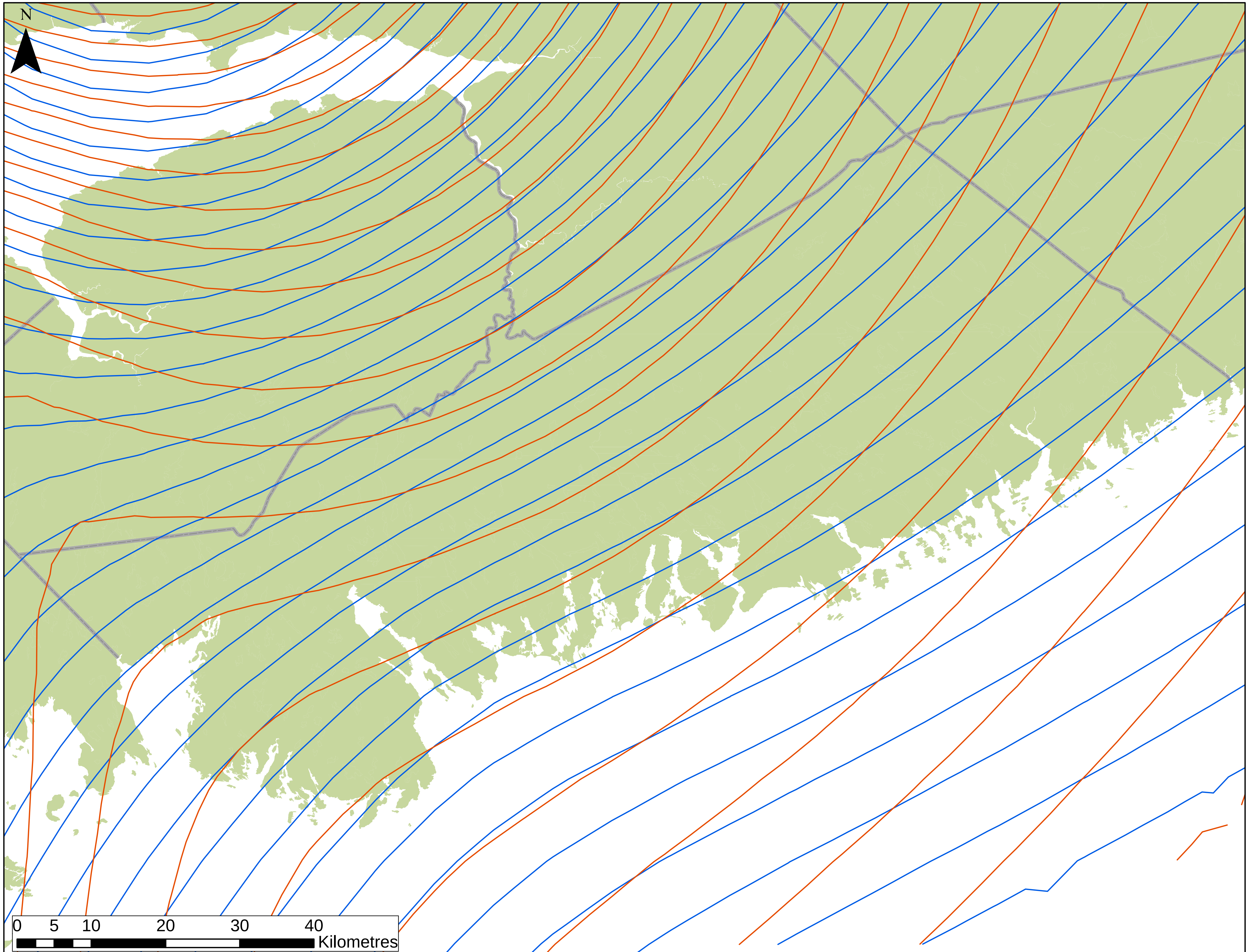
Fall 1960 - 1900

Fall 2011 - 2040


Greatest 5-Day Total Rainfall - Fall
Fall 1960 - 1900
Fall 2041 - 2070
N
0 5 10 20 30 40
Kilometres

Greatest 5-Day Total Rainfall - Fall

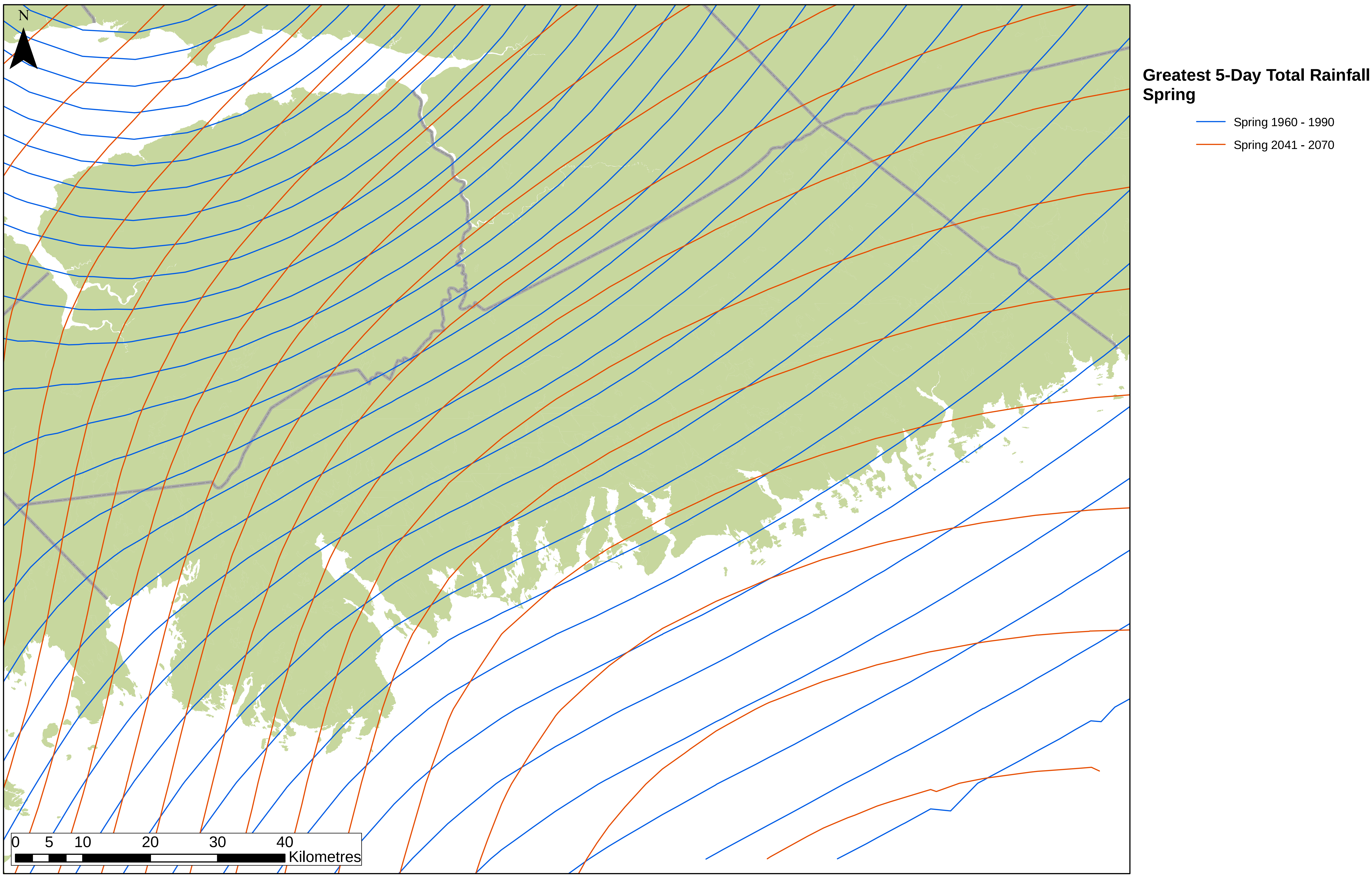


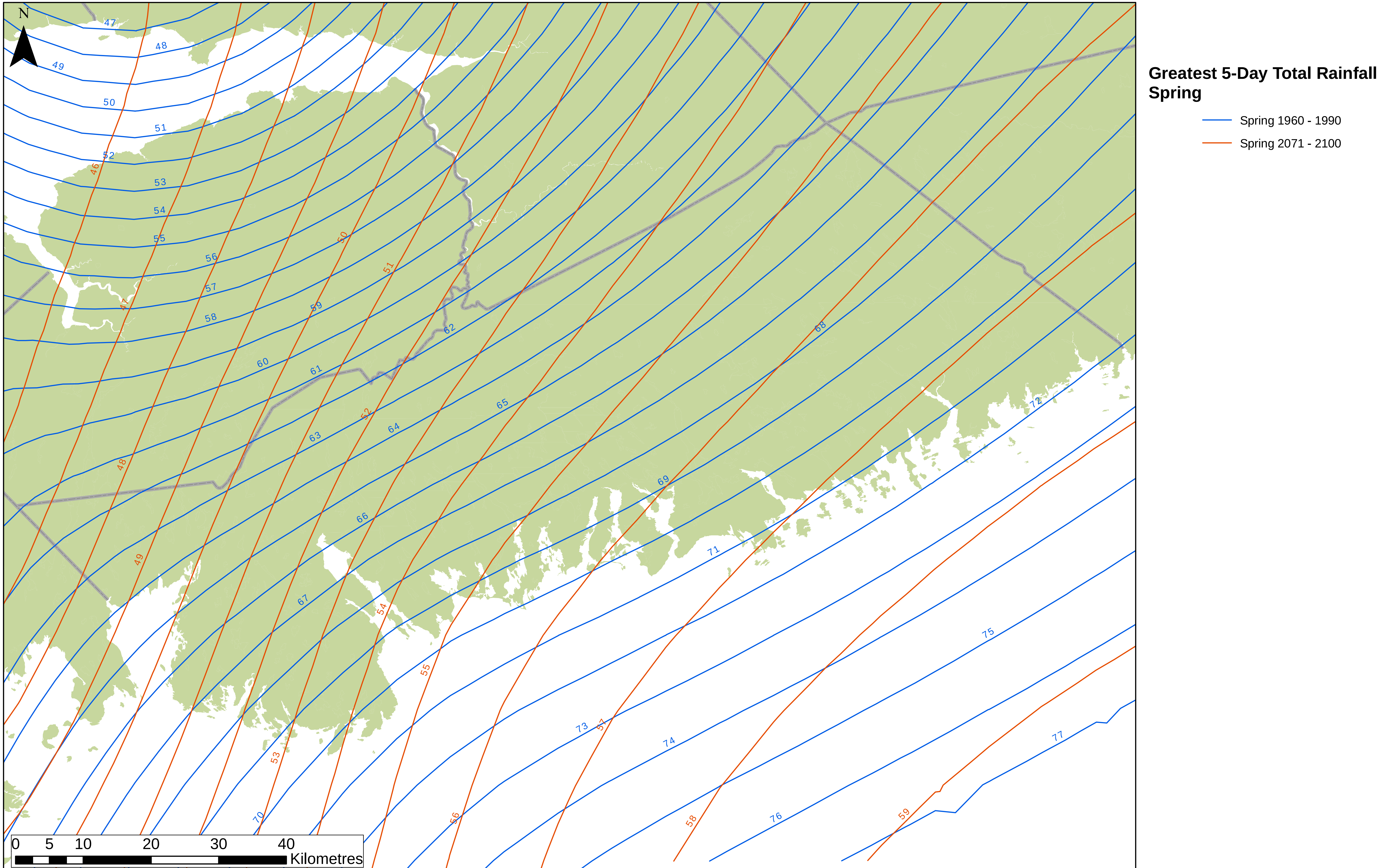


Greatest 5-Day Total Rainfall - Spring

Spring 2011 - 2040

Spring 1960 - 1990


N
0 5 10 20 30 40
Kilometres
Greatest 5-Day Total Rainfall - Spring
Spring 1960 - 1990
Spring 2041 - 2070


N
Greatest 5-Day Total Rainfall - Spring
Spring 1960 - 1990
Spring 2071 - 2100
0 5 10 20 30 40
Kilometres
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
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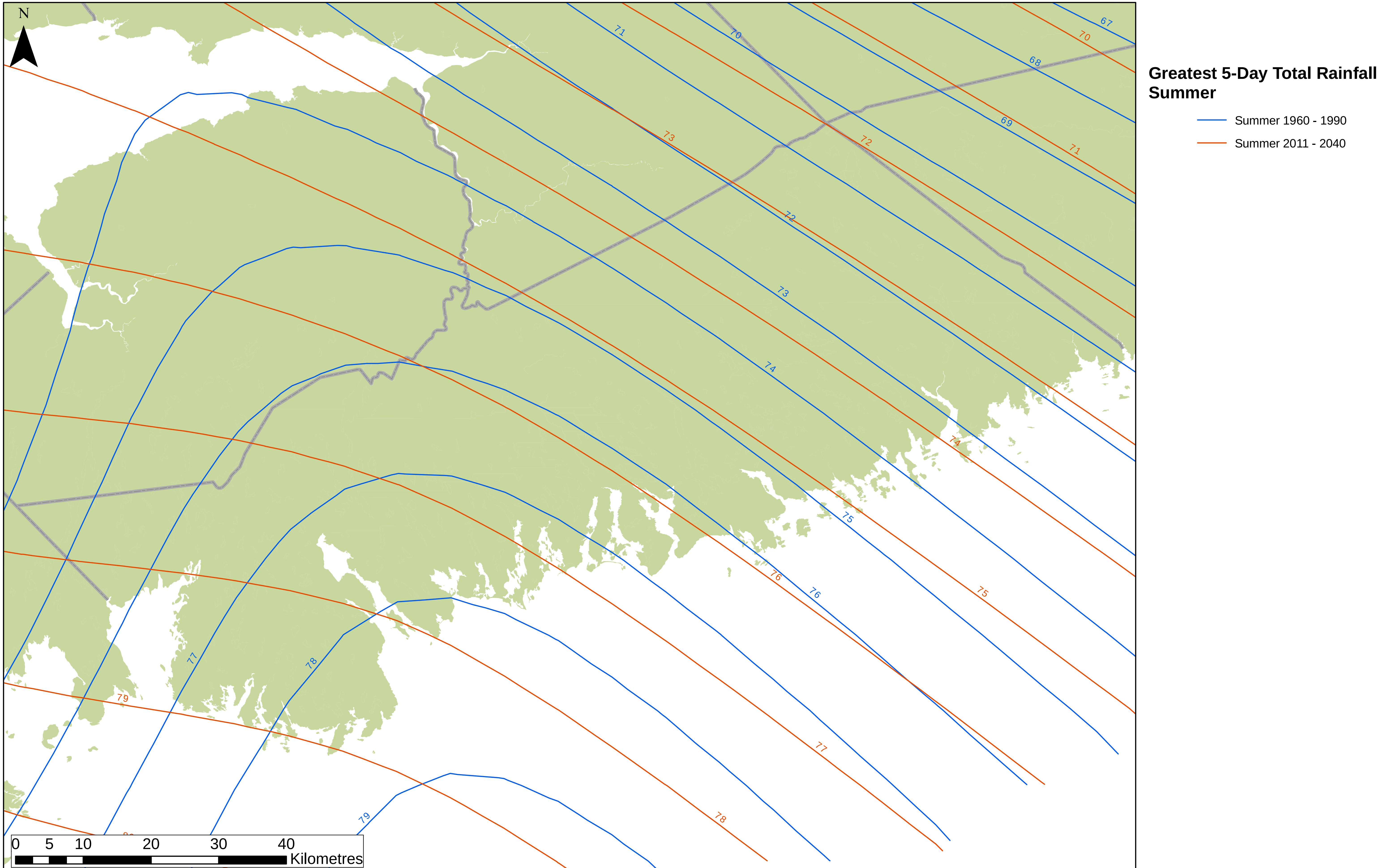
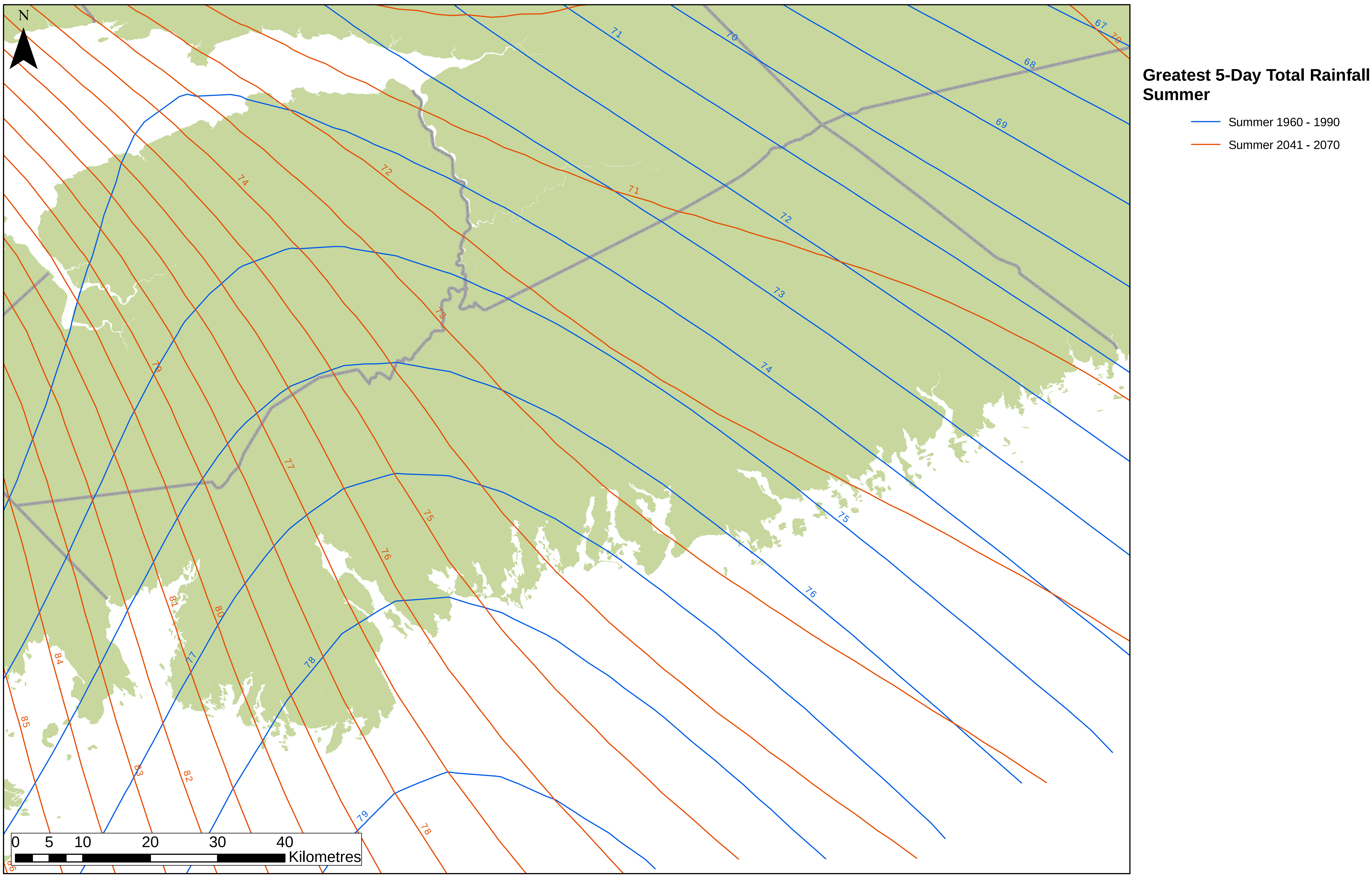
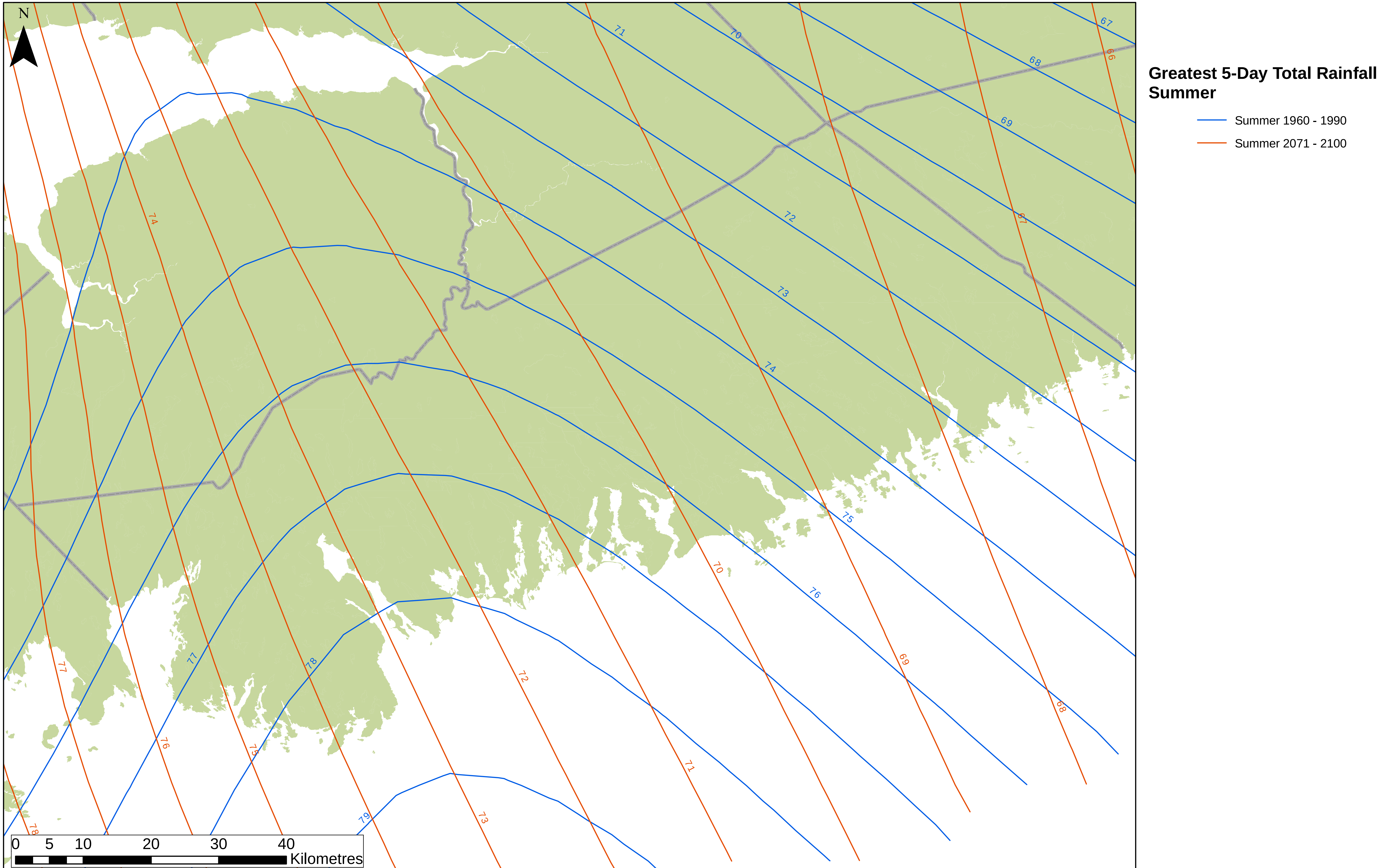

N
Greatest 5-Day Total Rainfall - Summer
Summer 1960 - 1990
Summer 2011 - 2040
0 5 10 20 30 40
Kilometres
67
68
69
70
71
72
73
74
75
76
77
78
79


N
0 5 10 20 30 40
Kilometres
Greatest 5-Day Total Rainfall - Summer
Summer 1960 - 1990
Summer 2041 - 2070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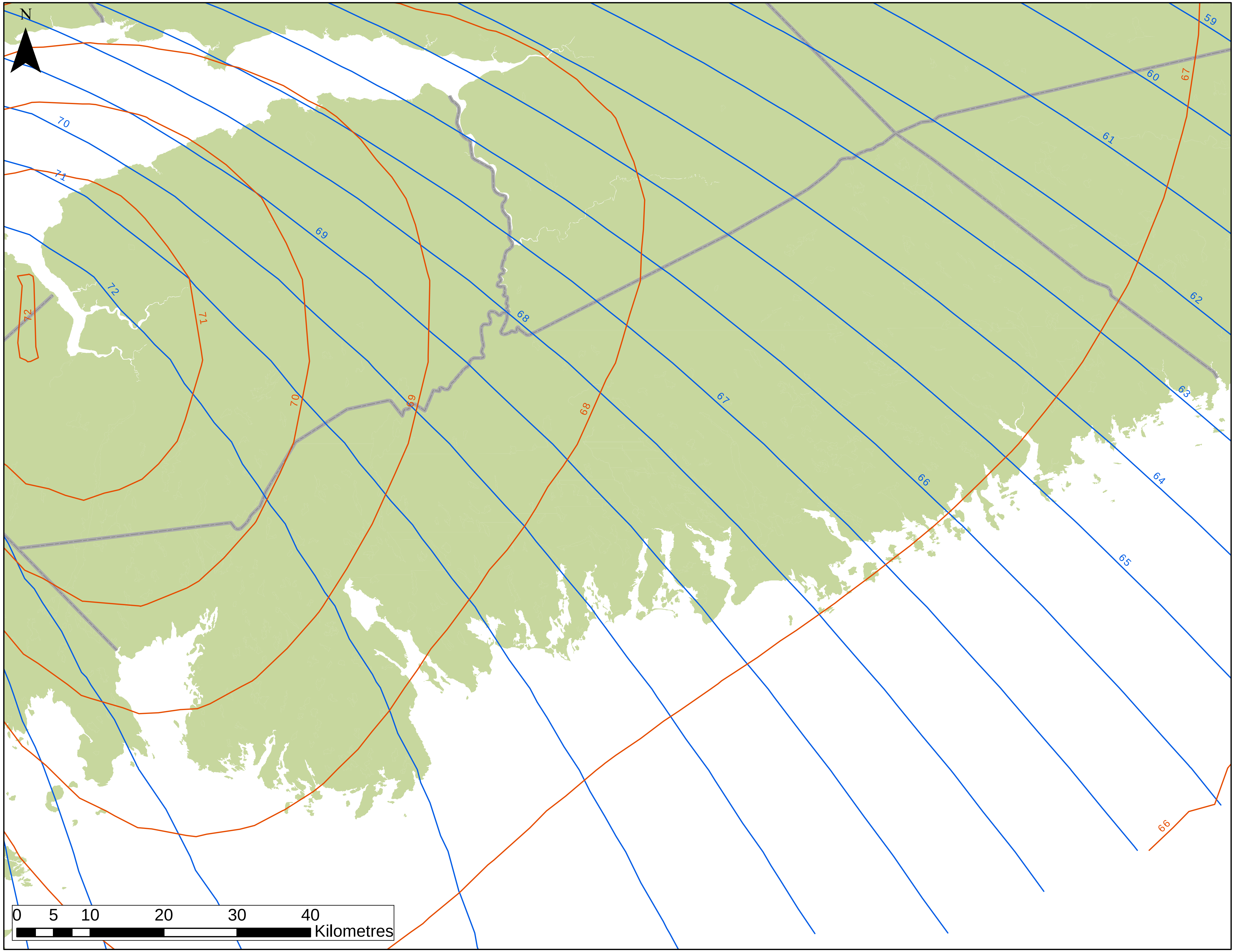
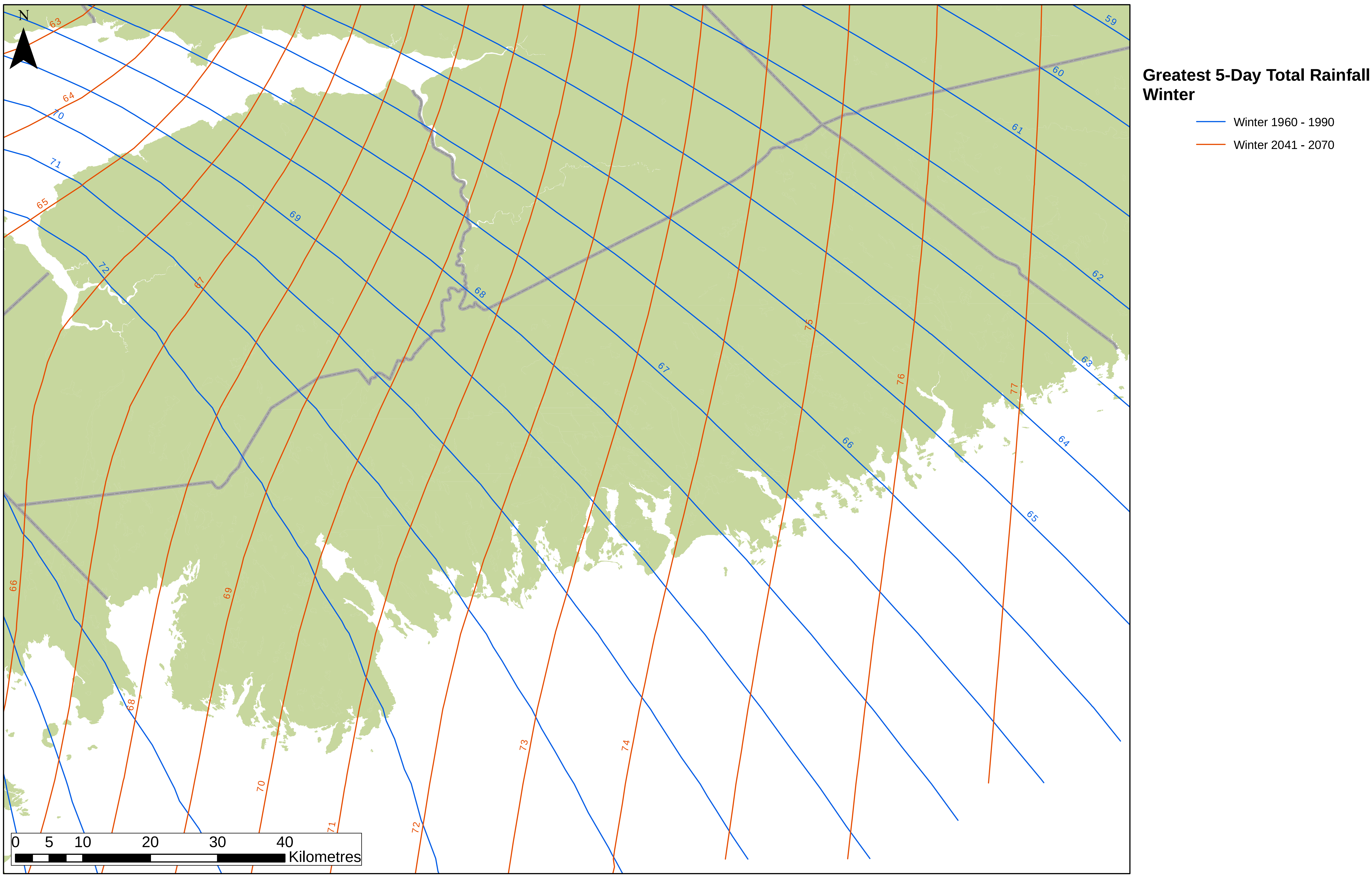
0 5 10 20 30 40
Kilometres
Greatest 5-Day Total Rainfall - Summer
Summer 1960 - 1990
Summer 2071 - 2100

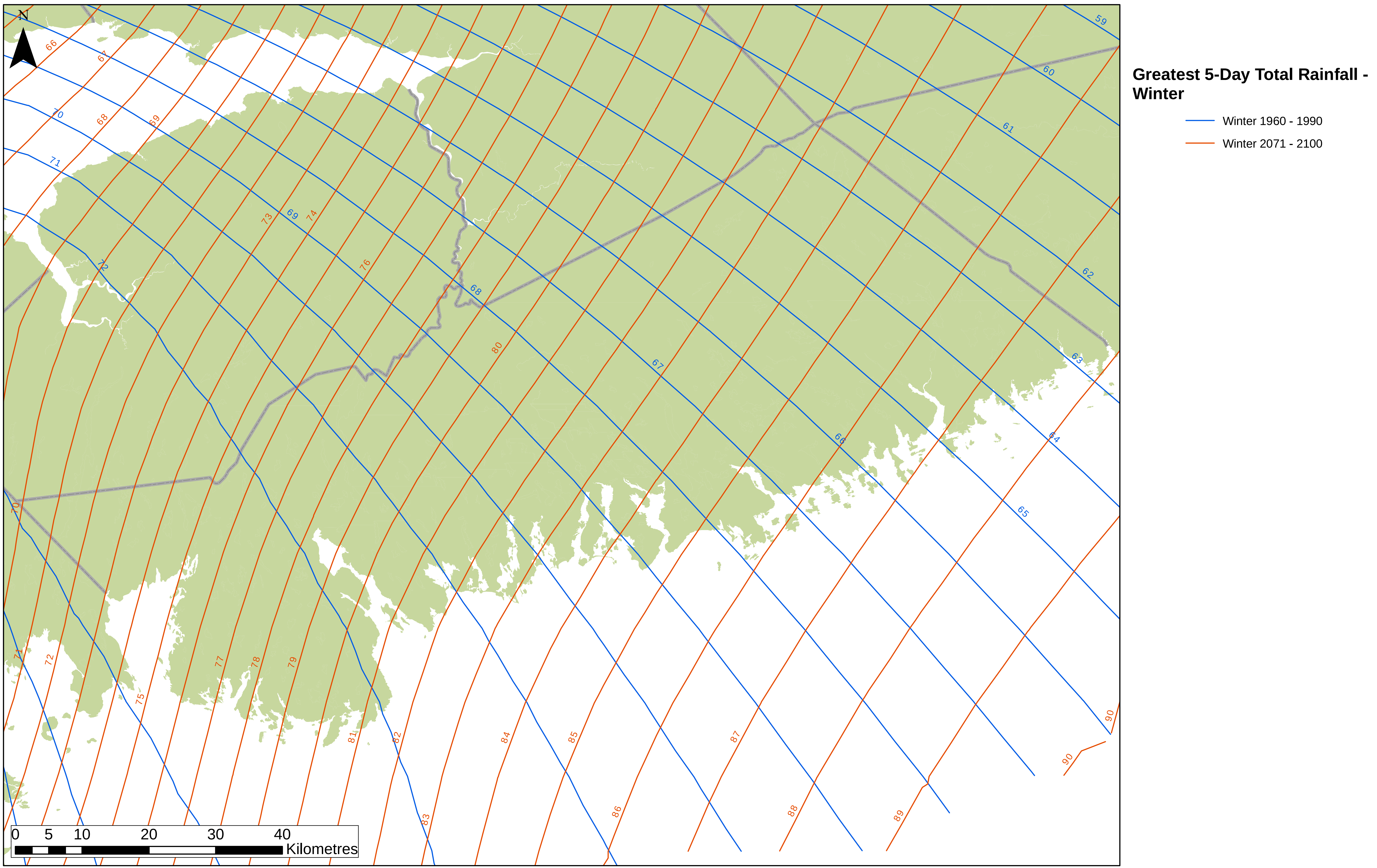


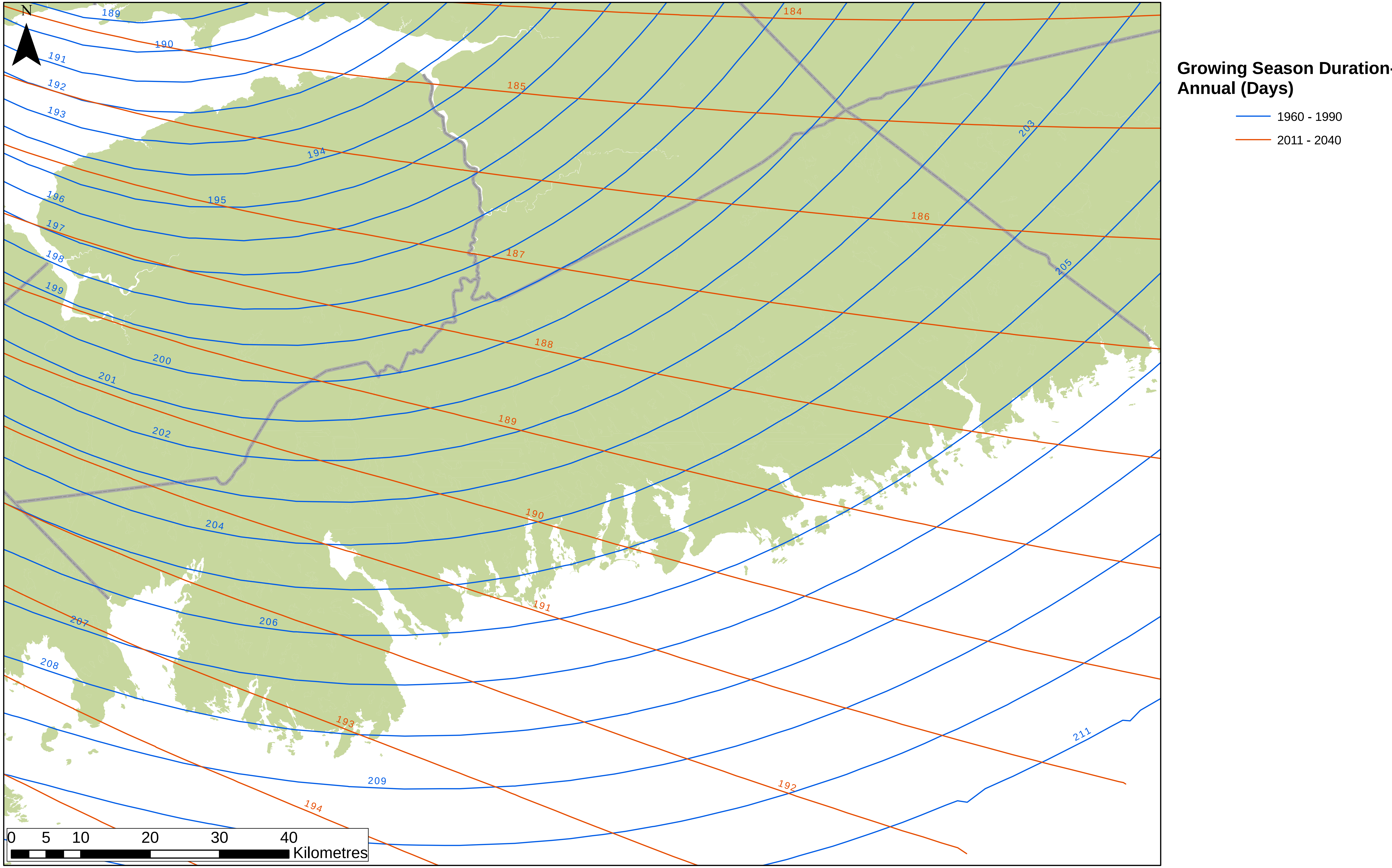
Greatest 5-Day Total Rainfall - Winter

Winter 1960 - 1990

Winter 2011 - 2040


N
Greatest 5-Day Total Rainfall - Winter
Winter 1960 - 1990
Winter 2041 - 2070
0 5 10 20 30 40
Kilometres


N
Greatest 5-Day Total Rainfall - Winter
Winter 1960 - 1990
Winter 2071 - 2100
0 5 10 20 30 40
Kilometres



Growing Season Duration-Annual (Days)
1960 - 1990
2011 - 2040
N
0 5 10 20 30 40
Kilometres
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
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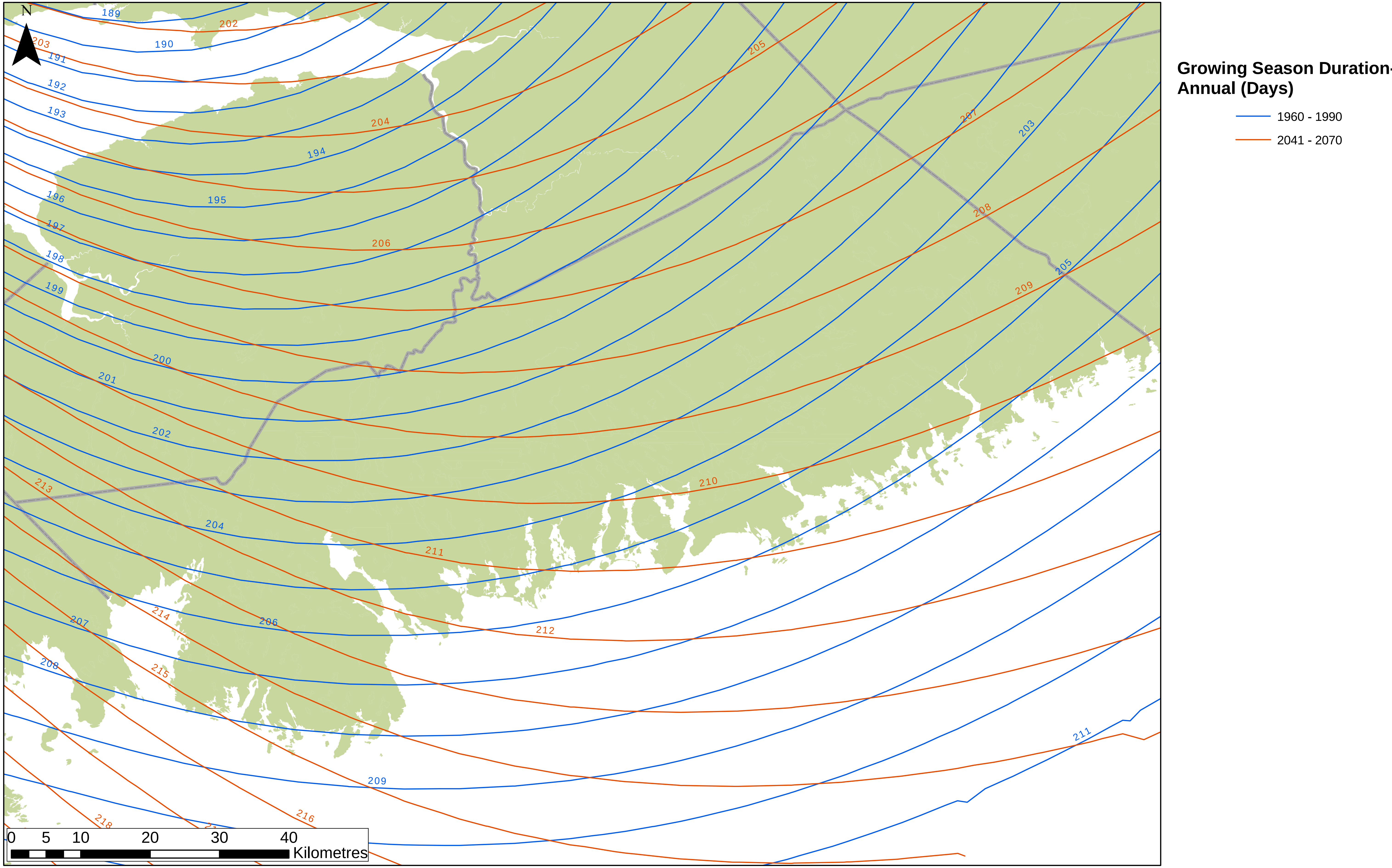
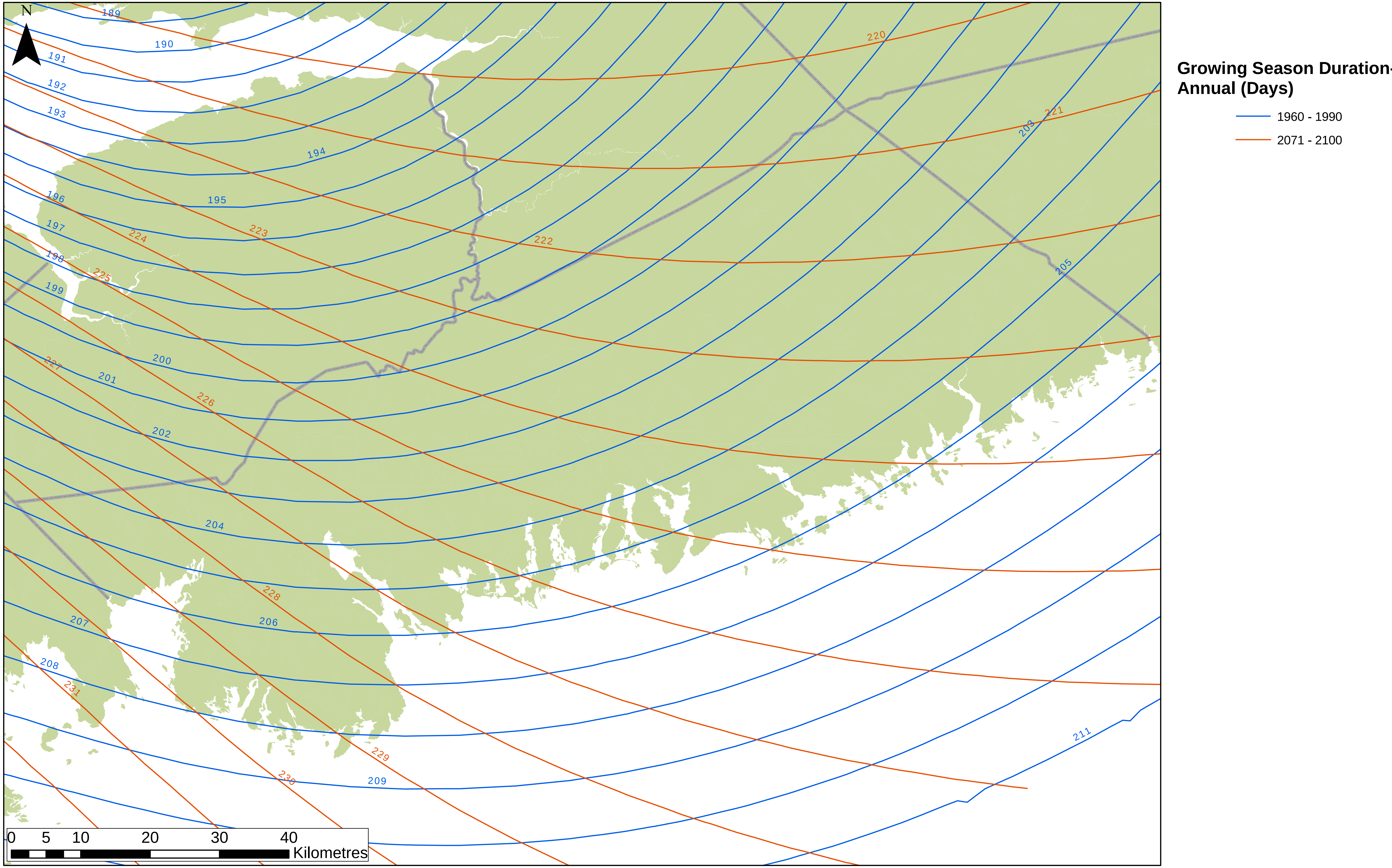
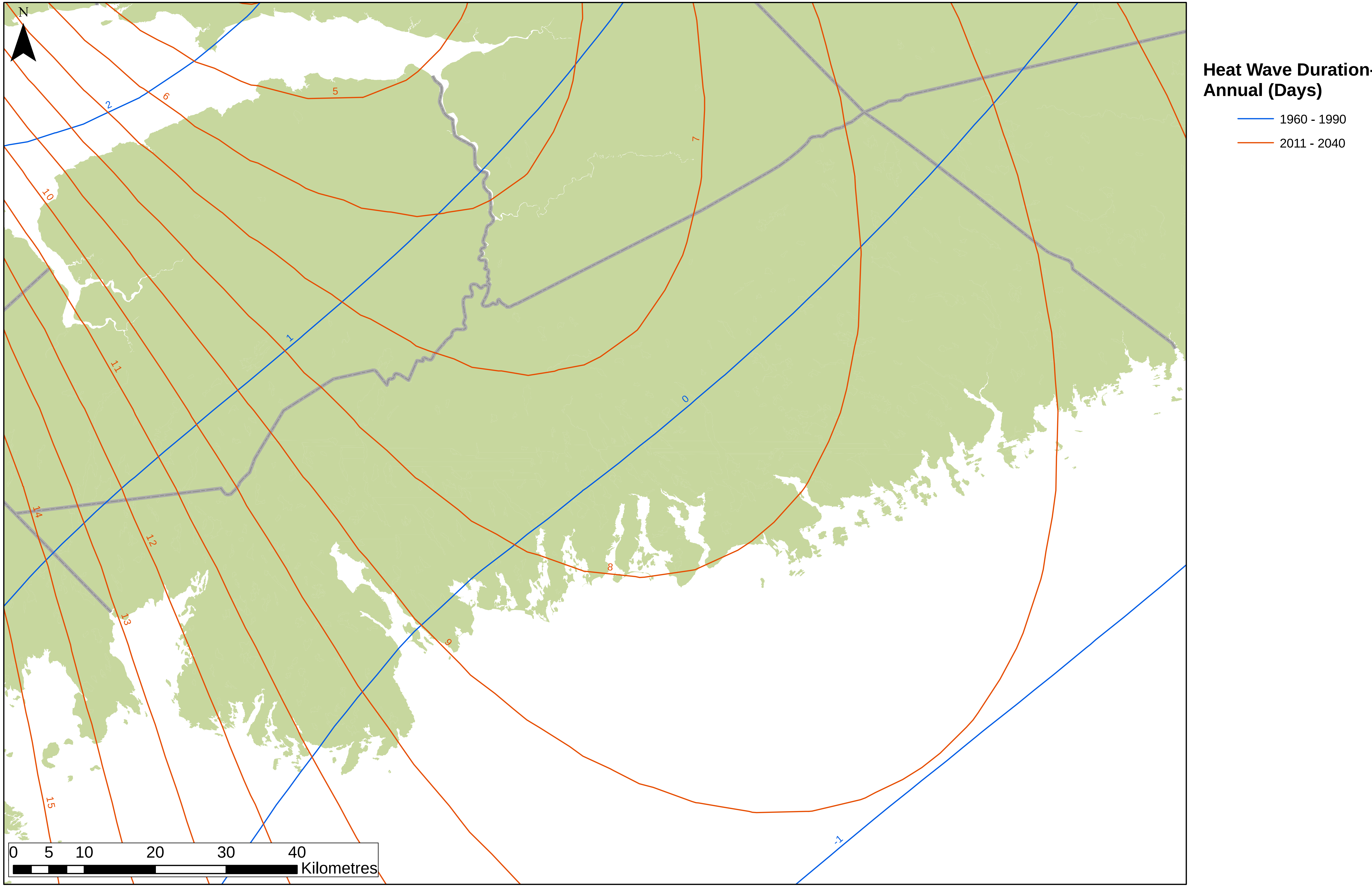
206
207
208
209
211

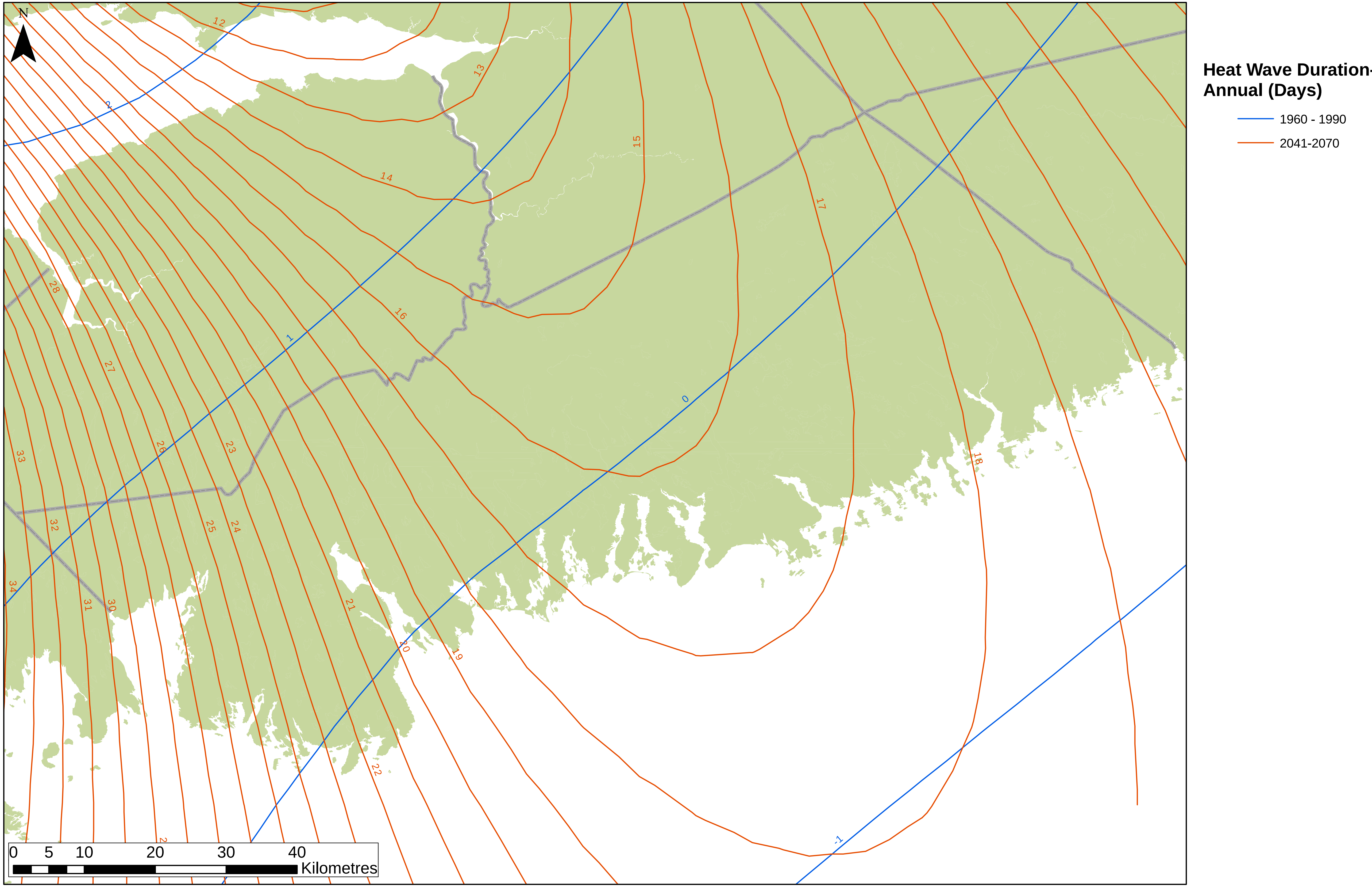

Growing Season Duration-Annual (Days)
1960 - 1990
2041 - 2070
N
0 5 10 20 30 40
Kilometres



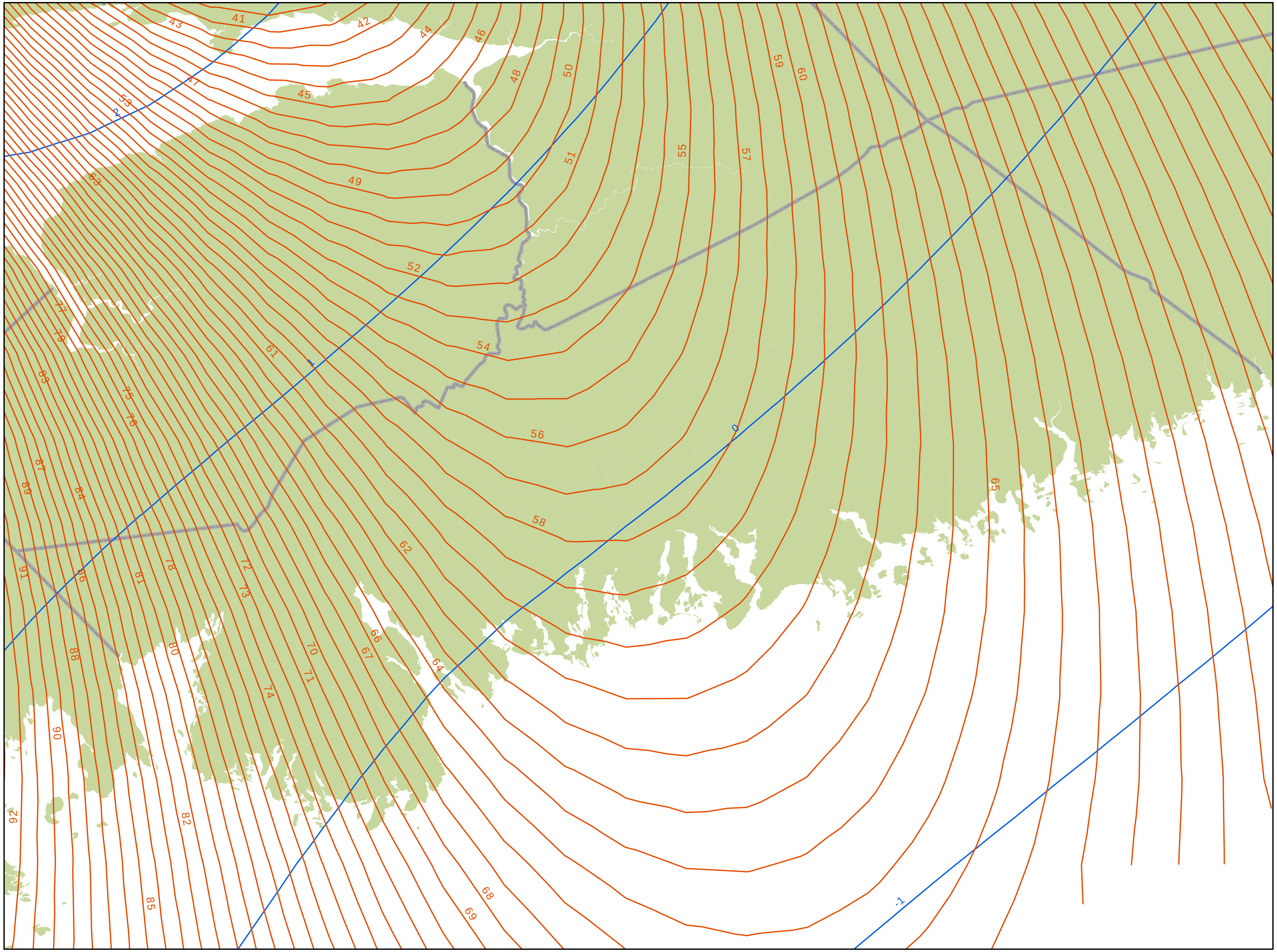
N
Growing Season Duration-
Annual (Days)
1960 - 1990
2071 - 2100
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
211
220
221
222
223
224
225
226
227
228
229
230
231
0 5 10 20 30 40
Kilometres



N
Heat Wave Duration-Annual (Days)
1960 - 1990
2011 - 2040
0 5 10 20 30 40
Kilometres



N
Heat Wave Duration-Annual (Days)
1960 - 1990
2041-2070
0 5 10 20 30 40
Kilometres
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
30
31
32
33
34
2
1
0
-1

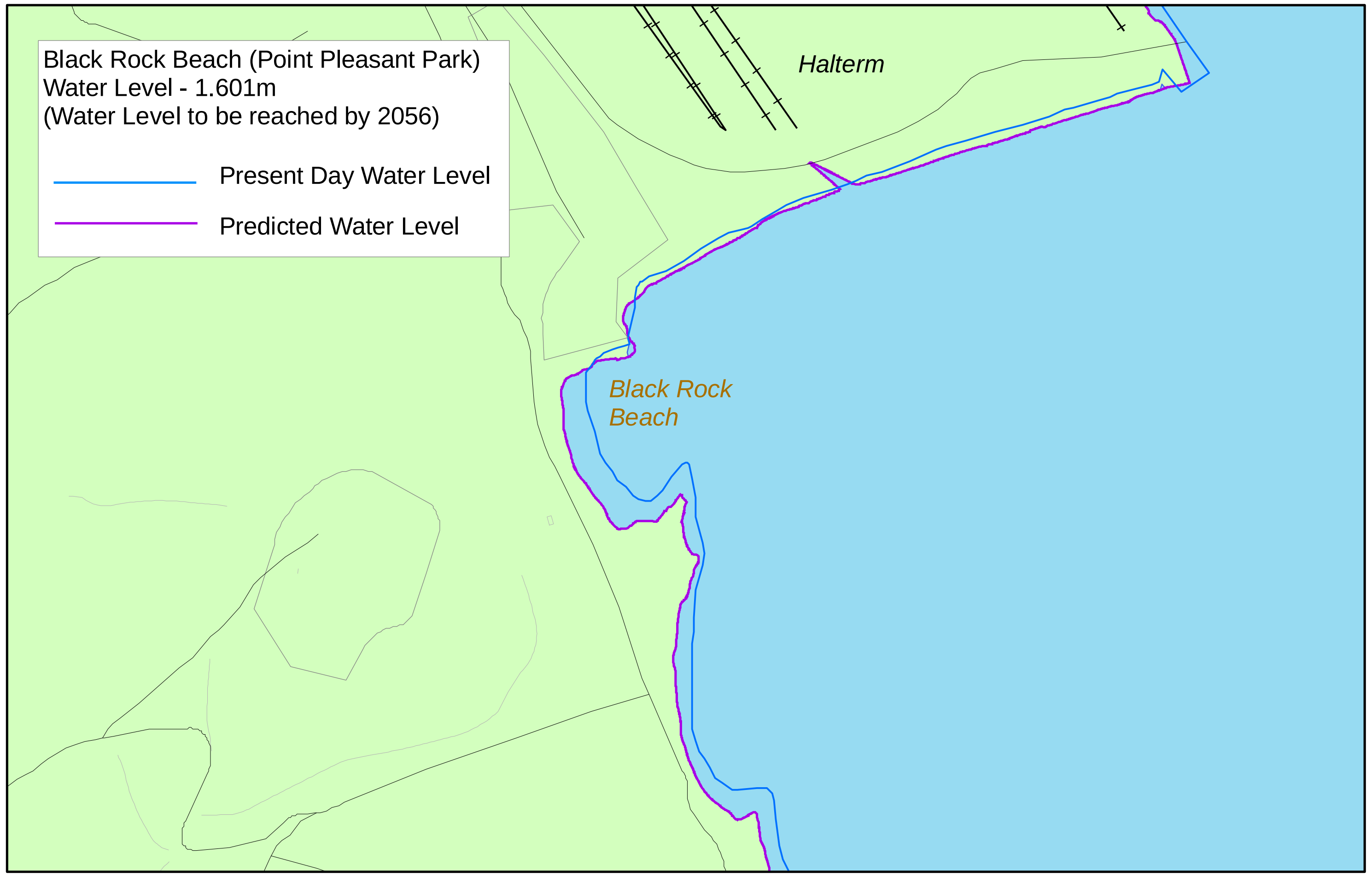


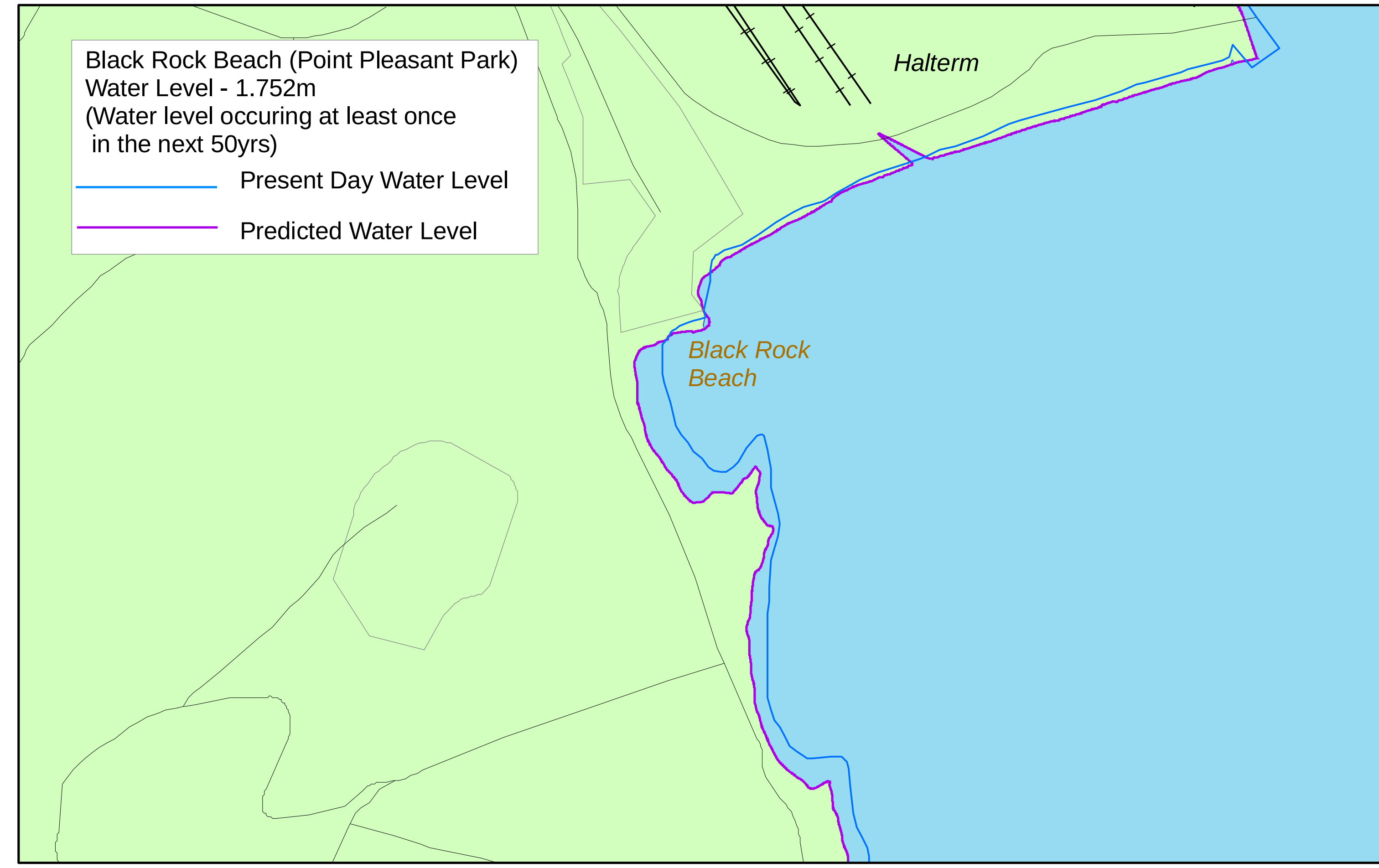
Heat Wave Duration-Annual (Days)

1960 - 1990

2071 - 2100

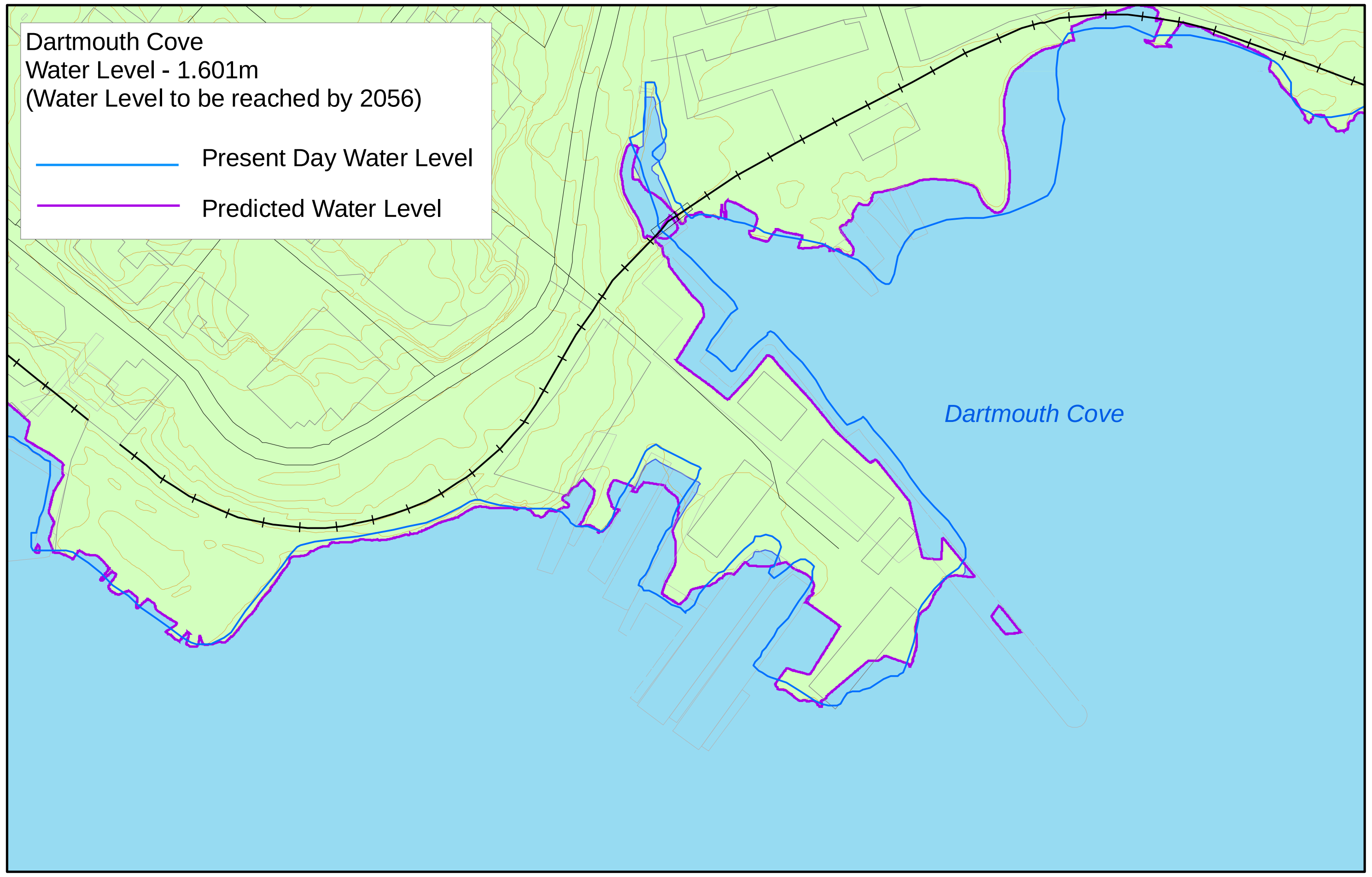
Appendix C
Water Modeller Results for Halifax Harbour

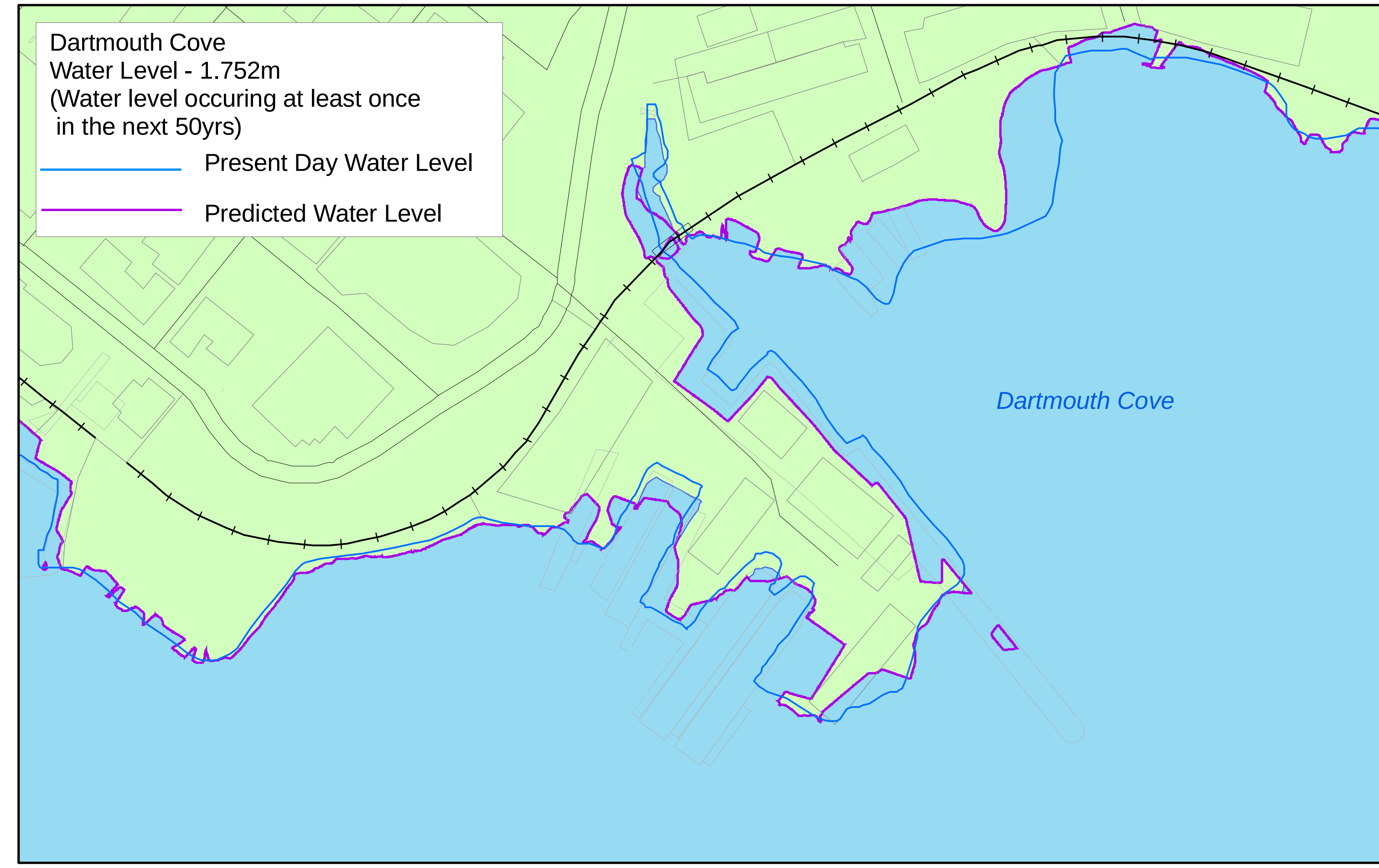

Black Rock Beach (Point Pleasant Park)
Water Level - 1.601m
(Water Level to be reached by 2056)
Present Day Water Level
Predicted Water Level
Halterm
Black Rock Beach

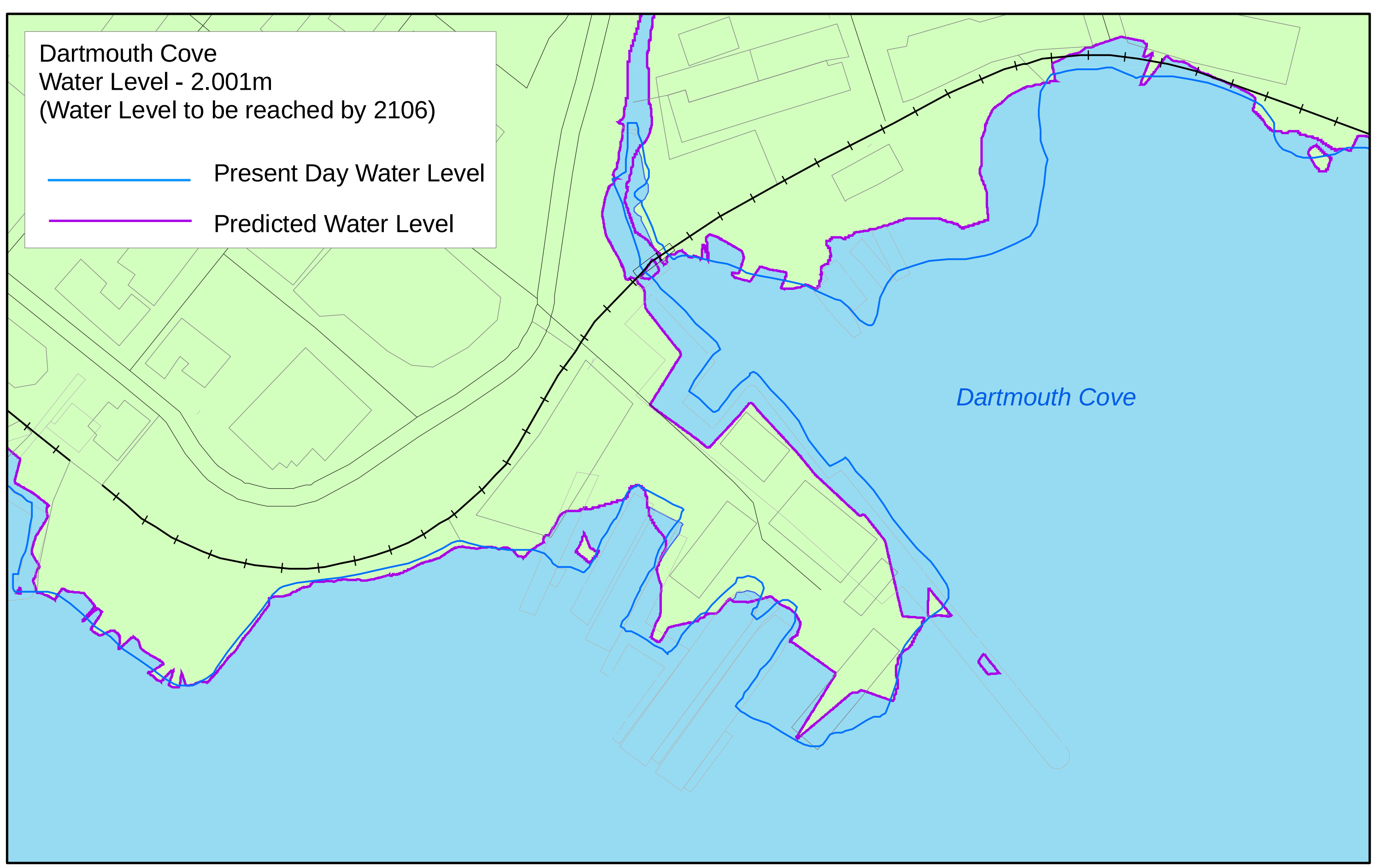

Black Rock Beach (Point Pleasant Park)
Water Level - 1.752m
(Water level occuring at least once in the next 50yrs)
Present Day Water Level
Predicted Water Level
Halterm
Black Rock Beach

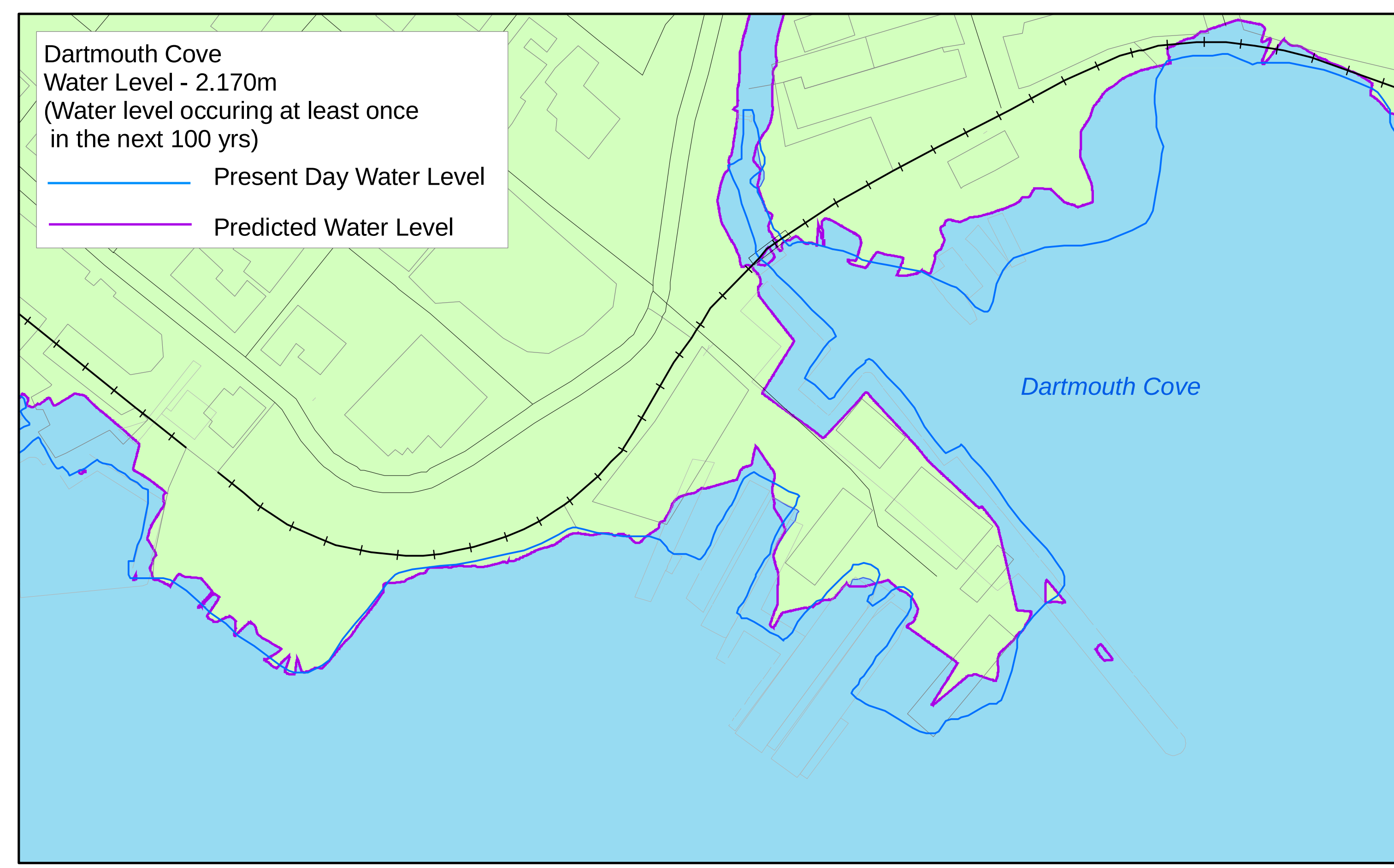

Black Rock Beach (Point Pleasant Park)
Water Level - 2.001m
(Water Level to be reached by 2106)
Present Day Water Level
Predicted Water Level
Halterm
Black Rock Beach

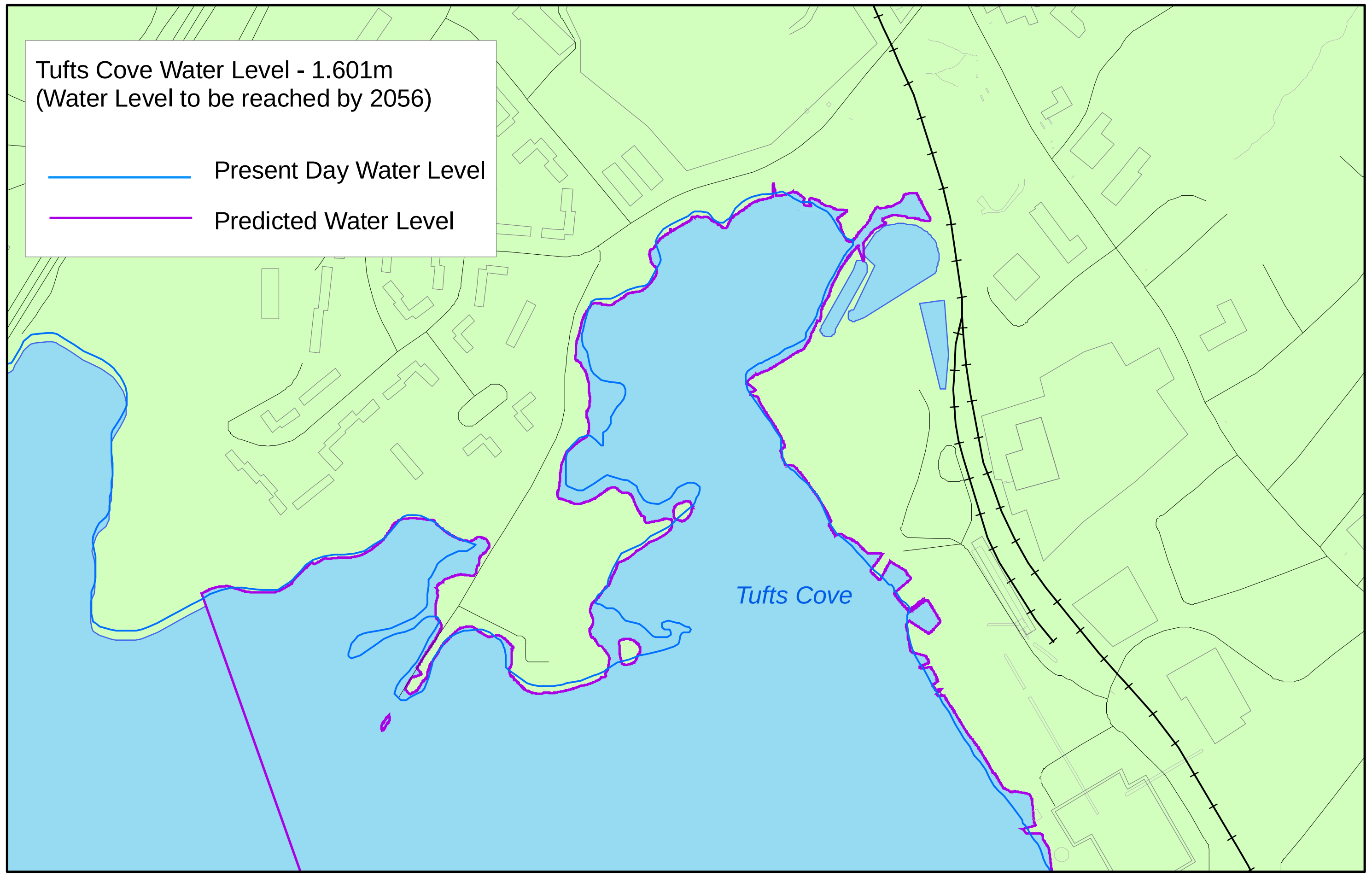

Black Rock Beach (Point Pleasant Park)
Water Level - 2.170m
(Water level occuring at least once in the next 100 yrs)
Present Day Water Level
Predicted Water Level
Halterm
Black Rock Beach

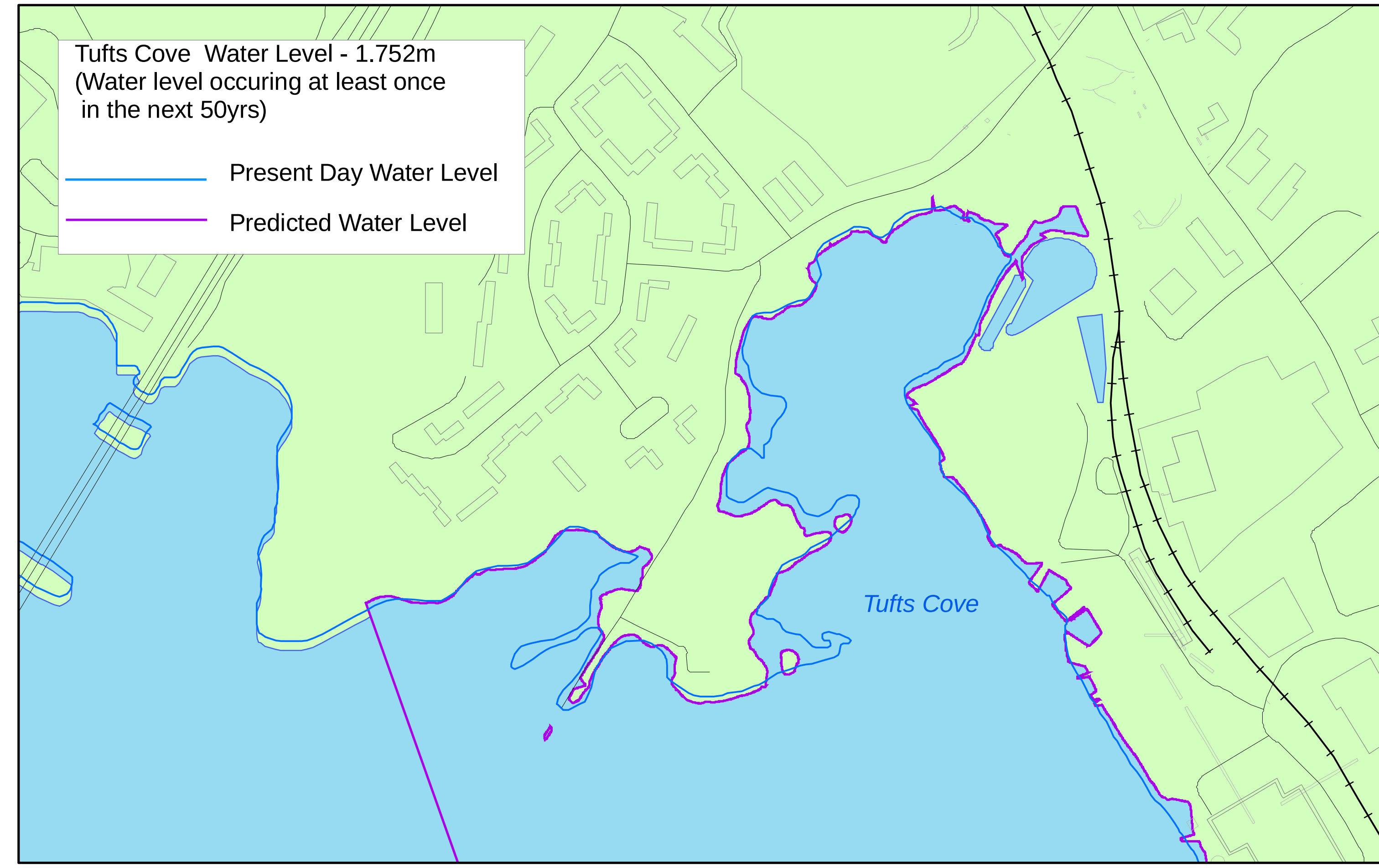

Dartmouth Cove
Water Level - 1.601m
(Water Level to be reached by 2056)
Present Day Water Level
Predicted Water Level
Dartmouth Cove

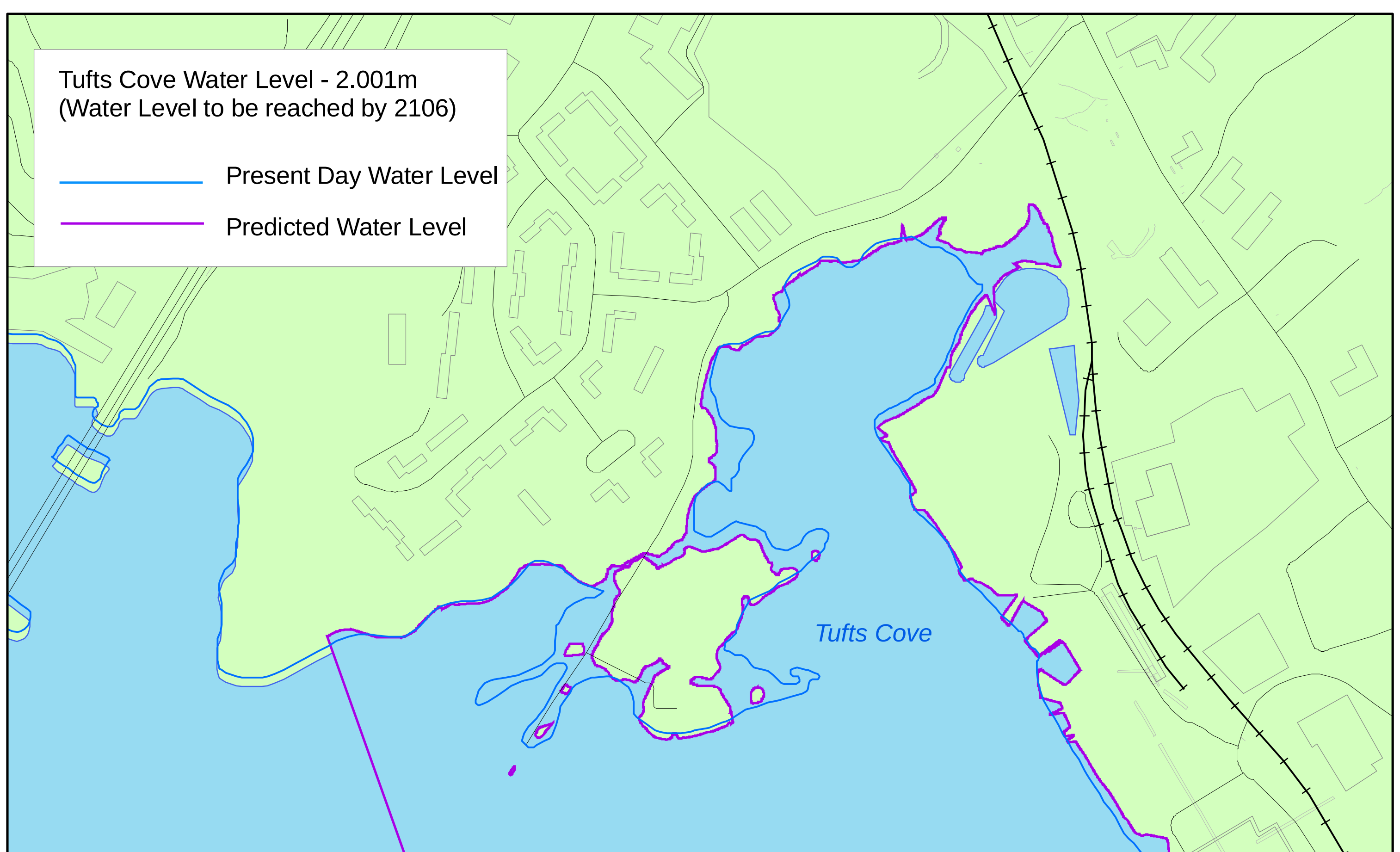

Dartmouth Cove
Water Level - 1.752m
(Water level occuring at least once
in the next 50yrs)
Present Day Water Level
Predicted Water Level
Dartmouth Cove

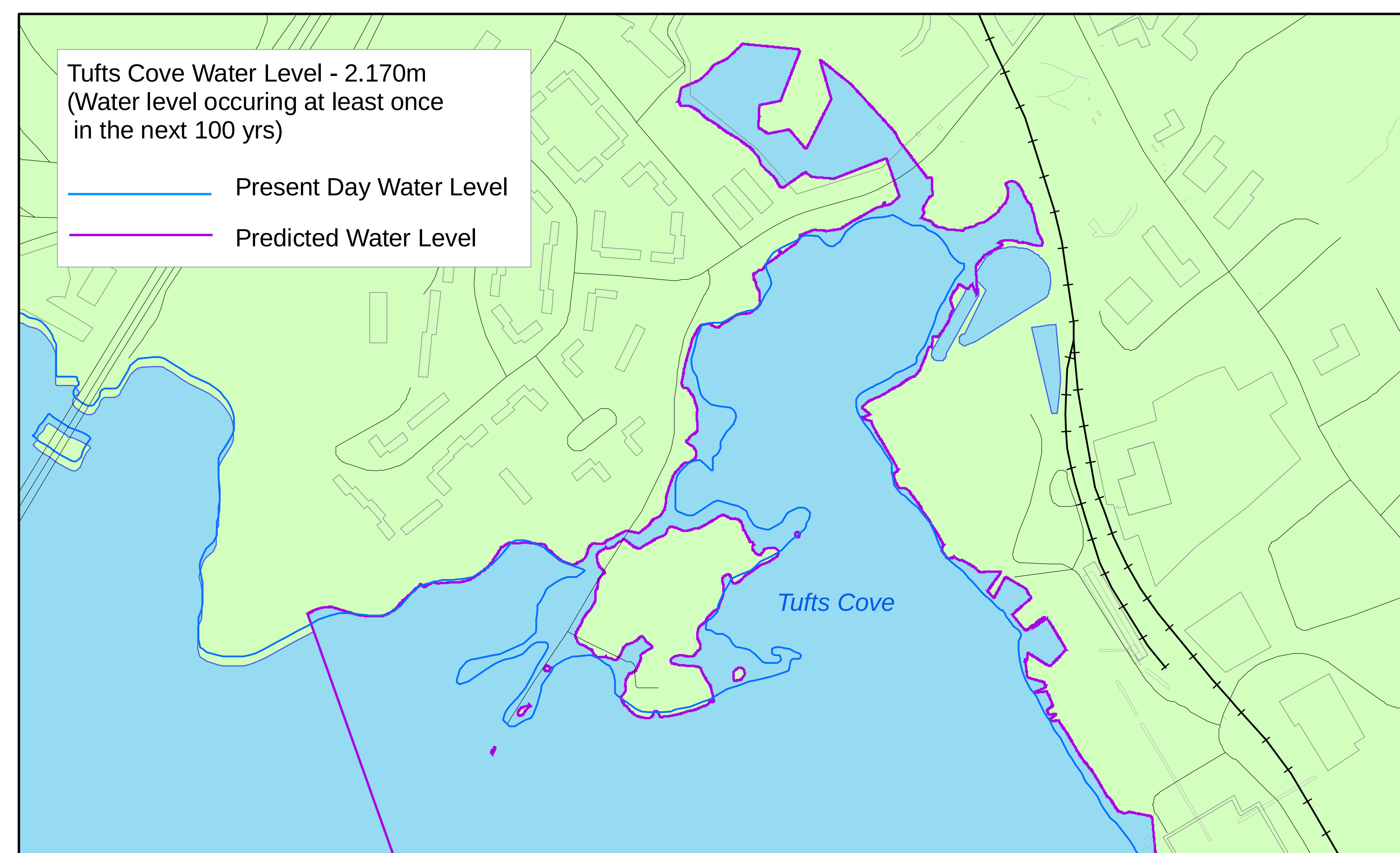

Dartmouth Cove
Water Level - 2.001m
(Water Level to be reached by 2106)
Present Day Water Level
Predicted Water Level
Dartmouth Cove


Dartmouth Cove
Water Level - 2.170m
(Water level occuring at least once
in the next 100 yrs)
Present Day Water Level
Predicted Water Level
Dartmouth Cove


Tufts Cove Water Level - 1.601m
(Water Level to be reached by 2056)
Present Day Water Level
Predicted Water Level
Tufts Cove


Tufts Cove Water Level - 1.752m
(Water level occuring at least once
in the next 50yrs)
Present Day Water Level
Predicted Water Level
Tufts Cove


Tufts Cove Water Level - 2.001m
(Water Level to be reached by 2106)
Present Day Water Level
Predicted Water Level
Tufts Cove


Tufts Cove Water Level - 2.170m
(Water level occuring at least once
in the next 100 yrs)
Present Day Water Level
Predicted Water Level
Tufts Cove

Appendix D
Climate Change Risk Assessment Protocol for HRM Business Units

Climate SMART
Risk Management Approach to Incorporating Climate Change
Into Decision Making

Test Case – Community Development Department

Summary

Introduction

A key project outcome of the Climate SMART (Sustainable Mitigation and Risk Tool Kit) project is the development of a risk management tool or process that HRM and other municipalities can use to more fully incorporate climate change in the decision making. The process proposed was developed based on *CSA Q850-97 – Risk Management: Guidelines for Decision-Makers* and CARICOM's *Caribbean Risk Management Guidelines for Climate Change Adaptation Decision Making.*

This session was designed to be an interactive walk through of the suggested method to incorporate climate change risk assessment as part of business unit planning activities and that the input received would be incorporated into the final guidance to be included in HRM's *Climate Change Risk Management Strategy*.

The risk management approach proposed consists of seven steps:

1. Document responsibilities of the business unit.
2. Identify the assets under the control of the business unit.
3. Identify potential impacts from climate change on those assets.
4. Quantify and qualify the risks.
5. Prioritize the risks.
6. Identify options to manage the risks.
7. Identify necessary resources, the barriers and the timeframes.

Results

Step 1 - Outline Responsibilities of Community Development

This step outlines the general responsibilities of a department.

- Regional and Community Planning
- Planning Applications
- Subdivisions and Development Approvals
- Permits and Inspections
- Economic development
- Culture, recreation

Step 2 - Identify 'assets' under Community Development.

This step identifies assets or issues the business unit controls. These assets will be evaluated in relation to climate change in the following steps.

In the case of Community Development the following assets were identified:

- Generation of policies, by-laws, regulations
- Policies re: use of land, infrastructure
- Mitigation of uses
- Efficiencies of infrastructure and land use
- Corrective measures – short term.

Because the business unit does not manage any physical assets, the above were used as assets but it is recognized that these are areas that the business unit has control over as opposed to assets. Regardless, the process can be used with either group of factors to identify where a business unit is at risk.

Step 3 – Identification of the potential impacts from climate change on the assets.

In this step, the business unit group assembles the available information on climate change impacts, specifically information generated through the Climate SMART project. For this session, the list of potential climate change impacts developed as part of the Climate SMART were distributed prior to the meeting. This was supplemented by a presentation by Gary Lines of Environment Canada who provided an update on climate change projections and issues. In future this information will be posted on the HRM website and will be accessible to all business units.

The identified climate change impacts are used as a basis for discussing the potential impacts relevant to the business unit and for developing a list of potential risks.

After reviewing the Summary of Risks presented in the Agenda, the group discussed potential risks that would be come under their area of responsibility, these included:

- Potential impacts on ground thermal district heating. What are the impacts on groundwater if rainfall decreases and temperatures increase? Will using ground thermal heating compound the problem?

- Flood inundation as a result of extreme precipitation events. Will need to change development policies for flood prone areas.

- Development in the urban/rural fringe. Higher temperatures and less precipitation could lead to increased risk of forest fires.

- Evacuation of residents in the event of extreme climate events. HRM is currently at risk given the nature of the transportation network, especially getting off the peninsula.

- Proximity of transportation infrastructure to coastline.

- Risk of damage/loss of infrastructure as a result of storms/coastal flooding or inundation.

- Public and private watercourse dams in HRM – where are they? What are the risks?

- Gaining public buy-in to climate adaptation and how to get past the unwillingness of the public to discuss loss of ownership and control.

- Allocation of resources for sea-level rise planning?

- Vector borne diseases.

- Power grid overload as a result of increased temperatures – Air conditioning demands.

- Can National Building Code be modified for new construction to include a requirement to take into account designs for passive cooling of homes.

Step 4 – Quantify and qualify the risks.

In quantifying and qualifying the risks, the business unit estimates both the severity of the impacts and frequency of the event occurring.

*The **severity** of the impact looks at identifying how significant a climate change risk is in terms of health, property damage, environmental and financial aspects. The severity is qualitatively estimated based on prior events and professional judgement. The severity is ranked as presented as Low, Medium, or High, where:*

Low = Minor instances of impact that would be short term and reversible.

Medium = Noticeable social and environmental impact that will require additional resources to adequately respond to. Opportunities for reversing impacts are limited.

High = Significant social, economic and environmental impact leading to reduced quality of life. Impacts not reversible.

*The **frequency**[33] relates to the relative frequency with which the risk can be expected to occur. For example, with climate change it is expected that storm surge flooding will occur more frequently. The frequency can also be presented as Low, Medium or High occurrence.*

Low = the frequency of the impact occurring is improbable to unlikely.

[33] As an outcome of the session, the use of frequency was reassessed and the following definition and modified table reflect input received and the use of frequency described in the *Caribbean Risk Management Guidelines for Climate Change Adaptation Decision Making*.

Medium = current knowledge indicates that the impact is likely to occur.

High = the impact is highly likely or virtually certain to occur.

Based on the time remaining, the group decided to focus on two risk issues that were at top of mind: forest fires and flooding. The impact of forest fires on rural communities as a result of drier conditions was seen as a developing issue given the increased land development at the urban/rural fringe. Flooding was also examined as it is an issue HRM has had to address in the past.

Climate Change Impact Ranking Matrix (for Step 4)

Forest Fire Impact

Projected Severity

Impact / Severity	Social Factors			Economic Factors				Environmental Factors			
	Health	Loss of Livelihood	Displacement	Property Loss	Financial Loss	GDP Impact	Cultural Aspects	Air	Land	Water	Ecosystems
Low						X		X			
Medium		X					X			X	X
High	X		X	X	X		X		X	X	
N/A											

Projected Frequency – Likely to occur several times during the planning period.

Combined Risk

Impact / Risk	Social Factors			Economic Factors				Environmental Factors			
	Health	Loss of Livelihood	Displacement	Property Loss	Financial Loss	GDP Impact	Cultural Aspects	Air	Land	Water	Ecosystems
Low		X				X					
Medium	X	X					X	X		X	X
High			X	X	X				X		X
N/A											

Flooding

Projected Severity

Impact / Severity	Social Factors			Economic Factors				Environmental Factors			
	Health	Loss of Livelihood	Displacement	Property Loss	Financial Loss	GDP Impact	Cultural Aspects	Air	Land	Water	Ecosystems
Low							X	X			X
Medium	X					X			X	X	X
High		X	X	X	X	X			X		
N/A											

Projected Frequency – Likely to occur at least once in the planning period.

Combined Risk

Impact / Risk	Social Factors			Economic Factors				Environmental Factors			
	Health	Loss of Livelihood	Displacement	Property Loss	Financial Loss	GDP Impact	Cultural Aspects	Air	Land	Water	Ecosystems
Low	X						X	X			
Medium	X	X	X	X	X	X				X	X
High									X		
N/A											

Step 5 – Prioritize the risks.

This step involves summarizing the outputs of Steps 3 and 4 in order to rank impacts in terms of overall risk to provide the business unit with guidance on prioritizing actions to adapt to climate change. In this step, the frequency and consequence rankings are combined to produce and overall risk ranked as Low, Medium or High, where:

Low = Risks that require no or minimal actions. Minimal actions could include public education/awareness.

Medium = Some actions controls will be required to reduce risks to low or negligible levels.

High = These risk areas will require high-priority actions to reduce risks to low or negligible levels.

This example only lists two impacts or risks due to time limitations but the business unit would list several risks related to climate change when the assessment is completed in full.

Using the information from tables in Step 4, the risks were prioritized for each of the selected risks.

Risk Evaluation Tabulation (for Step 5)

Impact	Probability (Frequency of event)	Consequence (Impact severity)	Overall Risk
Forest Fire	Likely occur several times	High	Medium - High
Flooding	Likely to occur at least once	High	Medium
Groundwater			
Efficient evacuation			
Coastal transportation infrastructure			
Public and private dams			
Public reaction			
Sea level rise			
Vector borne disease			
Power grid overloading			
Updated building code			

Step 6 - Identify options to manage the risks.

The business unit reviews and identifies options to manage the potential impacts identified in the preceding steps.

Step 7 - Identification of resources, barriers and timeframes.

In this step the business unit takes the adaptation options identified in Step 6 and determines resources (financial and technical) needed to implement the measures; the timeframe in which they should occur; and the possible barriers to be overcome to implement the measures.

For this test case, the group essentially combined Steps 6 and 7 and worked through a number of options for mitigating the risk as well as the potential resources required and the possible barriers. The group argued that prioritization of options was a preferred starting point as the assessment of timeframes involved a number of factors and could not be as easily assigned during the timeframe allotted for the test case.

The following tables show the output of Steps 6 and 7 for risks associated with forest fire and flooding.

Adaptation Options Evaluation (Steps 6 and 7)

Adaptation Option	Priority	Resources	Barriers
Manage or curtail open burning	High	By-law enforcement staff	Public opposition
Include fire hazard assessment in development application	High	Legislation, qualified person(s)	Added consumer cost, higher level of government.
Enable municipality to require fire resistant building materials	High	Legislation	Added consumer cost
New subdivisions need requirements for development of second access to major road (direct)	High	Staff time to revisit buffer (100 lots)	Added consumer cost
Include installation of dry hydrants in rural subdivisions	High	Subdivision regulations	Added consumer cost
Forest management	Medium	GIS mapping, fuel source inventory/removal	Financial, jurisdiction
Increased fire response	Low	Personnel, equipment	Financial
Improved evacuation options for subdivision old subdivision with single road– access roads	Low	Design/construction	Financial

Adaptation Option	Priority	Resources	Barriers
Restrict/relocate development in floodplains	High	Flood risk mapping and regulations; insurance restrictions encourage	Property owner opposition; financial
Maintain/modify existing flood control devices	High	Staff, financial	Financial, jurisdictional responsibility, liability
Floodplain restoration/parkland use	High	Land acquisition	Financial; compensation
Infrastructure upsizing	High	Engineering studies	Financial
Emergency preparedness e.g. sandbags/shelters Warning systems Evacuation measures	High	Information, communication	Staff, knowledge of event
Flood insurance	High	Flood risk mapping	Finding provider of flood insurance.
New flood control measures	Low		
Flood proofing structures	Low	Flood risk mapping	Uncertainty re. flood risk; consumer cost

Appendix E
Climate Change Decision Tools

Appendix E
Climate Change Decision Tools

Climate SMART

Available Data Sets for Incorporating Climate Change in HRM Decision Making

(Climate Change Section, Environment Canada Atlantic, 2006)

<u>Introduction</u>

In order to determine which data sets and tools HRM may require to properly assess their vulnerability and determine adaptation measures to the impacts of climate change, the first step is to identify the expected impacts of climate change in HRM. The expected climate change impacts are described in Section 3 of the Risk Management Strategy report. This process included identifying the impacts of climate change on HRM, developed from Environment Canada's understanding of the current and projected climate for HRM and surrounding regions, and the sensitivities to those impacts inherent in the systems on which the efficient running of HRM is dependent, such as transportation systems, water systems and the built environment.

Most municipalities have a range of vulnerabilities depending on their size, geographical location and economic dependencies. For example, HRM is a coastal port with substantial built up coastal areas and is dependent on trade, tourism and small industry for its livelihood.

Climate change related impacts on HRM can include coastal inundation from intense winter and tropical storms, extended heat waves and dry spells. As described in Risk Management Strategy, its vulnerability is directly related to its geographical location, on the Atlantic coast of Nova Scotia. Damage to infrastructure due to heavy precipitation (rain and/or snow) and high winds from more frequent and more intense storms as well as the disruption of transportation by these extreme weather events will become increasing expensive to remediate and hence should become the focus of adaptive, proactive planning by HRM.

<u>Tool Identification</u>

Once specific vulnerabilities were identified, the appropriate data sets, tools or set of tools were selected to help decision makers mitigate current and future effects of climate change impacts. HRM can utilize a variety of tools, thereby taking action now to address current climate related vulnerabilities or planning for future impacts. The tools necessary to take action on current vulnerabilities, such as infrastructure susceptible to hurricane damage are similar, if not identical, to those required to plan for and potentially mitigate the impacts of climate change related events.

The following summary provides specific types of information available to address climate change risk.

Summary of Tools	
Data Sets	• Temperature and Precipitation information for HRM. • Climate Indices information – Growing Degree Days, Rainfall Amounts, etc.
Display Tools	• GIS Mapping Interface • Coastal Inundation Mapping – Halifax Harbour
Hazard Maps	• Atmospheric Hazards Website
Extreme Event Information	• Heavy Precipitation Events • Up-to-date IDF charts

Data Sets

- **Temperature and Precipitation information for a municipality**

Values for temperature and precipitation change were generated through a statistical downscaling technique (Lines et al. 2005)[34] and the results for Shearwater NS (as a proxy for downtown Halifax) are illustrated. These values are based on global climate model results derived from the Canadian Global Coupled Model (CGCM1). When utilizing such climate projections it is advisable that the range of values for a specific site from more than one model be employed to gain a sense of possible future outcomes.

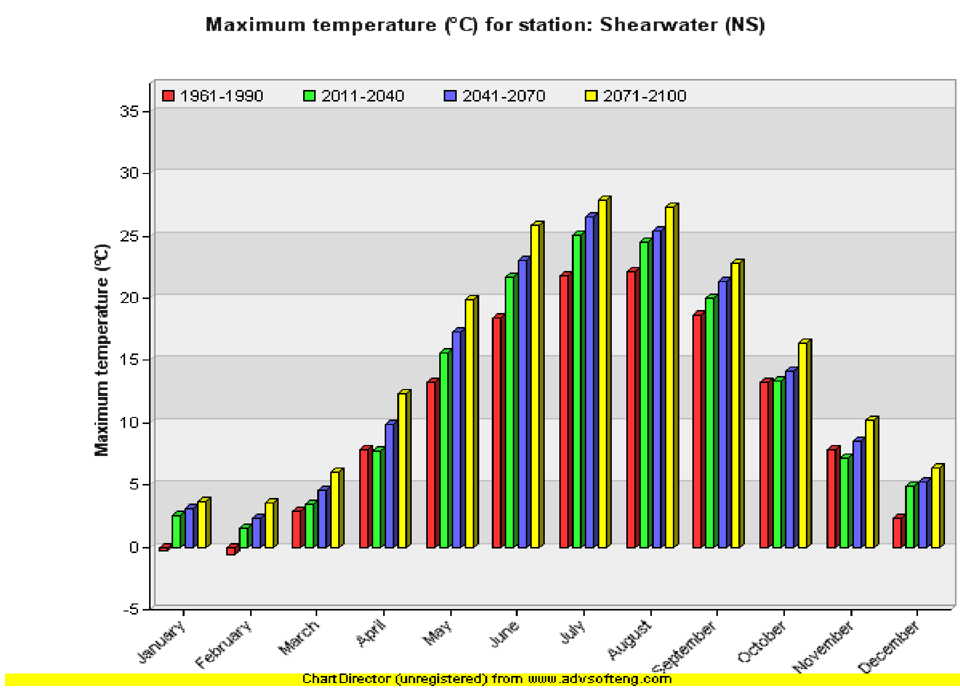


Figure 1. Temperature Projections for Shearwater

[34] **Lines**, G.S., Pancura, M., Lander, C., 2005. *Building Climate Change Scenarios of Temperature and Precipitation in Atlantic Canada Using the Statistical Downscaling Model (SDSM).* Environment Canada, Meteorological Service of Canada, Atlantic Region. Science Report Series No. 2005-9, October 2005.

The simplest and most straight-forward data set describes the plausible future values for temperature and precipitation change for a specific municipality. For this project, the climatological data for Shearwater, NS was used as a proxy (physically close to downtown Halifax). The examples provided here give results for Shearwater, NS. Figure 1 describes the projected maximum temperature values by month for three tri-decadal periods in the future (2020's, 2050's and 2080's) as compared to a historical period (1961-90). Figure 2 describes the expected change in precipitation amount by month for Shearwater.

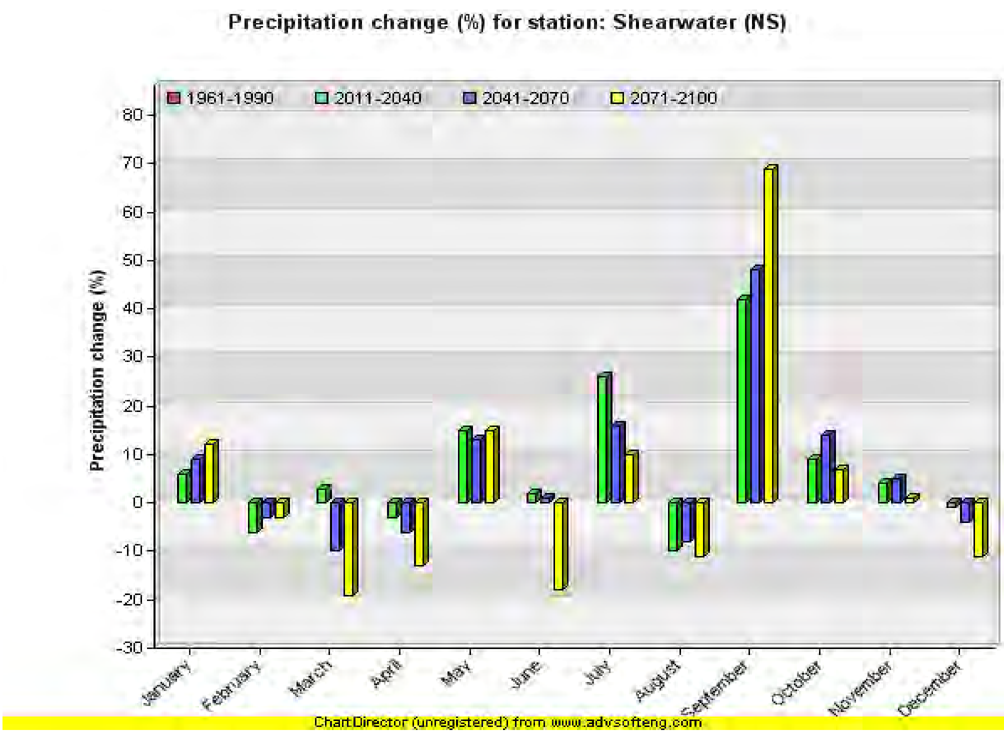


Figure 2. Precipitation Change for Shearwater

Application

Application of this information to determine vulnerabilities to impacts can range from identifying a temperature threshold or precipitation sensitivity (for example, the tourism sector may be concerned about maximum temperature values exceeding 25 degrees Celsius on an average basis) to using the projected values to calculate other indicators or indices. For precipitation it may be important to identify which season we expect the most change to precipitation amounts. Water management or transportation concerns can utilize such information. For example, at Shearwater (Figure 2) while there is an increase in annual precipitation there is a distinct reduction in the amount of precipitation projected for the late fall and early winter as well as most of the spring. This may lead to river and stream flow reductions in late spring and require consideration of water conservation during those times.

As well, a combination of temperature and precipitation values may result in an indication of precipitation type. Warming temperatures through the winter season may result in more occurrences of freezing precipitation rather than snow, however, this work has not been fully evaluated in Atlantic Canada as yet. It may also impact snow cover amounts over the long term.

- **Climate Indices information – Growing Degree Days, Rainfall Amounts, etc.**

Once data sets of future projections have been completed, this information can be further transformed into sets of climate indices, i.e. values that describe specific characteristics of climate that are of much more use to a specific client. Figure 3 describes Growing Season Length based on Shearwater NS projected temperature information. Figure 4 provides projected values of 3-day rainfall.

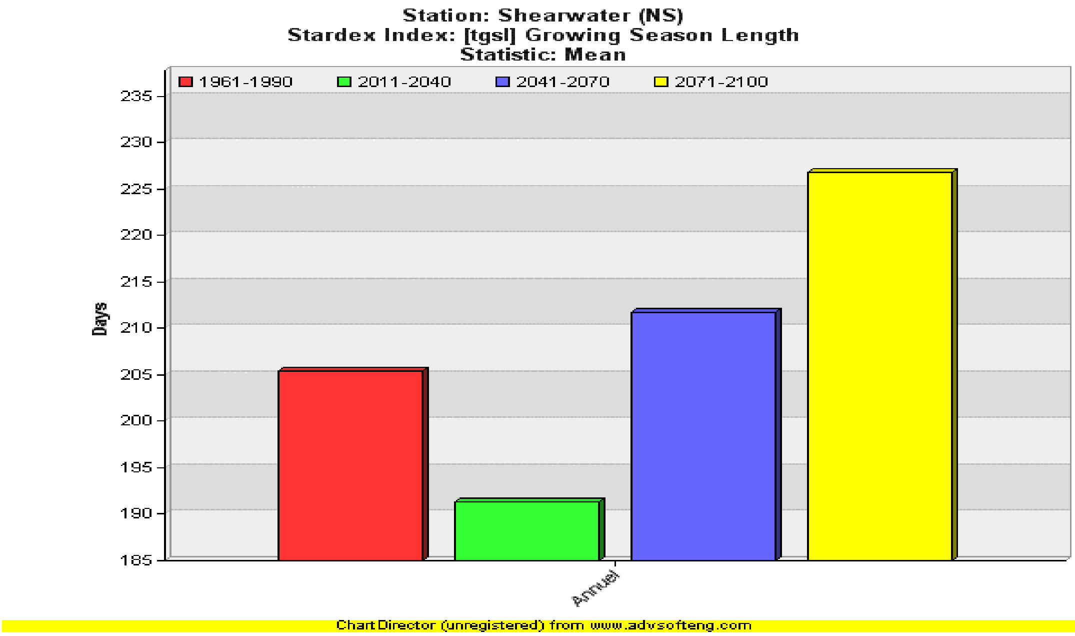


Figure 3. Growing Season Length Projections

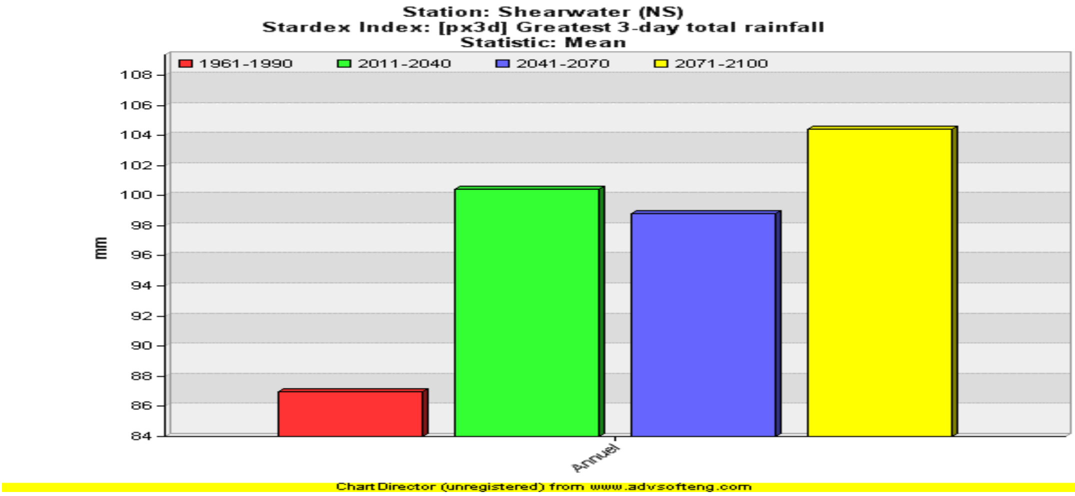


Figure 4. 3-day Rainfall Projections

Application

A number of climate indices may be useful to HRM planners. Those currently available for Shearwater are itemized in Table 1.

Table 1 Listing of Available Climate Indices for Shearwater

Climate Indices	
Temperature Related	**Precipitation Related**
Mean diurnal temperature range	Number of days with precipitation >= 10 mm
Number of frost days (Tminimum <0°C)	Max number consecutive dry days
Number of days without defrost (ice days)	Max number consecutive wet days
Tmaximum <0°C	Mean wet-day persistence
Growing degree days > threshold	Mean dry-day persistence
Intra-annual extreme temperature range	Correlation for spell lengths
Growing Season Length	Greatest 3-day total rainfall
Heat Wave Duration	Greatest 5-day total rainfall
Cold Wave Duration	Greatest 10-day total rainfall
Frost Season Length (0°C)	Simple Daily Intensity (rain per rain day)

Both agricultural concerns as well as potential habitat impact can be addressed utilizing specific indices such as the Growing Season Length.

Display Tools

- **GIS Mapping Interface**

The Climate Change Section (CCS) of the Meteorological Service of Canada Atlantic Operations and the GIS Mapping Lab of the Science and Technology Branch (STB) Atlantic partnered to develop a Climate Change GIS Mapping Interface useful for extracting climate change information in the Atlantic Region in general and more specifically for HRM.

The concept for this tool was to provide a user with the capability to access climate change information in a number of ways based on their requirements. At one level is the ability to query the database by site, time slice, parameter, and period, and graphically or in a table, display the results. Figures 1 and 2 are examples of bar graph output for Shearwater from that database.

The second level is the ability of the client to contour the chosen parameter across the entire region (see Figures 5 and 6). For example, the client may decide to contour projections of maximum temperature for January for the tri-decade of the 2050s. Such a contouring would then be displayed over a base geographical map of HRM and become a “layer”, not unlike maps of lakes, roads, rivers, etc. already available in other regional databases. Such contoured maps can be used as “layers” in the GIS mapping sense and overlaid with other fields provided by the user such as landscape (tree species) mapping, turning the contoured map into an effective research tool.

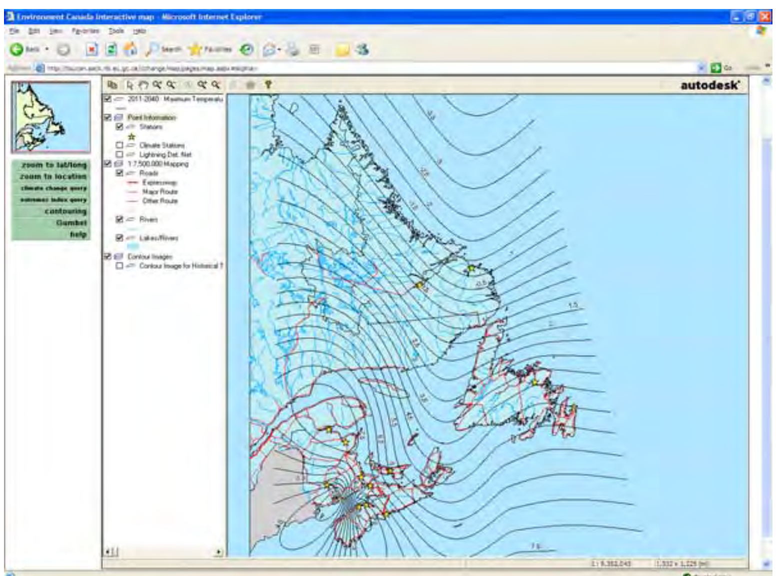


Figure 5. Screen Capture of Contoured Map over Atlantic Region.

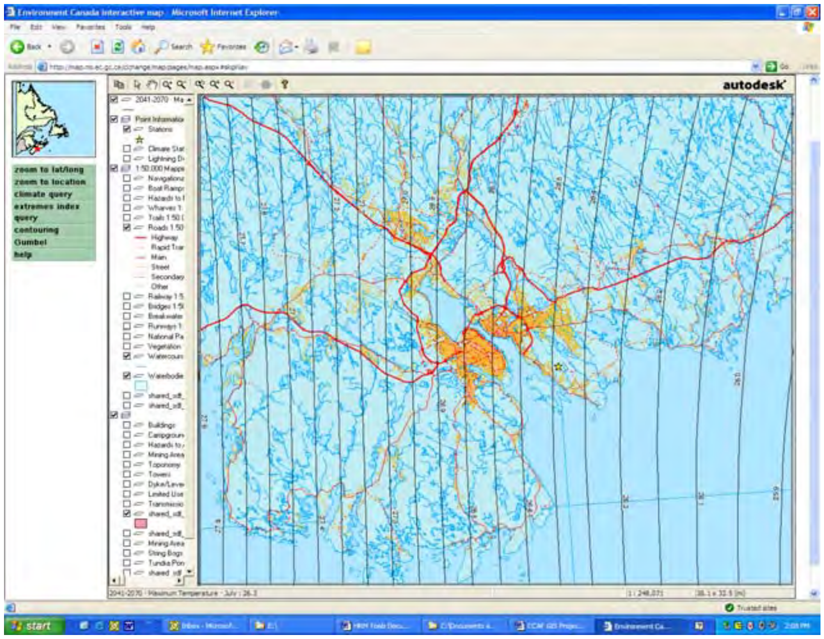


Figure 6. Screen Capture of Contoured Map of Maximum Temperature over HRM

Application

The climate data allows HRM users to extract specific climate change information for 14 sites in Atlantic Canada, including Shearwater NS. That information ranges from values of temperature change to specific extreme climate indices such as heavy rainfall amounts.

The contoured maps can be used as “layers” in a number of GIS platforms so that HRM users can overlay these fields with ones of their choosing and concern. For example, planners may be able to overlay contoured fields of precipitation projections of heavy rainfall amounts over watershed features to attempt correlating the impact of certain precipitation amounts on that watershed.

As described in Section 3 of the report, these layers are now available to HRM as users.

Hazard Maps

- **Atmospheric Hazards Website**

Environment Canada is developing a website that presents background material and map data about risks and hazards from naturally occurring events. The purpose is to enable the evaluation of multiple risks and to assist municipalities and provinces in their emergency planning.

Hazards, such as Winter Hazards, Summer Hazards, are prvoided and the clients can choose the significance of various factors to customize their search. As each parameter is selected, the client can observe it individually and determine its contribution to the combination of parameters specified.

As an example of maps that can be accessed, a current operational website exists for Ontario www.hazards.ca.

Currently, a site for Atlantic Canada is under development, but the following examples show what the data look like. Amount or frequency of an event, such as number of blizzard events in Figure 7 and extreme heat frequency (return period) in Figure 8 are shown in these examples.

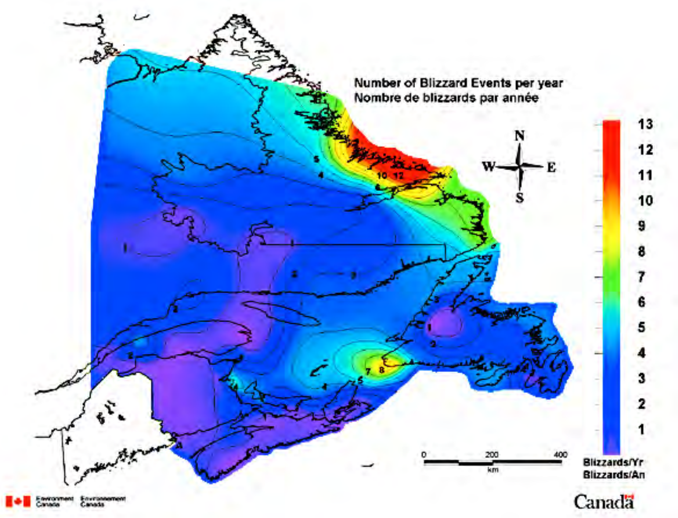


Figure 7. Snowfall Events

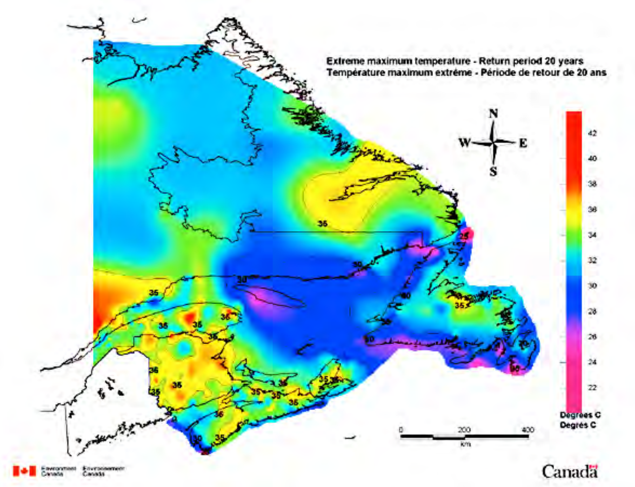


Figure 8. Extreme Heat

Application

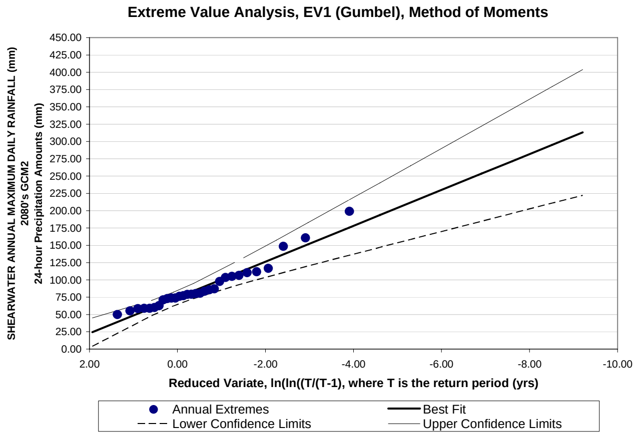
A client can access a series of maps that identify the amount and frequency of specific atmospheric hazards over the Atlantic region. The client can zero in on specific areas and utilize the information to better inform decisions related to extreme event preparation and emergency preparedness. These hazard maps will compliment the AIS based mapping already available on the HRM server.

Extreme Event Information

- **Heavy Precipitation Events**

One of the most utilized weather/climate parameters is the magnitude and frequency of extreme rainfall events. For HRM, planning for these events has implications for both the built and natural environment. One way to identify these events is to provide frequency information in the form of return periods. For example, the historical 100 year event at Shearwater for one-day rainfall is about 150 mm (see Table 2). As we analyse this parameter in a climate changing world, we find that the 100 year event becomes a 10 year event in the first 40 years of this century (2020's) and by the 2080's the 100 year event is projected to be in excess of 190mm.

Figure 9. Historical Return Periods for Shearwater



Return Period	Reduced Variate
1.001	1.93
1.2	0.58
1.5	0.09
2	-0.37
5	-1.50
10	-2.25
20	-2.97
50	-3.90
100	-4.60
200	-5.30
500	-6.21
1000	-6.91
2000	-7.60
5000	-8.52
10000	-9.21

Figure 10. Projected Return Periods for Shearwater

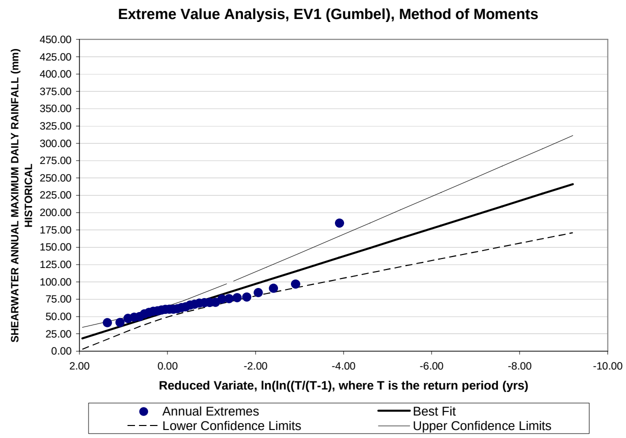


Table 2. Return Period Projections for Shearwater

Period	10 Years	50 Years	100 Years
Historical	102.1 mm	135.1 mm	149.1 mm
2020's	148.9 mm	202.6 mm	225.4 mm
2050's	130.1 mm	165.8 mm	180.8 mm
2080's	132.8 mm	175.6 mm	193.7 mm

Application

Return period information for extreme events can be applied in a number of scenarios. For example, if the watershed system is sensitive to a certain amount of precipitation falling over a short period of time (24 hours or three days), the frequency of these events can be shown both historically and with climate change accounted for. In Table 2, extreme daily rainfall amounts are noted against the return period and time frame. If the watershed has a sensitivity at 150 mm, i.e. flooding occurs above that amount, historical values would provide a comforting result since the 100 year event is still under 150 mm. However taking into account climate change, that 150 mm amount is exceeded as a 50-year event with consistency.

Another approach may be related to design models that require applying the 100 year event amount as the maximum design failure amount. It is clear in Table 2 for Shearwater that the 100 year event amount approach and sometime exceed 200mm. Another way of applying these amounts is to compare the historical to the projected. For example, the 100 year event historical is 149 mm. By the 2020s, that amount has become a 10 year event.

- **Up-to-date IDF Charts**

In common use by infrastructure designers are the Intensity-Duration-Frequency Charts generated and maintained by Environment Canada to allow for better design criteria to be established.

These charts (referred to as IDF charts) represent extreme precipitation return period amounts (millimetres) for various accumulation periods (24 hours down to 5 minutes) and recurrence intervals (2-yr, 5-yr, 10-yr, 25-yr, 50-yr, 100-yr) for specific locations. They are based on data received from observing site “tipping-bucket” rain gauges that provide information on accumulation rate by minute.

The most recent charts for Atlantic Canada were last updated in 1993. Currently the charts are being updated with the latest observations, to include 2005. This work is expected to continue this year for sites across Canada.

Application

The IDF charts are very useful in providing a clear picture of the rate, intensity and frequency of precipitation at a particular location. However these charts are still based on historical climate. The latest versions will contain information up to and including 2005. From that perspective it should contain some of the current climate change signal.

These products can be very useful in determining design criteria. However it is difficult to incorporate climate change into the development of each of these charts as a result, users need to recount for climate change impacts and add it to the expected return periods as provided by the IDF charts.

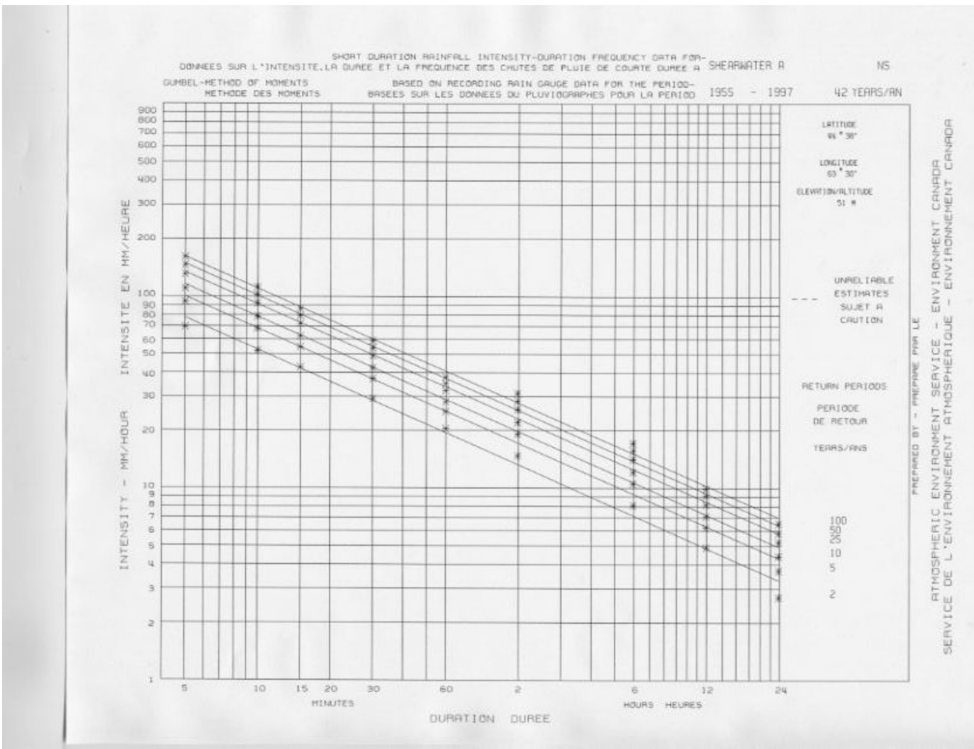


Figure 11. Historical Intensity, Duration and Frequency Chart for Shearwater NS