Supporting Document 3-5

Surface Water Quantity Effects Assessment Report

Eastern Ontario Waste Handling Facility Future Development Environmental Assessment

GFL Environmental Inc.

Moose Creek, Ontario

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Executive Summary

The purpose of this Surface Water Effects Assessment Report is to present the potential environmental effects of the alternative methods for the future development of the Eastern Ontario Waste Handling Facility (EOWHF) on Surface Water Quantity and on-site Surface Water Quality, as well as comparison of the net effects of the alternative methods, identification of a preferred alternative, commitments and monitoring, and approval requirements. The effects of the EOWHF landfill expansion on off-site Surface Water Quality are assessed in a separate report.

Two alternative methods for carrying out the undertaking were identified in the approved Terms of Reference (ToR) and are developed to a preliminary conceptual design level in the Conceptual Design Report (CDR). The main differences between Alternative Methods 1 and 2, as described in the CDR, are the configuration of the landfill stages and the geometries of the proposed stormwater management (SWM) ponds. Alternative Method 1 consists of implementing the future development through five stages, and Alternative Method 2 consists of four stages. For both alternatives, a SWM system will be constructed consisting of conveyance ditches around the perimeter of each stage and a new wet pond. The permanent pool in the wet pond will facilitate the removal of 80% of long-term suspended solids. For Stage 5, which is north of the existing landfill, the existing SWM pond in the northeast corner will be modified, if required, to attenuate peak flows.

Since the drainage area, the global ground cover, and the associated rate of infiltration are similar for Alternative Methods 1 and 2, the total required storage volumes are similar. Because both SWM alternatives are designed to match the surface water pre-development conditions and satisfy quantity and quality requirements, there are no substantial differences between the two alternative methods.

The net effect analysis for Alternative Methods 1 and 2 was conducted in consideration of the following:

- Final landfill topography as the worst-case scenario, since the slopes of the disposal cells are steepest following completion of filling, and thus, the time of concentration is shortest;
- The imperviousness of the landfill cells, since all cells are closed, capped, and covered, and do not allow any significant infiltration;
- Adjusted Manning's number and impervious depression storage to account for the vegetated cover of the cells; and
- Future climate conditions with an increase in precipitation volumes to account for the increased severity of storm events.

Both alternative methods are expected to be equally impacted by climate change effects on storm event duration, frequency, or intensity, and will provide the same level of mitigation for climate change. The proposed SWM ponds will be designed for the anticipated runoff increase. There are no substantial differences in net effects predicted for both alternative methods.

Both alternative methods are anticipated to provide adequate on-site water quality treatment and no adverse impacts are expected to occur to the receiving water course from stormwater discharge.

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Acronyms, Units and Glossary

Acronyms

Acronym	Definition
CDR	Conceptual Design Report
EAA	Environmental Assessment Act
EOWHF	Eastern Ontario Waste Handling Facility
GFL	GFL Environmental Inc.
GHG	Greenhouse Gas
HDR	HDR Corporation
MECP	Ministry of Environment, Conservation and Parks
MNRF	Ministry of Natural Resources and Forestry
OES	Ontario Electronic Stewardship
ToR	Terms of Reference

Units

Unit	Definition
km	kilometre
m	metre
ha	hectares
m^3	cubic metres
m^3/s	cubic metres per second

Glossary

Term	Definition
Approval	Permission granted by an authorized individual or organization for an undertaking to proceed. This may be in the form of program approval, certificate of approval or provisional certificate of approval
Bulking Material	Material added to waste to increase its solidity or porosity. Ex. woodchips added to high nitrogen food scraps to provide a carbon source and increase the porosity of the compost feed stock.
Capacity (Disposal Volume)	The total volume of air space available for disposal of waste at a landfill site for a particular design (typically in m^3); includes both waste and daily cover materials, but excludes the final cover.
Composting	The controlled microbial decomposition of organic matter, such as food and yard wastes, in the presence of oxygen, into finished compost (humus), a soil-like material. Humus can be used in vegetable and flower gardens, hedges, etc.

Glossary

Term	Definition
Composting facility	A facility designed to compost organic matter either in the presence of oxygen (aerobic) or absence of oxygen (anaerobic).
Environment	As defined by the Environmental Assessment Act, environment means: • air, land or water; • plant and animal life, including human life; • the social, economic and cultural conditions that influence the life of humans or a community; • any building, structure, machine or other device or thing made by humans; • any solid, liquid, gas, odour, heat, sound, vibration or radiation resulting directly or indirectly from human activities; or • any part or combination of the foregoing and the interrelationships between any two or more of them (ecosystem approach).
Environmental Assessment	A systematic planning process that is conducted in accordance with applicable laws or regulations aimed at assessing the effects of a proposed undertaking on the environment
Evaluation criteria	Evaluation criteria are considerations or factors taken into account in assessing the advantages and disadvantages of various alternatives being considered
Greenhouse gas	Any of the gases whose absorption of solar radiation is responsible for the greenhouse effect, including carbon dioxide, methane, ozone, and the fluorocarbons.
Indicators	Indicators are specific characteristics of the evaluation criteria that can be measured or determined in some way, as opposed to the actual criteria, which are fairly general
Landfill gas	The gases produced from the wastes disposed in a landfill; the main constituents are typically carbon dioxide and methane, with small amounts of other organic and odour-causing compounds
Landfill site	An approved engineered site/facility used for the final disposal of waste. Landfills are waste disposal sites where waste is spread in layers, compacted to the smallest practical volume, and typically covered by soil.
Leachate	Liquid that drains from solid waste in a landfill and which contains dissolved, suspended and/or microbial contaminants from the breakdown of this waste.
Methane gas	A colourless, odourless highly combustible gas often produced by the decomposition of decomposable waste at a landfill site. Methane is explosive in concentrations between 5% and 15% volume in air.
Mitigation	Measures taken to reduce adverse impacts on the environment.
Proponent	A person who: • carries out or proposes to carry out an undertaking; or • is the owner or person having charge, management or control of an undertaking.
Receptor	The person, plant or wildlife species that may be affected due to exposure to a contaminant.
Terms of Reference	A terms of reference is a document that sets out detailed requirements for the preparation of an Environmental Assessment.

Glossary

Term	Definition
Undertaking	Is defined in the Environmental Assessment Act as follows: • An enterprise or activity or a proposal, plan or program in respect of an enterprise or activity by or on behalf of Her Majesty in right of Ontario, by a public body or public bodies or by a municipality or municipalities; • A major commercial or business enterprise or activity or a proposal, plan or program in respect of a major commercial or business enterprise or activity of a person or persons other than a person or persons referred to in clause (1) that is designated by the regulations; or • An enterprise or activity or a proposal, plan or program in respect of an enterprise or activity of a person or persons, other than a person or persons referred to in clause (a), if an agreement is entered into under section 3.0.1 in respect of the enterprise, activity, proposal, plan or program ("enterprise").
Waste	Refuse from places of human or animal habitation; unwanted materials left over from a manufacturing process.

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1 Introduction

HDR was contracted by GFL Environmental Inc. (GFL) to conduct an assessment of the effects of the future development of the Eastern Ontario Waste Handling Facility (EOWHF) on Surface Water Quantity as part of the EOWHF Future Development Environmental Assessment (EA).

The EA is being carried out in accordance with the requirements of the *Environmental Assessment Act* (EAA) and Terms of Reference (ToR), which was approved by the Ministry of Environment, Conservation and Parks (MECP) on January 14, 2021.

The environment was divided into environmental aspects, components and evaluation criteria as listed in **Table 1-1.**. Existing conditions reports and effects assessment reports have been prepared to address the environmental components.

Table 1-1. Environmental Aspects, Components and Evaluation Criteria

Environmental Aspect	Environmental Component	Evaluation Criteria
Natural Environment	Atmospheric Environment	• Air Quality • Noise • Odour
	Geology and Hydrogeology	• Groundwater Quality • Groundwater Quantity
	Surface Water Environment	• Surface Water Quality • Surface Water Quantity
	Ecological Environment	• Terrestrial Ecosystems • Aquatic Ecosystems
Socio-Economic Environment	Economic	• Economic Effects on / Benefits to Local Community
	Social	• Effects on Local Community • Visual Impact of Facility
Cultural Environment	Cultural Environment	• Cultural Heritage Resources • Archaeological Resources
Built Environment	Transportation	• Effects from Truck Transportation along Access Roads
	Current and Planned Future Land Use	• Effects on Current and Planned Future Land Uses
	Aggregate Extraction and Agricultural	• Aggregate Resources • Effects on Agricultural Land

This Surface Water Quantity Effects Assessment Report assesses the effects of the EOWHF Future Development Project on the Surface Water Quantity and on-site Surface Water Quality portion of the Surface Water Environment. The effects of the Project on off-site Surface Water Quality are assessed in a separate report.

The purpose of the proposed undertaking is to provide approximately 15.1 million cubic metres (m^3) of additional landfill disposal capacity at the existing EOWHF over a 20-year planning period, with operations anticipated to begin in 2025 and closure anticipated in 2045. The undertaking will enable GFL to continue to provide disposal services for residual non-hazardous solid waste to their customers once the landfill reaches its currently approved disposal capacity, and continue to provide economic support to the local community over the long term. No changes to the approved fill rates or site access routes are proposed.

Two alternative methods for carrying out the undertaking were identified in the approved ToR and are developed to a preliminary conceptual design level in the Conceptual Design Report (CDR). Both alternatives provide a landfill volume of approximately 15.1 million m^3 based on the approved fill rate of 755,000 tonnes per year over a 20-year planning period. Studies completed for the EOWHF have indicated that, based on the underlying soils, the design alternatives are limited to varying lateral configurations with a consistent height. Both alternative methods continue to use established operating procedures currently in place at the EOWHF and would maximize the use of existing site infrastructure.

Alternative Method 1 (**Figure 1-1**) consists of implementing the future development through five stages: one stage adjacent to and north of the existing landfill (Stage 5); and four stages oriented east-west within the future development lands (Stages 6 through 9). Stages 6 through 8 will be identical in size, while Stages 5 and 9 will be smaller. A stormwater management system will be constructed consisting of conveyance ditches around the perimeter of each stage and a wet pond located northwest of Stage 8. For Stage 5, further hydrologic analysis will be conducted during detailed design, and the existing pond in the northeast corner of the existing waste handling facility will be modified, if required, to attenuate peak flows.

Alternative Method 2 (**Figure 1-2**) consists of implementing the future development through four stages: one stage adjacent to and north of the existing landfill (Stage 5); and three stages oriented north-south within the future development lands (Stages 6 through 8). Stages 6 and 7 will be identical in size, while Stages 5 and 8 will be smaller. A stormwater management system will be constructed consisting of conveyance ditches around the perimeter of each stage and a wet pond located north of Stages 6 and 7. For Stage 5, further hydrologic analysis will be conducted during detailed design, and the existing pond in the northeast corner of the existing waste handling facility will be modified, if required, to attenuate peak flows.

For both alternative methods, the design of the stages will be consistent with the existing landfill design. Visual screening will be constructed along the north and east perimeters and a portion of the south perimeter consisting of earthen berms and/or vegetation plantings. A new road entrance will be constructed from Laflèche Road, which will include a new scale facility.

The purpose of this Effects Assessment Report is to present the potential environmental effects of the alternative methods on Surface Water Quantity and on-site Surface Water Quality, a comparison of the net effects of each alternative method, the selection of a preferred alternative, an assessment of the environmental effects of the preferred alternative, commitments and monitoring, and approvals. The results from this study will be documented in an EA Study Report in accordance with the approved ToR, which will be submitted to the MECP for review.

Figure 1-1. Alternative Method 1

Figure 1-2. Alternative Method 2

2 Effects Assessment Methods

Using the evaluation criteria, indicators, rationale and data sources from the approved ToR and the information from the Surface Water Quantity Existing Conditions Report, the effects assessment is carried out as follows:

- predict the potential environmental effects for each alternative method (Section 3);
- identify the preferred alternative based on a comparative evaluation of the potential environmental effects of each alternative method (Section 4); and
- conduct an effects assessment on the preferred alternative, including the identification of mitigation measures and monitoring programs (Sections 4 and 5).

2.1 Predict Potential Environmental Effects for Alternative Methods

The potential environmental effects for each alternative method are identified based on the application of the evaluation criteria, indicators and data sources in the approved ToR and based on the maximum allowable waste receipt level for the EOWHF landfill. The potential effects can be positive or negative, direct or indirect, and short- or long-term. Mitigation measures are identified to minimize or mitigate the potential effects and then the net effects are evaluated taking into consideration the application of mitigation measures.

2.1.1 Study Areas

The existing EOWHF is located within the Township of North Stormont, approximately 5 km north-northwest of the village of Moose Creek, Ontario, and 5 km east of the village of Casselman, Ontario, on the western half of Lot 16 and Lots 17 and 18, Concession 10, Township of North Stormont, United Counties of Stormont, Dundas and Glengarry, near the intersection of Highway 417 and Highway 138. The municipal street address for the facility is 17125 Laflèche Road, Moose Creek, Ontario. The lands to the east of the existing EOWHF being considered for the future development include the eastern half of Lot 16, Lots 14 and 15, and the majority of Lot 13 of Concession 10. The existing EOWHF encompasses a site area of 189 hectares, while the lands to the east of the existing EOWHF being considered for future development include approximately 240 hectares.

The study areas include the existing site as well as potentially affected surrounding areas. The on-site and off-site study areas identified for the EA in the approved ToR are as follows (**Figure 2-1**):

- On-site Study Area – the existing EOWHF, and the future development area comprising the eastern half of Lot 16, Lots 14 and 15, and the majority of Lot 13 of Concession 10 east of the EOWHF; and
- Off-site Study Area – the lands in the vicinity of the future development extending approximately 1 kilometre from the On-site Study Area.

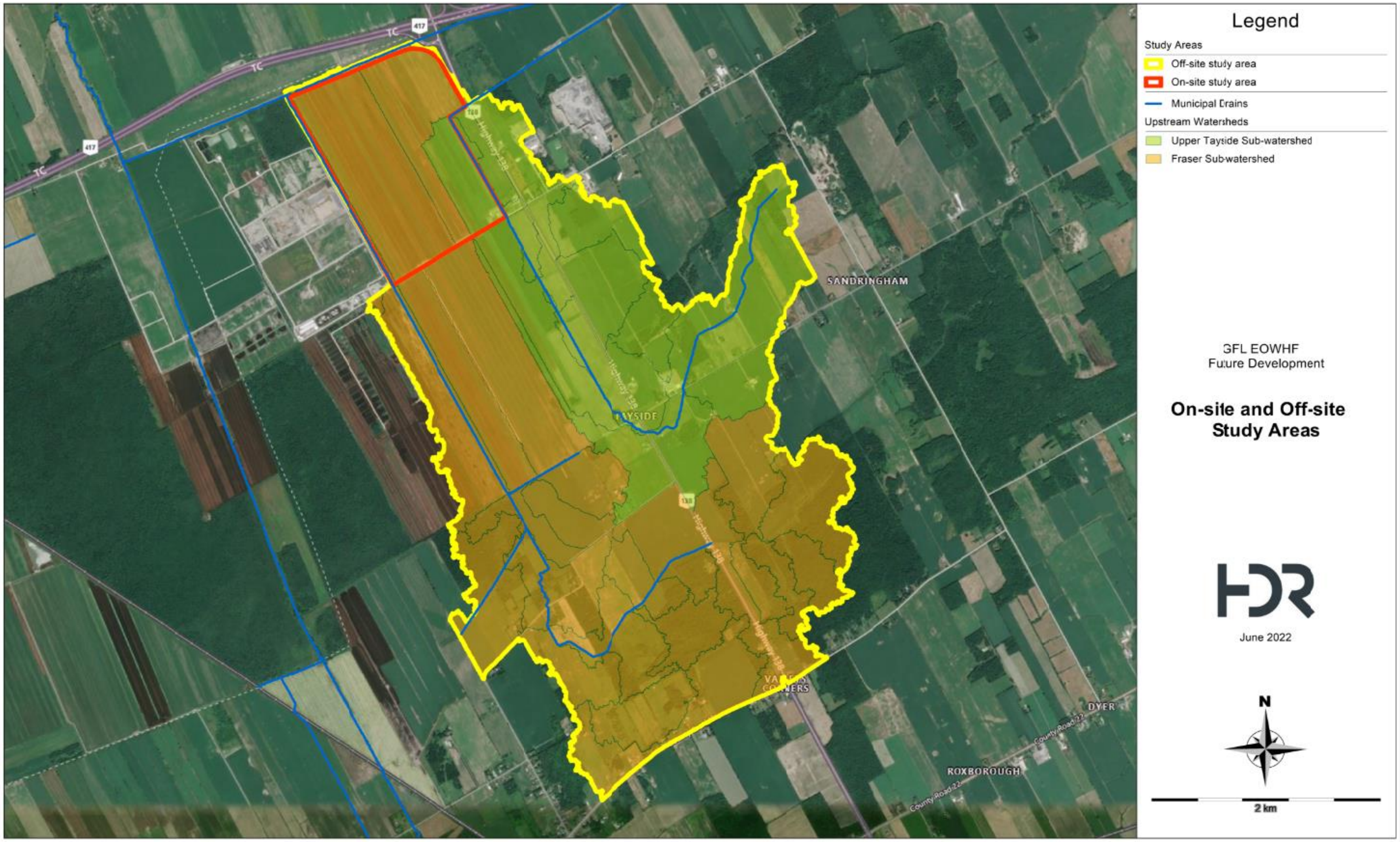
Figure 2-1. Study Areas for the EA

For the Surface Water Quantity effects assessment, the potentially-affected areas are defined based on local watershed delineation and surface water features around the future development lands.

The existing stormwater management system in the existing EOWHF site discharges at the north-west corner of the EOWHF, where Fraser Drain flows westerly and ultimately confluences with Moose Creek flowing in a northerly direction. Since the discharge point of the existing EOWHF is downstream of the future development lands, the existing EOWHF and the downstream Moose Creek watershed is not included in the Off-site Study Area.

Accordingly, the general On-site and Off-site Study Areas have been modified for the purposes of the Surface Water Quantity effects assessment to include the Fraser Drain sub-watershed upstream of the existing EOWHF site and the Upper Tayside sub-watershed, as presented on **Figure 2-2**.

Figure 2-2. Study Areas for Surface Water Quantity



2.1.2 Evaluation Criteria, Indicators and Data Sources

The evaluation criteria, rationale, indicators and data sources used for the Surface Water Quantity effects assessment as per the approved ToR are provided in **Table 2-1**.

Table 2-1. Evaluation Criteria, Indicators and Data Sources for Surface Water Quantity and Quality (on-site)

Evaluation Criteria	Rationale	Indicators	Data Sources
Surface Water Environment			
Surface Water Quality (on-site)	Sediment associated with the potential erosion of surficial soils at waste disposal sites create suspended solids in the surface water runoff draining to surface water receptors.	• Predicted effects on surface water quality on-site and off-site [a]	• On-site stormwater management design for expanded landfill • On-going site monitoring reports
Surface Water Quantity	Construction of physical works may disrupt natural surface drainage patterns and may alter runoff and peak flows. The presence of the expanded landfill may also affect base flow to surface water.	• Change in drainage areas • Predicted occurrence and degree of off-site impacts	• On-site stormwater management design for expanded landfill • Annual monitoring reports • Published flow information from MECP, Environment Canada and local conservation authorities • Engineer's Report for municipal drains • Site reconnaissance • Proposed facility characteristics • Landfill design and operations data

[a] Off-site surface water quality is addressed in a separate report. On-site surface water quality for this report pertains to increased suspended solids in the stormwater runoff as a result of the proposed development.

2.1.3 Key Design Considerations and Assumptions

The alternative methods of carrying out the undertaking are described in detail in the CDR. Regarding the alternative methods, the key design considerations and assumptions as they relate to Surface Water Quantity are described below.

Summary of Existing Conditions

A Surface Water Quantity Existing Conditions Report was prepared for the future development lands to establish the existing surface water quantity conditions in order to investigate the potential impacts of the development on the receiving Fraser and Upper Tayside Municipal Drains (HDR, 2022). The existing surface water quantity conditions for the existing EOWHF site were previously documented in the Surface Water Part A: Water Quantity Existing Conditions Report (J.F. Sabourin and Associates Inc., 2017) as part of the 2018 EOWHF Landfill Expansion EA.

The EOWHF landfill future development lands are located in the Fraser Drain and Upper Tayside Drain sub-watersheds, which ultimately drain into Moose Creek and Scotch River, respectively. The Fraser Drain flows along the west boundary, and the Upper Tayside Drain flows along a portion of the east boundary of the future development, respectively. Under existing conditions, tile drains in the future development area direct runoff primarily into a perimeter ditch along the north boundary of the site and discharge into the Fraser Drain, where the Fraser Drain changes flow direction from north to west. The tile drains direct a small portion of the runoff to the Upper Tayside Drain.

As presented in the Surface Water Quantity Existing Conditions Report (HDR, 2022), a PC-SWMM hydrologic model was developed and peak flows were estimated for rainfall and snowmelt with rain events with the 2- to 100-year return periods, in the drains upstream and downstream of the future development area. The rainfall events with a SCS Type II 24-hr distribution yielded the highest peak flows. The peak flow rates in the Fraser Drain downstream of the future development lands generated by the PC-SWMM model are shown in **Table 2-2**.

Table 2-2. Fraser Drain Peak Flow Estimates Downstream of the Future Development Lands

Return Period	Peak Flow [a] (m^3/s)
2 Year	4.20
5 Year	6.20
10 Year	7.48
25 Year	9.15
50 Year	10.18
100 Year	11.18

[a] Using a SCS Type II 24-hr rainfall distribution

A 1-D/2-D integrated PC-SWMM hydraulic model was developed for existing conditions to generate a floodplain map within and in the vicinity of the future development lands. Flooding was observed within the future development lands along the north perimeter channel, as well as across the northeast area of the future development lands, where flows overtopped the Upper Tayside Drain and spilled towards the perimeter channel. Flooding outside of the future development lands was observed at multiple locations along Fraser Drain, the utility area south-west of the future development lands, and along the ditch on the south side of Laflèche Road between the Fraser and Upper Tayside drains.

Design Considerations and Assumptions

The proposed development will increase the impervious surface area, peak flows, and volume of surface runoff. To prevent an increase in risk of flooding and negative impacts to water quality, a proposed conceptual stormwater management (SWM) design has been developed that will mitigate potential negative impacts to the existing surface water drainage system.

Relevant SWM criteria as identified by the MECP in O. Reg. 232/98 and its related guidance document (MECP, 2012) include:

- Water quality enhancement features (e.g., sedimentation ponds) of non-contaminated stormwater should be designed to temporarily treat/store the runoff volume generated from a 4-hour, 25 mm storm event and will be sized to provide "Enhanced" (Level 1) protection (i.e., 80 percent long-term suspended solids removal) and meet the SWM design requirements of the MECP Stormwater Management Planning and Design Manual (2003).
- Surface water quantity control (i.e., peak flow reduction) measures of non-contaminated stormwater to be designed to temporarily store the runoff volume generated from storm events up to the higher of the 24-hour, 100-year design storm or the prevailing Regional Storm event, and release at or below the existing condition peak flows, such that there is no appreciable change in the potential for flooding and/or erosion in the watercourses receiving surface water discharges.

The following design storms were used to assess the design of the SWM system:

- Environment Canada's rain gauge station: Ottawa CDA RCS Station (6105978).
- Quantity control design storms: SCS Type II 24-hour rainfall distribution for the 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year return periods.

In order to satisfy quantity and quality requirements, the proposed SWM systems for both alternative methods include a new wet pond in the northwest corner of the future development area and oversized drainage ditches on the site. The proposed wet pond will discharge into the Fraser Drain just upstream of where the Fraser Drain changes flow direction from north to west. Based on the available topographic information, the bottom elevation of the Fraser Drain is at approximately 63.7 m, and the 100-year flow depth is approximately 1.5 m. All the runoff from the future development site is proposed to be directed to the Fraser Drain, and accordingly will not generate negative water quality or quantity impacts to the Upper Tayside Drain.

For stormwater quality control, the wet ponds have been designed to provide an "Enhanced" protection level (i.e., 80% long-term TSS removal). Under proposed conditions, the site imperviousness is 74%, which corresponds to a volumetric water quality criterion of 240 m^3/ha, including 40 m^3/ha for extended detention. An orifice plate will be provided in the outlet structure for extended detention.

For stormwater quantity control, the wet pond is designed to temporarily store the runoff volume generated by storm events up to the 24-hour, 100-year design storm and maintain peak flow discharge below existing conditions levels. The storage volume and conveyance capacity of the perimeter ditches will be confirmed during detailed design. Stage-storage tables for the ponds in Alternative Methods 1 and 2 are included in **Appendix A**.

There is no difference in the design of Stage 5 within the existing EOWHF site for Alternative Methods 1 and 2. Further hydrologic and hydraulic analysis will be conducted during detailed design to confirm that sufficient storage can be provided in the perimeter ditches and/or appropriate changes are made to the existing northeast pond, such that there is no increase in peak flows to the Fraser Drain. Changes to the existing northeast pond could include additional berming around the perimeter of the pond or modifications to the outlet structure to control the peak flow discharge.

The net effect analysis for Alternative Methods 1 and 2 was conducted in consideration of the following:

- Final landfill topography as the worst-case scenario, since the slopes of the disposal cells are steepest following completion of filling, and thus, the time of concentration is shortest;
- The imperviousness of the landfill cells, including the localized perimeter ditches around each stage, are modelled as 95%, since all cells are closed, capped, and covered, and will not allow for infiltration;
- A Manning's number of 0.3 and an impervious depression storage of 5.0 mm to account for the vegetated cover of the cells; and
- Future climate conditions: an additional precipitation scenario was considered with a 14% increase in precipitation volumes in addition to the 24-hour, 100-year design storm volume, to account for the increased severity of storm events. This adjustment is based on the Ministry of Natural Resources and Forestry (MNRF) Climate Change Research Report (CCRR-44). Additional details are included in Section 4.2 and rainfall information is included in **Appendix B**.

In order to assess the surface water quantity effects, the PC-SWMM model developed for the existing conditions assessment was advanced to evaluate peak flows and the required storage for the proposed alternative methods (Alternative 1 and Alternative 2). The model for both alternatives was used to calculate the storage volume required to maintain peak discharge flows at or below the pre-development (existing) conditions.

The main differences between Alternative Method 1 and Alternative Method 2 as described in the CDR are the configuration of the cells and geometries of the proposed SWM ponds. Since the drainage area, the global ground cover, and the associated rate of infiltration are similar for Alternative Method 1 and Alternative Method 2, despite the differences in the geometry, the total storage volume required is similar.

The hydrologic model input parameters for the modelling which supports the effects assessment for Alternative Methods 1 and 2 are presented in **Appendix C** and **Appendix D**, respectively.

2.2 Comparative Evaluation and Identification of the Preferred Alternative

The two alternative methods are comparatively assessed and evaluated using the criteria and indicators identified in **Table 2-1** to determine the preferred alternative. The differences in the potential environmental effects remaining following the implementation of potential mitigation/management measures (i.e., net effects) are used to identify and compare the advantages and disadvantages of each alternative method.

The net environmental effects are utilized in a comparison of the two alternatives to one another at the criteria and indicator level for each discipline. The following two step methodology was applied in order to carry out the comparative evaluation for Surface Water Quantity:

1. Identify the predicted net effect(s) associated with each alternative for each indicator and assign a preference rating (i.e., Preferred, Not Preferred, No Substantial Difference); and
2. Rate each alternative at the criteria level (i.e., Preferred, Not Preferred, No Substantial Difference) based on the identified preference rating for each indicator and provide a rationale.

2.3 Effects Assessment of the Preferred Alternative

An assessment of the environmental effects of the preferred alternative is carried out considering the same criteria, indicators and data sources, taking into account potential mitigation/management measures and cumulative effects. The preferred alternative's effect on climate change, and the potential effect of climate change on the preferred alternative, are also examined. The effects assessment of the preferred alternative will be presented in the EA Study Report.

3 Net Effects Assessment

The results of the net effects assessment for each alternative method are provided in Sections 3.1 and 3.2.

3.1 Alternative Method 1

As mentioned in Section 2.1.3., the SWM system for Alternative Method 1 consists of one wet pond and an oversized perimeter ditch along the north, east, and west perimeter of the site. Smaller, localized ditches around each stage convey runoff to the oversized perimeter ditch.

The proposed SWM system was evaluated using the PC-SWMM model. The proposed wet pond includes a permanent pool volume of 41,240 m^3 for water quality control and provides an active storage volume of 166,820 m^3 for extended detention and water quantity control, for a total pond volume of 208,060 m^3. To account for higher runoff volumes attributed to climate change, an additional berm is to be constructed around the pond perimeter to provide a minimum 0.3 m freeboard. The height of the berm will be confirmed during detailed design based on the design of the pond outlet structure.

The permanent pool facilitates the removal of 80% of long-term suspended solids. For quantity control, the active storage volume will attenuate discharge flows from the future development lands under ultimate conditions to levels lower than the pre-development discharge peak flows for storm events up to a 100-year return period, including consideration for climate change. The pond outlet structure will be designed in the detailed design stage to achieve the target peak flow rates.

The net effects assessment for Alternative Method 1 is presented in **Table 3-1**.

Table 3-1. Net Effects Assessment – Alternative Method 1

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Surface Water Quality (on-site)	Predicted effects on surface water quality on-site	• SWM wet pond has a permanent pool storage volume of 41,230 m³ and extended detention storage volume of 30,840 m³ for water quality control. On-site surface water quality control facilities will be appropriately designed to achieve 80% TSS removal (in-design mitigation).	• Increase in runoff volume and suspended solids to the site outlet	• Wet ponds need maintenance to ensure proper quality control (i.e., sediment removal). Operational and maintenance requirements for the proposed wet ponds will be specified in the amended ECA that will be issued for the project. • Complete ECA amendment (ECA No. 7899-CBQP6L) for the proposed SWM system including SWM discharge outlet to Fraser Drain.	• Surface water will meet MECP monitoring requirements with regards to TSS. • Increase in TSS, but no net effects to site outlet since stormwater quality is treated in the wet pond by providing sufficient extended detention and settling in the permanent pool prior to discharge.
Surface Water Quantity	Change in drainage areas	• Drainage area to Fraser Drain downstream of the future development site is increased by 33.1 ha due to catchment area diverted from Upper Tayside Drain to Fraser Drain. • All cells are closed, capped, covered and allow minimal infiltration, which increases the global imperviousness of the site. • Total area draining to Fraser Drain from future development: 215 ha. • Sufficient storage in the perimeter ditches and the existing northeast pond (to be confirmed in detailed design). • On-site surface water quantity control storage and conveyance will be appropriately designed to meet the site operational practice (in-design mitigation).	• Increase in runoff volume and peak flow rate to the site outlet.	• Stormwater management facilities will be designed in accordance with MECP's Stormwater Management Planning and Design Manual (2003) and O. Reg 232/98. The design of the pond will be submitted to MECP for review and approval prior to incorporation into the amended ECA that will be issued for the project. • Discharge from the proposed SWM pond and LTF will follow the requirements of the amended ECA that will be issued for the project.	• Increase in total surface water quantity volume, but no net effects since peak flows to the site outlet will be controlled with the SWM ponds within the pre-development conditions values up to a 100-year return period.

Table 3-1. Net Effects Assessment – Alternative Method 1

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
	Predicted occurrence and degree of off-site impacts	• SWM wet pond has an active storage volume of 166,820 m^3. • Perimeter channel can convey a 100-year storm event. • On-site surface water and quantity control storage and conveyance will be appropriately designed to meet the site operational practice (in-design mitigation).	• Increase in runoff volume and peak flow rate to the site outlet.	• None required.	• Increase in total surface water quantity volume, but no net effects since peak flows to the site outlet will be controlled with the SWM ponds within the pre-development conditions values up to a 100-year return period.

3.2 Alternative Method 2

As mentioned in Section 2.1.3., the SWM system for Alternative Method 2 consists of one wet pond and oversized ditches running in a northerly direction along the outer perimeter of the site and between the stages. Smaller, localized ditches around each stage convey runoff to the oversized perimeter ditch.

The proposed SWM system was evaluated using the PC-SWMM model. The proposed wet pond includes a permanent pool volume of 40,500 m^3 for water quality control and provides an active storage volume of 151,220 m^3 for extended detention and water quantity control, for a total pond volume of 191,720 m^3. To account for higher runoff volumes attributed to climate change, an additional berm is to be constructed around the pond perimeter to provide a minimum 0.3 m freeboard. The height of the berm will be confirmed during detailed design based on the design of the pond outlet structure.

The permanent pool facilitates the removal of 80% of long-term suspended solids. For quantity control, the active storage volume will attenuate discharge flows from the future development lands under ultimate conditions to levels lower than the pre-development discharge peak flows for storm events up to a 100-year return period, including consideration of climate change. The pond outlet structure will be designed in the detailed design stage to achieve the target peak flow rates.

The net effects assessment for Alternative Method 2 is presented in **Table 3-2**.

Table 3-2. Net Effects Assessment – Alternative Method 2

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
Surface Water Quality (on-site)	Predicted effects on surface water quality onsite	• SWM wet pond has a permanent pool storage volume of 40,500 m^3 and extended detention storage volume of 25,160 m^3 for water quality control. • On-site surface water quality control facilities will be appropriately designed to achieve 80% TSS removal (in-design mitigation).	• Increase in runoff volume and suspended solids to the site outlet	• Wet ponds need maintenance to ensure proper quality control (i.e., sediment removal). Operational and maintenance requirements for the proposed wet ponds will be specified in the amended ECA that will be issued for the project. • Complete ECA amendment (ECA No. 7899-CBQP6L) for the proposed SWM system including SWM discharge outlet to Fraser Drain.	• Surface water will meet MECP monitoring requirements with regards to TSS. • Increase in TSS, but no net effects to site outlet since stormwater quality is treated in the wet pond by providing sufficient extended detention and settling in the permanent pool prior to discharge.
Surface Water Quantity	Change in drainage areas	• Drainage area to Fraser Drain downstream of the future development site, is increased by 33.1 ha due to catchment area diverted from Upper Tayside Drain to Fraser Drain. • All cells are closed, capped, covered and allow minimal infiltration, which increases the global imperviousness of the site. • Total area draining to Fraser Drain from future development: 215 ha. • Sufficient storage in the perimeter ditches and the existing northeast pond (to be confirmed in detailed design). • On-site surface water quantity control storage and conveyance will be appropriately designed to meet the site operational practice (in-design mitigation).	• Increase in runoff volume and peak flow rate to the site outlet	• Stormwater management facilities will be designed in accordance with MECP's Stormwater Management Planning and Design Manual (2003) and O. Reg 232/98. The design of the pond will be submitted to MECP for review and approval prior to incorporation into the amended ECA that will be issued for the project. • Discharge from the proposed SWM pond and LTF will follow the requirements of the amended ECA that will be issued for the project.	• Increase in total surface water quantity volume, but no net effects since peak flows to the site outlet will be controlled with the SWM ponds within the pre-development conditions values up to a 100-year return period.

Table 3-2. Net Effects Assessment – Alternative Method 2

Evaluation Criteria	Indicator	Key Design Considerations and Assumptions	Potential Effects	Mitigation Measures	Net Effects
	Predicted occurrence and degree of off-site impacts	• SWM wet pond has an active storage volume of 151,220 m³. • Perimeter channel can convey a 100-year storm event. • On-site surface water quantity control storage and conveyance will be appropriately designed to meet the site operational practice (in-design mitigation).	• Increase in runoff volume and peak flow rate to the site outlet	• None required.	• Increase in total surface water quantity volume, but no net effects since peak flows to the site outlet will be controlled with the SWM ponds within the pre-development conditions values up to a 100-year return period.

4 Comparative Evaluation of Net Effects and Identification of the Preferred Alternative

A comparative evaluation of the net effects of each alternative method and the identification of a preferred alternative are carried out in accordance with the methods described in Section 2.2. The results of the comparative evaluation are provided below.

4.1 Comparative Evaluation Results

The main differences between Alternative Method 1 and Alternative Method 2 as described in the CDR are the configuration of the stages and the geometries of the proposed SWM ponds. Since the drainage area, the global ground cover, and the associated rate of infiltration are similar for Alternative Method 1 and Alternative Method 2, the total storage volume required is similar. Because both SWM alternatives are designed to match the surface water pre-development conditions and satisfy quantity and quality requirements, there are no substantial differences between the two alternative methods. No preferred alternative is identified.

The results of the comparative evaluation for Surface Water Quantity are provided in **Table 4-1**.

Table 4-1. Comparative Evaluation of Net Effects for Surface Water Quantity

Evaluation Criteria	Indicators	Net Effects of Alternative Methods	
		Alternative Method 1	Alternative Method 2
Surface Water Quality (on-site)	Predicted effects on surface water quality on-site	• Surface water quality meets MECP requirements of 80% long term TSS removal. • No net effects to surface water quality at the site outlet are anticipated since the stormwater will be treated in the wet pond via sufficient extended detention and settling in the permanent pool prior to discharge. **No Substantial Difference**	• Surface water quality meets MECP requirements of 80% long term TSS removal. • No net effects to surface water quality at the site outlet are anticipated since the stormwater will be treated in the wet pond via sufficient extended detention and settling in the permanent pool prior to discharge. **No Substantial Difference**
Surface Water Quantity	Change in drainage areas	• Increase in total surface water quantity volume to the site outlet but no net effects on peak flows since peak flows to the site outlet are controlled with the SWM ponds within pre-development conditions values up to a 100-year return period. **No Substantial Difference**	• Increase in total surface water quantity volume to the site outlet but no net effects on peak flows since peak flows to the site outlet are controlled with the SWM ponds within pre-development conditions values up to a 100-year return period. **No Substantial Difference**
	Predicted occurrence and degree of off-site impacts	• Increase in total surface water quantity volume to the site outlet but no net effects on peak flows since peak flows to the site outlet will be controlled with the SWM ponds within pre-development conditions values up to a 100-year return period. **No Substantial Difference**	• Increase in total surface water quantity volume to the site outlet but no net effects on peak flows since peak flows to the site outlet will be controlled with the SWM ponds within pre-development conditions values up to a 100-year return period. **No Substantial Difference**
	Criteria Rating & Rationale	***There is no substantial difference in the potential effects between the two alternative methods.***	

4.2 Climate Change Considerations

According to the Canadian Climate Normals Ottawa CDA data from Environment Canada, for the 1971 – 2000 period, the average annual precipitation is 914.2 mm. The 2015 Climate Change Research Report CCRR-44, titled *Climate change projects for Ontario: An updated synthesis for policymakers and planners*, prepared by the Ministry of Natural Resources and Forestry (MNRF), was referenced for climate change considerations. In accordance with the CCRR-44, the maximum increase in annual precipitation from baseline conditions (1971 – 2000) for the 2011-2040 projected period under the representative concentration pathway (RCP) 8.5 is 128 mm. This corresponds to a 14.0% increase in annual precipitation.

Accordingly, climate change was taken into consideration in the hydrologic simulations by including a scenario with a 14% increase in total precipitation for the 100-year event to confirm that the SWM ponds will have sufficient capacity.

Both alternative methods are expected to be equally impacted by climate change effects on storm event duration, frequency, or intensity, and will provide the same level of mitigation for climate change. The proposed SWM ponds will be designed for the anticipated runoff increase.

4.3 Advantages and Disadvantages of the Preferred Alternative

The differences in net effects are used to identify and compare the advantages and disadvantages of each alternative method. As there are no substantial differences in net effects predicted for both alternative methods that were presented, no preferred alternative was identified. As a result, the same advantages and disadvantages listed in **Table 4-2** apply to both alternative methods.

Table 4-2. Advantages and Disadvantages of the Alternative Methods

Evaluation Criteria	Advantages	Disadvantages
Surface Water Quality (on-site)	• Surface water quality meets MECP requirements of 80% long term TSS removal.	• No disadvantages to on-site surface water quality are anticipated.
Surface Water Quantity	• Peak flows to the site outlet will be controlled with the ponds within the pre-development conditions values up to a 100-year return period.	• No disadvantages to the receiving watercourse are anticipated.

5 Commitments and Monitoring

To confirm that the commitments related to Surface Water Quantity and on-site Surface Water Quality are carried out, and that the proposed mitigation measures address the predicted effects for Surface Water Quantity and on-site Surface Water Quality, monitoring is proposed for construction of the additional drainage infrastructure and SWM ponds, as well as for on-going maintenance to ensure that erosion is prevented and sediment is periodically removed from the ponds to prevent any significant reduction in their storage capacity. Monitoring for compliance will be undertaken to confirm that the project complies with the commitments and mitigation measures identified in the effects assessment.

The commitments associated with Surface Water Quantity and on-site Surface Water Quality are listed in Section 5.1. The proposed environmental effects monitoring is provided in Section 5.2. Compliance monitoring for Surface Water Quantity is described in Section 5.3.

5.1 On-site Surface Water Quality Commitments

Additional mitigation from increased runoff of either alternative method is provided by the storage and settlement of suspended solids in the proposed SWM ponds. Periodic maintenance in the form of sediment removal to avoid the impacts on the storage capacity of the ponds will be required based on annual maintenance inspections. No further mitigation measures are required. On-site surface water quality can be assessed and confirmed by the surface water quality monitoring program for the future development site.

5.2 Environmental Effects Monitoring for Surface Water

Monitoring plans are developed as part of the detailed effects assessments carried out for the Preferred Alternative to confirm:

- the net effects are as predicted;
- unanticipated negative effects are addressed; and
- the effectiveness of the proposed mitigation measures.

Table 5-1 summarizes the environmental effects monitoring for the Preferred Alternative.

5.3 Surface Water Compliance Monitoring

Compliance monitoring will be undertaken to confirm that the construction, operation and maintenance of the project are carried out in accordance with the mitigation measures and commitments identified in the effects assessment. Compliance monitoring is summarized in **Table 5-1**. The results of compliance monitoring, including details of the effectiveness of mitigation measures and fulfillment of commitments, will be provided to the MECP.

Table 5-1. Environmental Effects and Compliance Monitoring

Evaluation Criteria	Potential Effect	Commitment for Mitigation	Commitment for Monitoring	Compliance Monitoring
Surface Water Quality (on-site)	• Surface water quality meets MECP requirements of 80% long term TSS removal.	• New SWM pond will reduce 80% of long term TSS removal in stormwater runoff prior to discharge. • Wet ponds need maintenance to ensure proper quality control (i.e., sediment removal). Operational and maintenance requirements for the proposed wet ponds will be specified in the amended ECA that will be issued for the project. • Complete ECA amendment (ECA No. 7899-CBQP6L) for the proposed SWM system including SWM discharge outlet to Fraser Drain.	• On-going surface water quality monitoring program.	• SWM ponds will be monitored in accordance with the requirements outlined in the amended ECA that will be issued for the project . • Five times annually during current surface water monitoring program, or revised as specified in the amended ECA that will be issued for the project.
Surface Water Quantity	• Increase in total surface water quantity volume to the site outlet but no net effects on peak flows, since peak flows to the site outlet are controlled with the ponds within the pre-development conditions values up to a 100-year return period.	• No additional mitigation measures required beyond the in-design mitigation measures (e.g., construction of new SWM pond to control volume and peak flows to the future development site outlet, and providing sufficient storage in the perimeter ditches and the existing northeast pond to control volume and peak flows to the existing site outlet). • Stormwater management facilities will be designed in accordance with MECP's Stormwater Management Planning and Design Manual (2003) and O. Reg 232/98. The design of the pond will be submitted to MECP for review and approval prior to incorporation into the amended ECA that will be issued for the project. • Discharge from the proposed stormwater management pond will follow requirements of the amended ECA that will be issued for the project.	• Inspection for erosion and sediment accumulation in SWM pond as part of landfill monitoring programs. • Annual inspection of stormwater works and maintenance to address sedimentation and excessive vegetation growth.	• Annually during current site inspection program.

6 Surface Water Approvals

In addition to EA approval, the following Surface Water approvals may be required:

- Permit from South Nation Conservation Authority;
- Approval from the Township of North Stormont Drainage Superintendent; and
- Environmental Compliance Approval (ECA) amendment (ECA No. 7899-CBQP6L) for the proposed SWM system, including SWM discharge outlet to Fraser Drain, from Ministry of the Environment, Conservation, and Parks (MECP).

7 References

JFSA

2017 Water Quantity Existing Conditions Report – Part A: Water Quantity. Eastern Ontario Waste Handling Facility Landfill Expansion Environmental Assessment. August 4, 2017.

HDR

2022 Surface Water Quantity Existing Conditions Report. Environmental Assessment for Future Development of Eastern Ontario Waste Handling Facility. March 15, 2022.

Ontario Ministry of the Environment, Conservation, and Parks (MECP)

2003 Stormwater Management Planning and Design Manual

2012 Landfill Standards: A guideline on the regulatory and approval requirements for new or expanding landfilling sites

Ontario Ministry of Natural Resources and Forestry (MNRF)

2015 Climate Change Research Report CCRR-44 – Climate change projections for Ontario: An updated synthesis for policymakers and planners. 2015.

Tetra Tech

2017 Surface Water Draft Effects Assessment Report. Eastern Ontario Waste Handling Facility Landfill Expansion Environmental Assessment. December 14, 2017.

Appendix A. Pond Stage-Storage Curves

Project	GFL EOWHF Surface Water Quantity EA	No.	--
By	J. Look	Date	23-Jun-2022
Checked	S. Kashi	Checked	--

TABLE 1

STAGE-STORAGE CURVES

ALTERNATIVE METHOD 1

Elev.	Depth above PP (m)	Surface Area (m^2)	Permanent Pool Volume (m^3)	Storage Volume (m^3)	
64.40	0.00	39289	0	0	
64.50	0.00	39676	3948	0	
64.60	0.00	40063	7935	0	
64.70	0.00	40452	11961	0	
64.80	0.00	40842	16026	0	
64.90	0.00	41234	20130	0	
65.00	0.00	41626	24273	0	
65.10	0.00	42020	28455	0	
65.20	0.00	42415	32677	0	
65.30	0.00	42811	36938	0	
65.40	**0.00**	**43208**	**41239**	**0**	Note 1
65.50	0.10	191019	41239	11711	
65.60	**0.20**	**191734**	**41239**	**30849**	Note 2
65.70	0.30	192450	41239	50058	
65.80	0.40	193168	41239	69339	
65.90	0.50	193887	41239	88692	
66.00	0.60	194607	41239	108117	
66.10	0.70	195329	41239	127613	
66.20	0.80	196052	41239	147182	
66.30	0.90	196776	41239	166824	

ALTERNATIVE METHOD 2

Elev.	Depth above PP (m)	Surface Area (m^2)	Permanent Pool Volume (m^3)	Storage Volume (m^3)	
64.40	0.00	38410	0	0	
64.50	0.00	38825	3862	0	
64.60	0.00	39241	7765	0	
64.70	0.00	39658	11710	0	
64.80	0.00	40077	15697	0	
64.90	0.00	40498	19725	0	
65.00	0.00	40919	23796	0	
65.10	0.00	41342	27909	0	
65.20	0.00	41766	32065	0	
65.30	0.00	42191	36263	0	
65.40	**0.00**	**42618**	**40503**	**0**	Note 1
65.50	0.10	153243	40503	9793	
65.60	**0.20**	**154107**	**40503**	**25161**	Note 2
65.70	0.30	154972	40503	40614	
65.80	0.40	155838	40503	56155	
65.90	0.50	156706	40503	71782	
66.00	0.60	157575	40503	87496	
66.10	0.70	158445	40503	103297	
66.20	0.80	159317	40503	119185	
66.30	0.90	160189	40503	135161	
66.40	1.00	161063	40503	151223	

Note 1 Top of permanent pool, orifice invert

Note 2 Extended detention

Appendix B. Rainfall Data and Climate Change Projections Reference

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Short Duration Rainfall Intensity-Duration-Frequency Data
Données sur l'intensité, la durée et la fréquence des chutes de pluie de courte durée

Gumbel - Method of moments/Méthode des moments

2020/03/27

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OTTAWA CDA RCS ON 6105978

Latitude: 45 23'N Longitude: 75 43'W Elevation/Altitude: 79 m

Years/Années : 1905 - 2017 # Years/Années : 57

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Table 1 : Annual Maximum (mm)/Maximum annuel (mm)

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Year Année	5 min	10 min	15 min	30 min	1 h	2 h	6 h	12 h	24 h
1905	10.4	17.8	20.8	26.4	36.1	42.2	43.9	46.2	53.1
1906	9.1	16.8	21.6	26.7	32.3	32.3	39.1	39.6	39.6
1907	9.9	15.5	17.5	17.5	21.6	24.4	29.5	42.4	47.2
1935	4.3	7.1	8.9	10.7	18.8	25.4	41.7	46.5	46.5
1937	9.7	10.2	14.2	24.4	25.7	25.7	29.5	37.8	38.9
1938	14.0	19.0	23.4	31.7	32.5	34.5	71.1	71.6	71.6
1954	-99.9	-99.9	10.2	20.3	25.7	27.2	39.9	41.1	41.4
1957	-99.9	-99.9	16.3	21.8	28.4	42.7	42.7	42.7	42.7
1959	10.7	18.8	24.1	27.4	28.2	37.3	42.4	44.4	44.4
1960	7.1	8.4	12.2	15.7	19.6	25.7	34.5	37.6	37.6
1961	7.9	12.4	15.7	19.6	24.9	25.1	25.1	25.1	26.4
1962	7.9	13.2	14.0	24.1	29.0	30.2	30.7	37.1	37.1
1963	10.4	16.5	17.8	18.0	18.0	20.6	49.3	57.9	58.2
1964	6.1	9.1	13.7	19.6	23.6	25.7	25.7	30.2	32.5
1965	9.1	13.7	15.7	16.3	18.3	22.4	30.7	36.1	36.1
1966	7.4	12.4	15.2	19.6	23.1	28.4	28.7	28.7	30.5
1967	5.6	8.4	11.9	15.0	21.8	36.3	43.7	47.5	52.8
1968	7.6	8.4	8.4	9.4	15.7	21.6	34.5	43.4	43.4
1969	10.4	14.2	19.6	30.7	38.6	38.6	39.1	51.3	61.0
1970	10.2	11.9	15.2	16.3	23.1	31.0	36.1	40.9	48.8
1972	11.7	19.6	22.4	27.2	33.0	33.0	45.5	48.3	55.4
1973	10.9	15.7	17.8	22.6	41.4	42.2	59.7	60.5	60.5
1974	11.2	14.5	16.3	17.3	21.6	24.6	31.2	33.0	33.8
1975	8.1	10.9	13.2	16.5	21.6	24.1	25.1	32.8	42.7
1976	14.0	18.3	24.4	27.2	33.8	34.3	34.3	34.3	44.2
1977	12.7	18.0	23.9	36.6	42.7	43.7	43.7	43.7	43.7
1978	10.3	12.2	16.3	16.7	19.0	20.1	24.7	33.6	37.4
1980	11.8	12.9	12.9	16.2	19.0	20.8	26.7	43.8	53.9
1981	7.8	15.1	21.7	31.6	38.0	40.6	48.5	51.0	51.8
1982	9.6	10.7	13.4	23.1	24.0	24.2	30.5	34.6	34.6
1983	7.4	14.0	17.8	20.6	33.4	33.8	33.8	33.8	47.4
1984	7.1	9.6	12.0	15.8	22.4	24.7	30.6	32.7	42.6
1985	11.2	13.9	16.3	17.7	20.0	27.4	34.9	34.9	34.9
1986	7.3	7.3	9.4	14.4	20.8	27.2	47.2	75.6	83.4
1987	8.2	11.0	13.9	16.5	16.7	16.8	33.9	40.0	50.8
1988	10.7	20.8	31.2	36.4	53.8	71.0	80.6	82.0	82.0
1989	9.4	11.6	15.3	17.9	20.4	38.2	57.6	59.5	59.9
1990	16.4	19.2	20.8	22.7	22.7	25.5	31.6	62.6	62.6
1991	8.4	10.2	10.4	14.3	15.8	15.8	25.8	37.1	42.9
1992	5.1	6.7	8.6	15.4	25.7	32.4	36.2	38.0	38.2
1993	8.1	13.6	15.5	19.9	20.9	21.3	24.5	26.6	47.4
1994	9.9	12.3	17.3	18.9	20.6	31.2	41.1	42.9	42.9
1995	6.9	9.7	11.9	12.6	19.0	28.0	45.6	74.2	79.4
1996	7.5	14.7	20.4	28.5	33.6	47.1	74.8	74.8	74.8
2000	8.2	12.4	17.3	19.7	21.6	24.3	52.1	66.4	66.4
2001	8.0	12.7	16.8	18.6	18.6	18.6	21.8	31.4	44.7

2002	4.9	6.7	8.9	13.6	17.9	21.3	26.3	37.4	57.3
2003	7.0	11.4	14.4	19.2	20.8	22.4	22.4	34.2	41.6
2004	7.9	10.0	10.4	17.1	28.3	40.6	99.7	122.5	131.9
2005	11.6	14.9	15.6	20.3	24.5	40.0	47.1	47.1	47.1
2006	7.0	13.2	14.2	22.6	27.8	36.8	52.0	54.4	54.6
2007	11.4	18.8	21.2	21.4	25.2	26.4	51.6	75.4	75.6
2008	8.4	12.4	15.0	15.2	15.2	19.0	32.8	43.2	43.4
2009	9.2	12.6	16.0	23.0	23.0	23.0	29.4	41.4	69.2
2010	10.0	18.0	21.8	29.4	32.8	34.6	40.0	46.0	56.6
2011	8.0	10.8	12.2	15.8	16.6	22.6	33.0	34.0	42.2
2015	7.4	9.6	10.6	13.6	13.8	17.2	28.4	42.2	49.2
2016	11.2	17.0	19.2	22.4	25.6	34.2	42.6	55.2	59.4
2017	10.4	14.4	17.6	18.8	19.4	22.6	44.0	60.0	74.0
# Yrs. Années	57	57	59	59	59	59	59	59	59
Mean Moyenne	9.1	13.2	16.1	20.5	25.0	29.6	39.8	46.9	51.7
Std. Dev. Écart-type	2.3	3.6	4.7	5.9	7.8	9.5	14.8	16.9	17.2
Skew. Dissymétrie	0.53	0.19	0.61	0.82	1.33	1.57	1.83	1.97	2.04
Kurtosis	3.92	2.42	3.70	3.54	5.25	7.75	7.52	8.81	10.07

*-99.9 Indicates Missing Data/Données manquantes

Warning: annual maximum amount greater than 100-yr return period amount
Avertissement : la quantité maximale annuelle excède la quantité pour une période de retour de 100 ans

Year/Année	Duration/Durée	Data/Données	100-yr/ans
1988	15 min	31.2	30.8
1988	1 h	53.8	49.5
1988	2 h	71.0	59.5
2004	6 h	99.7	86.2
2004	12 h	122.5	100.0
2004	24 h	131.9	105.5

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Table 2a : Return Period Rainfall Amounts (mm)
Quantité de pluie (mm) par période de retour

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Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	8.7	10.8	12.2	13.9	15.2	16.4	57
10 min	12.6	15.8	17.9	20.6	22.6	24.5	57
15 min	15.3	19.5	22.2	25.7	28.2	30.8	59
30 min	19.5	24.8	28.2	32.6	35.9	39.1	59
1 h	23.7	30.6	35.2	41.0	45.2	49.5	59
2 h	28.1	36.5	42.0	49.1	54.3	59.5	59
6 h	37.4	50.4	59.1	70.0	78.1	86.2	59
12 h	44.2	59.1	69.0	81.5	90.8	100.0	59
24 h	48.9	64.0	74.1	86.8	96.2	105.5	59

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Table 2b :

Return Period Rainfall Rates (mm/h) - 95% Confidence limits
Intensité de la pluie (mm/h) par période de retour - Limites de confiance de 95%

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Duration/Durée	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans	#Years Années
5 min	104.9	129.6	145.9	166.5	181.8	197.0	57
	+/- 6.7	+/- 11.2	+/- 15.1	+/- 20.4	+/- 24.4	+/- 28.4	57
10 min	75.5	94.7	107.4	123.4	135.3	147.1	57
	+/- 5.2	+/- 8.7	+/- 11.8	+/- 15.9	+/- 19.0	+/- 22.1	57
15 min	61.4	77.9	88.9	102.7	112.9	123.1	59
	+/- 4.4	+/- 7.4	+/- 10.0	+/- 13.4	+/- 16.1	+/- 18.7	59
30 min	39.0	49.5	56.5	65.3	71.8	78.3	59
	+/- 2.8	+/- 4.7	+/- 6.3	+/- 8.5	+/- 10.2	+/- 11.9	59

1 h	23.7	30.6	35.2	41.0	45.2	49.5	59
	+/- 1.8	+/- 3.1	+/- 4.2	+/- 5.6	+/- 6.7	+/- 7.8	59
2 h	14.0	18.2	21.0	24.5	27.1	29.7	59
	+/- 1.1	+/- 1.9	+/- 2.5	+/- 3.4	+/- 4.1	+/- 4.8	59
6 h	6.2	8.4	9.8	11.7	13.0	14.4	59
	+/- 0.6	+/- 1.0	+/- 1.3	+/- 1.8	+/- 2.1	+/- 2.5	59
12 h	3.7	4.9	5.7	6.8	7.6	8.3	59
	+/- 0.3	+/- 0.6	+/- 0.8	+/- 1.0	+/- 1.2	+/- 1.4	59
24 h	2.0	2.7	3.1	3.6	4.0	4.4	59
	+/- 0.2	+/- 0.3	+/- 0.4	+/- 0.5	+/- 0.6	+/- 0.7	59

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Table 3 : Interpolation Equation / Équation d'interpolation: R = A*T^B

R = Interpolated Rainfall rate (mm/h)/Intensité interpolée de la pluie (mm/h)
RR = Rainfall rate (mm/h) / Intensité de la pluie (mm/h)
T = Rainfall duration (h) / Durée de la pluie (h)

****

Statistics/Statistiques	2 yr/ans	5 yr/ans	10 yr/ans	25 yr/ans	50 yr/ans	100 yr/ans
Mean of RR/Moyenne de RR	36.7	46.3	52.6	60.6	66.5	72.4
Std. Dev. /Écart-type (RR)	36.5	45.2	51.0	58.3	63.7	69.1
Std. Error/Erreur-type	8.1	10.5	12.1	14.1	15.6	17.1
Coefficient (A)	21.7	27.9	32.0	37.1	41.0	44.8
Exponent/Exposant (B)	-0.707	-0.694	-0.688	-0.682	-0.679	-0.676
Mean % Error/% erreur moyenne	7.5	8.1	8.4	8.7	8.9	9.0

Ministry of Natural Resources and Forestry

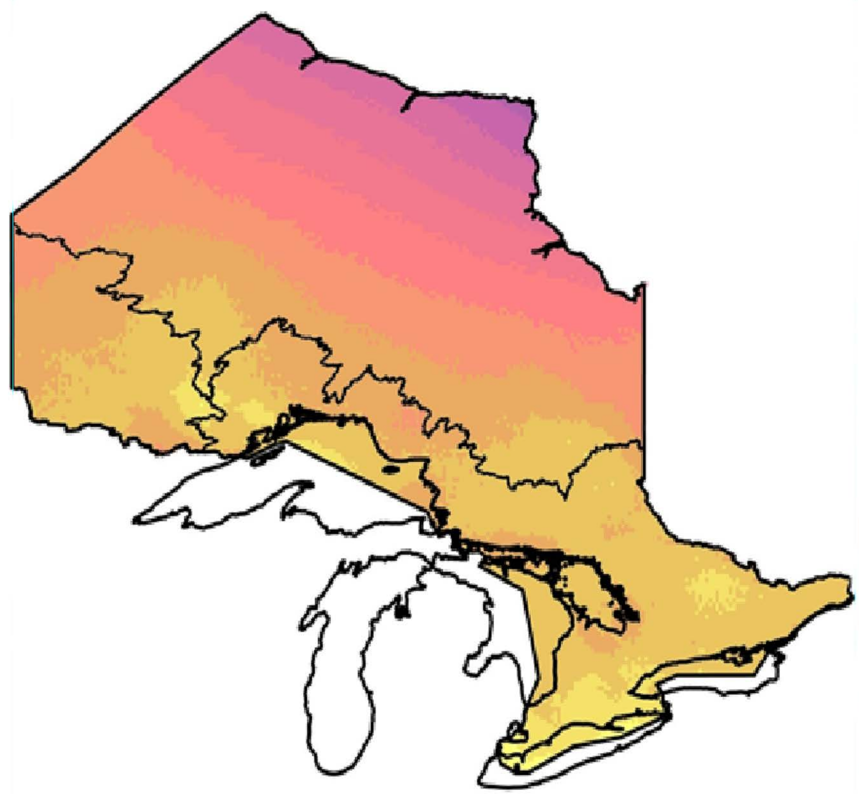
Science and Research

44

CLIMATE CHANGE RESEARCH REPORT

CCRR-44

Climate change projections for Ontario: An updated synthesis for policymakers and planners



Ontario

Sustainability in a Changing Climate: An Overview of MNRF's Climate Change Strategy (2011–2014)

Climate change will affect all MNRF programs and the natural resources for which it has responsibility. This strategy confirms MNRF's commitment to the Ontario government's climate change initiatives such as the Go Green Action Plan on Climate Change and outlines research and management program priorities for the 2011–2014 period.

Theme 1: Understand Climate Change

MNRF will gather, manage, and share information and knowledge about how ecosystem composition, structure and function – and the people who live and work in them – will be affected by a changing climate. Strategies:

- Communicate internally and externally to build awareness of the known and potential impacts of climate change and mitigation and adaptation options available to Ontarians.
- Monitor and assess ecosystem and resource conditions to manage for climate change in collaboration with other agencies and organizations.
- Undertake and support research designed to improve understanding of climate change, including improved temperature and precipitation projections, ecosystem vulnerability assessments, and improved models of the carbon budget and ecosystem processes in the managed forest, the settled landscapes of southern Ontario, and the forests and wetlands of the Far North.
- Transfer science and understanding to decision-makers to enhance comprehensive planning and management in a rapidly changing climate.

Theme 2: Mitigate Climate Change

MNRF will reduce greenhouse gas emissions in support of Ontario's greenhouse gas emission reduction goals. Strategies:

- Continue to reduce emissions from MNRF operations though vehicle fleet renewal, converting to other high fuel efficiency/low-emissions equipment, demonstrating leadership in energy-efficient facility development, promoting green building materials and fostering a green organizational culture.
- Facilitate the development of renewable energy by collaborating with other Ministries to promote the value of Ontario's resources as potential green energy sources, making Crown land available for renewable energy development, and working with proponents to ensure that renewable energy developments are consistent with approval requirements and that other Ministry priorities are considered.
- Provide leadership and support to resource users and industries to reduce carbon emissions and increase carbon storage by undertaking afforestation, protecting natural heritage areas, exploring opportunities for forest carbon management to increase carbon uptake, and promoting the increased use of wood products over energy-intensive, non-renewable alternatives.
- Help resource users and partners participate in a carbon offset market, by working with our partners to ensure that a robust trading system is in place based on rules established in Ontario (and potentially in other jurisdictions), continuing to examine the mitigation potential of forest carbon management in Ontario, and participating in the development of protocols and policies for forest and land-based carbon offset credits.

Theme 3: Help Ontarians Adapt

MNRF will provide advice and tools and techniques to help Ontarians adapt to climate change. Strategies include:

- Maintain and enhance emergency management capability to protect life and property during extreme events such as flooding, drought, blowdown and wildfire.
- Use scenarios and vulnerability analyses to develop and employ adaptive solutions to known and emerging issues.
- Encourage and support industries, resource users and communities to adapt, by helping to develop understanding and capabilities of partners to adapt their practices and resource use in a changing climate.
- Evaluate and adjust policies and legislation to respond to climate change challenges.

Climate change projections for Ontario: An updated synthesis for policymakers and planners

Jenni McDermid[1], Shannon Fera[2], and Adam Hogg[3]

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Cover image: Projected mean annual temperature for Ontario by 2050 under the 8.5 representative concentration pathway from the Intergovernmental Panel on Climate Change's Fifth Assessment Report.

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Executive Summary

In this report, climate change projections from the Intergovernmental Panel on Climate Change's Fifth Assessment Report are summarized for the province of Ontario. Projected changes in climate are described under three representative concentration pathways (i.e., low, medium, and high) for the three main drainage basins in Ontario: Hudson Bay, Nelson River (northwestern Ontario), and Great Lakes Basin and the five Great Lakes sub–basins (Lake Superior, Lake Huron, Lake Erie, Lake Ontario, and the Ottawa River). In each basin, projected mean annual, summer, and winter temperatures and total annual, summer, and winter precipitation are shown for three 30-year time periods: 2011–2040 (the 2020s), 2041–2070 (the 2050s), and 2071–2100 (the 2080s). Results of studies in which past observed climate trends were reviewed are also included to allow comparisons between past and future trends.

Across the province, warming is probable under all climate change scenarios throughout the century. The greatest temperature changes are projected in the Far North, with increases as high as 10 °C above 1971–2000 baseline levels by the 2080s. Across the three main drainage basins in Ontario, the Hudson Bay Basin is likely to experience the highest degree of warming, between 2.6 to 10.3 °C above the baseline by the 2080s. In comparison, projected temperature increases in the Nelson River Basin range from 2.6 to 8.8 °C above the baseline across the climate scenarios, while the Great Lakes Basin will experience a 1.5 to 7 °C increase in the same time frame. In all three basins, winter warming is likely to exceed summer warming.

Precipitation is projected to be more variable across the climate scenarios. The province could experience up to 240 mm more precipitation annually than historical levels. However, the Hudson Bay Basin may experience little change in precipitation, while the Nelson River and the Great Lakes Basins may experience drier summers (up to 60 mm less than historical levels by the 2080s in both basins, under the highest pathway). All three basins are likely to experience more precipitation in the winter; the largest increase in precipitation may be as much as 158 mm above historical levels, and is projected to occur in the Great Lakes Basin by the 2080s.

Within the Great Lakes Basin, temperature changes are projected to be largest in the northern portions of the basin. Mean annual air temperatures will increase the most in the Lake Superior sub-basin, ranging from 3.2 to 8.3 °C above historical levels by the 2080s, and lowest in Lake Erie, ranging from 2.8 to 7.2 °C above historical levels for the same time period. In all sub-basins and across the climate scenarios, winter warming will exceed summer warming. Projected precipitation patterns also indicate an annual increase across all five sub-basins, with the highest potential increases in Lake Superior sub-basin. Summers are projected to be drier basin-wide. Winter precipitation is likely to change more dramatically than summer precipitation, where the greatest change is projected in the Lake Huron sub-basin, averaging up to 85.2 mm above historical levels by the 2080s.

Acknowledgements

We thank Gary Nielsen and Jenny Gleeson for providing guidance throughout the project, and Steve Colombo and Paul Gray for providing revisions of this manuscript. We sincerely thank Greg Sikma for providing the GIS map colour schemes for the climate projections, Chad Cordes for GIS assistance while summarizing the models, and Dan McKenney for providing the updated raw climate model data used in this report. Lyn Thompson assisted with final edits and layout for this report. Funding for this project was provided by MNRF's Climate Change Program in the Priorities and Planning Section.

Contents

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Definitions of acronyms and terms used in this report

- IPCC: The Intergovernmental Panel on Climate Change. The panel base their projections on globally published literature of climate models.
- AR4: The IPCC's Fourth Assessment Report, with 40 different climate change scenarios.
- AR5: The IPCC's Fifth Assessment Report. This is the current report (2014).
- RCP: Representative Concentration Pathways. These are the scenarios in the AR5. The projections in this report are based on the RCP scenarios, also referred to as climate scenario and pathway.
- RF: Radiative Forcing. This is the aggregated climate driving forces used in the AR5. It is expressed in W m^{-2} (watts per square metre).
- GHG: Greenhouse gases. Gases that trap heat in the atmosphere including carbon dioxide and methane. They are the drivers of climate change.
- ESM: Earth System Model. These are global climate models. The projections used in this report are based on a composite model, which is an average of 4 ESMs (CanESM2, MIROC-ESM-CHEM, CESM1-CAMS, hadGEM2-ES).
- ArcGIS: Software for creating maps and conducting spatial analyses.
- Downscaling: the process of converting large-scale trends into small-scale predictions.

Introduction

Historical climate trends review

Climate, which includes temperature and precipitation, is closely linked with several characteristics of life on earth, including species distribution, abundance, productivity and important biological processes such as species migration, flowering, and bud burst (McKenney et al. 2011). Ontario's climate has warmed by up to 1.6 °C over the past 63 years, and increases in both temperature and precipitation are projected to continue over the next century (Colombo et al. 2007). Changes in climate may result in fundamental alterations in the environment that could affect the growth, distribution, and abundance of many species. Numerous studies have documented long term ecological changes attributed to climate change in species worldwide (McCarty 2001), including species' ranges, breeding and migration dates, and growing season length.

Environment Canada's weather station records include over 100 years of observations. To understand long-term climate trends, extensive efforts have been made to standardize weather station records by accounting for varying techniques of observation and local-scale station relocations (Vincent et al. 2012; Mekis and Vincent 2011). One long-term climate trend study, conducted by Vincent et al. (2012), indicated that mean annual daily temperatures in Ontario have increased by 0.5 °C to 1.5 °C over a 61-year period (1950–2010). Southern Ontario has experienced significant increasing trends in mean annual temperatures, while changes in the north have been variable. Ontario's spring and winter trends also tend to be similar: most significant and dramatic in the northwest and the south. In particular, increases in winter temperatures are noticeable in southern Ontario around the Great Lakes and St. Lawrence River. Though warming in Ontario is significant, changes are less than those in western and northern Canada.

In a similar study, Mekis and Vincent (2011) note increasing rainfall across Canada over a 60-year period (1950 to 2009). Generally, increases in rainfall are highest in the spring season. Weather stations in Ontario show that rainfall has generally increased in all seasons, but the most pronounced increases (by up to 50%) are seen in northwestern Ontario (i.e., the vicinity of Thunder Bay) during spring. Fewer significant changes in precipitation have occurred in the summer. On average, the stations situated on the north shores of the Great Lakes show significant increases. The total number and spatial distribution of weather stations showing significant trends are irregular across the province.

Mekis and Vincent (2011) documented a 4% increase in national mean annual snowfall for the same 60-year period (over the comparative normal period 1961–1990). The trend, though, is inconsistent both through time and across the country. In Ontario, stations that show significant winter snowfall increases (by 10–30%) are located in the southern portion of the province near the Great Lakes snow-belt areas. Changes to winter snowfall levels elsewhere in the province are not statistically significant. In both spring and fall, data from most weather stations shows no changes in snowfall, with the exception of southern Ontario and south of James Bay, where dramatic decreases in snowfall have been documented.

Weather station data is a useful, direct source of information to analyze climate trends. Still, climate is variable and complex, and there are several limitations to interpreting data from on-the-ground observations. To address this problem, grids have been developed for Ontario and Canada to interpret climate trends at many scales. These grids are useful tools for extending observed trends beyond the time and space the current weather station network is intended to cover. They therefore allow us to project changes in climate based on past and future possible trends. However, station data is crucial for calibrating and validating climate grids and large portions of Ontario (e.g., Ontario's Far North) have few weather stations. This limits our understanding of the precision and accuracy of the projections made in these climate grids. Therefore, caution should be used when interpreting climate trends in this part of the province.

Intergovernmental Panel on Climate Change climate projections

This report is an update to MNRF's Climate Change Research Report 5: Climate Change Projections for Ontario (Colombo et al. 2007), which was based on the Intergovernmental Panel on Climate Change (IPCC)'s A2 and B2 scenarios from the fourth assessment report (AR4). The primary difference in climate change modelling since the AR4 publication is the use of the new emission scenarios; the fifth assessment report (AR5) introduced four new emission scenarios, termed representative concentration pathways (RCPs), which replaced the 40 AR4 scenarios (Figure 1). The RCPs include climate driving forces (e.g., aerosols, land cover) not considered in the AR4 scenarios, in addition to greenhouse gases, which are combined into one product, termed Radiative Forcing (RF) and expressed as Watts per square metre ($W\ m^{-2}$). The four RCP climate scenarios are generally described as:

- RCP8.5 ($W\ m^{-2}$): Very high emission scenario and a failure to curb warming by 2100. GHG emissions are up to seven times higher than preindustrial levels. Similar to the highest AR4 emission scenario.
- RCP6.0 ($W\ m^{-2}$): A medium-high stabilization scenario where total RF stabilizes shortly after 2100 by the application of a range of technologies and strategies for reducing GHG emissions.
- RCP4.5 ($W\ m^{-2}$): A medium stabilization scenario where RF stabilizes by 2100. Similar to the lowest-emission scenario assessed in AR4.
- RCP2.6 ($W\ m^{-2}$): Medium-low scenario with aggressive mitigation. Emissions peak early, and then fall due to active removal of atmospheric carbon dioxide. Requires all the main GHG emitters, including developing countries, to participate early on in climate change mitigation policy.

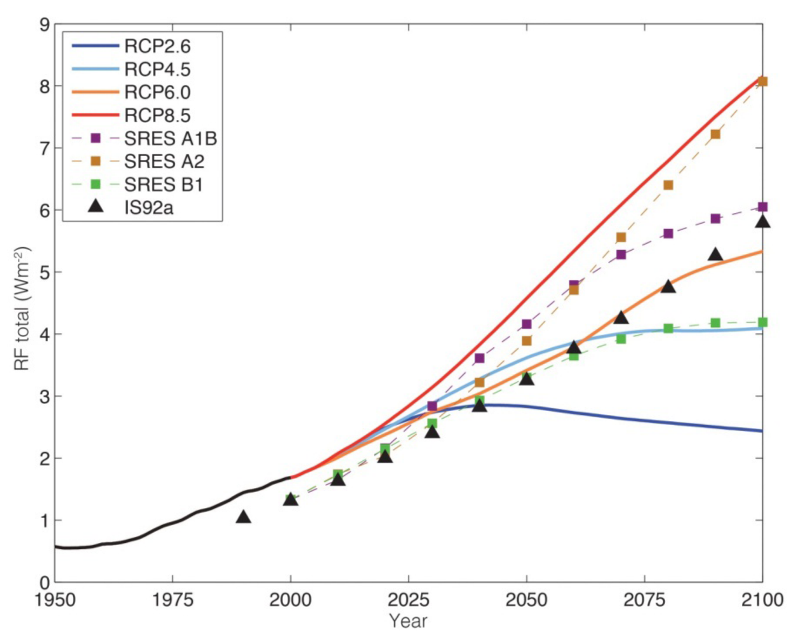

Figure 1. Comparison of emission scenarios and representative concentration pathways (RCP) from the fourth and fifth assessment reports (AR4 and AR5) (from IPCC 2013).

Methods

Projected changes in Ontario's climate are shown for three time periods (2011–2040, 2041–2070, and 2071–2100) and three climate scenarios (RCP 2.6, 4.5, and 8.5) from the AR5. Several methods can be used to project future climate in Ontario, including the data produced by Dan McKenney (Natural Resources Canada, Canadian Forest Service, Sault Ste. Marie, ON) that use statistically downscaled data from the composite AR5 Earth System Model. McKenney's data are the first available product in Ontario that uses the AR5 scenarios and are readily applicable to natural resource management and are therefore used for this report. The projections are in the form of 5 x 5 km grids for 35 climatic variables using thin-plate spline statistical downscaling (McKenney et al. 2006; 2011; 2013), and are available for four statistically downscaled Earth Systems Models (ESMs are the next generation of global climate models): CanESM2, MIROC-ESM-CHEM, CESM1-CAM5, HadGEM2-ES, plus a composite model, calculated using the arithmetic average of the four ESMs.

The World Meteorological Organization defines climate as the 30-year average of weather[1]. Climate variables vary considerably at annual time scales, so the 30-year average is the standard time frame used to smooth out this variation. Climate also varies with the time of year and location; therefore climate variability is summarized by annual and seasonal means. For each of the watersheds, we show summary statistics of changes in climate from the 1971–2000 baseline including mean (average of each basin, for each time period), standard deviation (used to quantify the variation in the values from each basin) and range (minimum and maximum values in the basin). The data is summarized in tabular, graphical, and map format, using ArcGISv.10.1, for total annual (January to December), winter (December to February), and summer (June to August) temperature and precipitation. The maps in this publication demonstrate examples of a full suite of maps available to practitioners for application in resource management decision-making and planning.

We have summarized the downscaled climate information by (i) climate scenario (also referred to as pathway (RCP 2.6, 4.5 and 8.5); (ii) time frame (2011–2040, also referred to as 2020s, 2041–2070, also referred to as 2050s, and 2071–2100, also referred to as 2080s); (iii) season (summer and winter); (iv) primary watershed in Ontario (Great Lakes, Hudson Bay, Nelson River) and the sub-basins of the Great Lakes watershed (Figure 2). All maps of future climate are shown as the change in temperature and precipitation compared to the 1971–2000 baselines. Generally speaking, the most dramatic changes are expected in winter. We have chosen to focus on summer and winter seasons to illustrate the two extremes of climate change. The objective of these syntheses is to provide end-users with a range of potential future climates for Ontario that can be considered in policy, management, and planning; however, if more specific data for fall and spring are needed, this information is readily available.[2]

1 wmo.int/pages/themes/climate/climate_data_and_products.php
2 See for example, Canadian Forest Service Regional, national and international climate modelling cfs.nrcan.gc.ca/projects/3

Figure 2. Map of the three primary watersheds in Ontario: Hudson Bay (yellow), Nelson River (blue), and Great Lakes (purple) basins, with the locations of cities shown for reference and a call out map of the five sub-basins on the Great Lakes Basin.

Results

Climate projections for Ontario

Warming is projected across the entire province throughout the 21st century (mean annual temperatures are shown in Figure 4). The greatest increase, of up to 10.3 degrees by the 2080s under RCP 8.5 (Table 1), is projected to occur in the Far North along the Hudson Bay coastline. Projected increases in mean annual temperature across Ontario average 2.3 °C by the 2020s, 4.1 °C by the 2050s, and 5.6 °C by the 2080s, varying by climate scenario (also referred to as pathway) (Table 1; Figure 4). Across the province, it is probable that warming will be greater in the winter with projected change in average temperatures ranging from 1.1 to 13.9 °C (Table 1), than in the summer with projected change in average temperatures ranging from 1.2 to 9.8 °C (Table 1), and greater in the north than the south (figures 4-6).

It is possible that the entire province may experience changes in total precipitation under the three pathways (Figure 7). Overall increases of up to 240 mm of precipitation annually may occur in Ontario by the 2080s, though the Nelson River Basin and Hudson Bay Basin may become drier with up to 60 mm less precipitation than baseline levels, while the Great Lakes Basin could become progressively wetter over time (Figure 3; Figure 7). Across the province, more precipitation is projected in the winter, though this could vary greatly by region (provincial range is from -56 to 158 mm from historical levels; Table 1; Figure 8). Summers are projected to be drier on average, with a range of -69 to 48 mm less precipitation than historical levels across the province by the 2080s (Table 1; Figure 9).

Table 1. Projected changes in temperature and precipitation from 1971–2000 baselines for the province of Ontario, under three representative concentration pathways (2.6, 4.5, and 8.5), and for three time periods (2011–2040, 2041–2070, 2071–2100). For each entry, the first row is the mean (standard deviation) and the second row is the range across the province (minimum to maximum).

	Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
		RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Annual	Temperature (°C)	2.3 (0.2)	2.2 (0.1)	2.5 (0.2)	3.3 (0.3)	4 (0.2)	4.9 (0.3)	3.3 (0.3)	5.1 (0.3)	8.5 (0.6)
		1.7 to 3.2	1.6 to 3.1	1.8 to 3.4	2.5 to 4.2	3.1 to 4.8	4 to 5.9	2.4 to 4.2	3.9 to 6.2	6.7 to 10.3
	Precipitation (mm)	34.8 (41.9)	25.6 (38.1)	33 (41.1)	63.9 (43.7)	53 (43.7)	69.2 (43.2)	64.8 (42.7)	57.2 (42)	82.1 (47.8)
		-125 to 189	-133 to 167	-130 to 187	-99 to 220	-100 to 206	-95 to 225	-102 to 217	-94 to 205	-81 to 240
Summer	Temperature (°C)	2 (0.2)	1.9 (0.2)	2.1 (0.2)	2.7 (0.2)	3.3 (0.2)	4.4 (0.2)	2.8 (0.3)	4.3 (0.3)	7.7 (0.4)
		1.2 to 4.6	1.2 to 4.5	1.3 to 4.7	1.8 to 5.2	2.5 to 5.7	3.7 to 6.8	1.9 to 5.3	3.3 to 6.7	6.8 to 9.8
	Precipitation (mm)	-1.4 (12.7)	-5.1 (11.8)	-5.2 (12)	6.6 (13.1)	-2.6 (12.6)	-9.1 (13.5)	7.3 (12.8)	-5.9 (13.3)	-21.2 (15.6)
		-63 to 39	-64 to 35	-61 to 36	-53 to 52	-57 to 38	-67 to 30	-59 to 48	-60 to 33	-69 to 32
Winter	Temperature (°C)	2.7 (0.5)	2.5 (0.4)	3.2 (0.6)	4 (0.8)	5.1 (0.8)	6.1 (0.9)	4.1 (0.7)	6.2 (0.9)	9.9 (1.3)
		1.3 to 4.4	1.1 to 4.1	1.8 to 5.2	2.3 to 6.8	3.5 to 7.9	4.2 to 9.3	2.6 to 6.7	4.3 to 9.5	6.6 to 13.9
	Precipitation (mm)	17.1 (17.8)	13.7 (16.1)	14.6 (17)	21.4 (19.1)	20.2 (17)	29.6 (21.6)	18.6 (17)	28.6 (19.6)	44.9 (28.5)
		-54 to 97	-56 to 85	-55 to 94	-53 to 99	-51 to 92	-48 to 121	-53 to 87	-49 to 116	-41 to 158

NOTE: The mean value is the average temperature or precipitation across Ontario. The standard deviation acts as measure of the variation or uncertainty around the mean. The range shows the spread, from minimum to maximum, of the values. For example, consider the average annual temperature in each time period under each representative concentration pathway. In all cases, both the mean temperature and the spread of temperatures are increasing at each time period compared to the base period. The fact that the standard deviation of the annual temperature increases for each time period could reflect that the variability may increase.

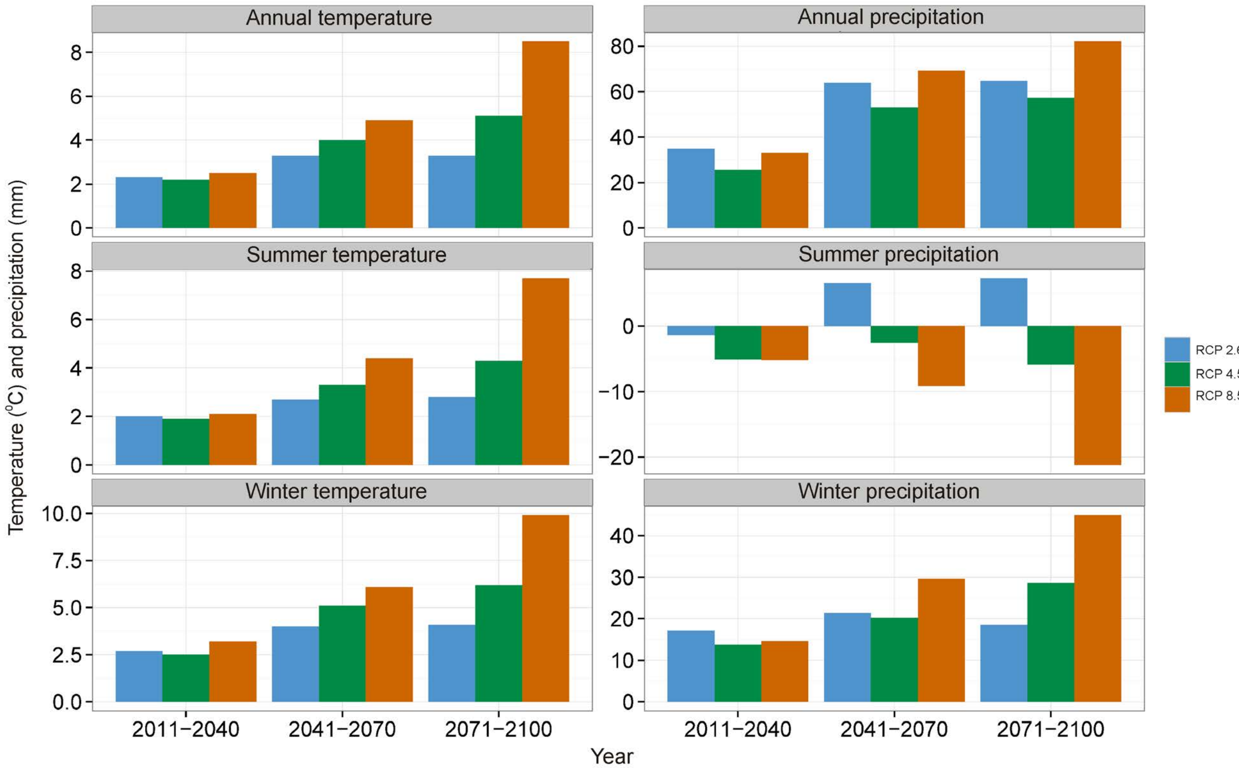

Figure 3. Projected changes in Ontario's mean annual temperature, annual precipitation, summer temperature, summer precipitation, winter temperature, and winter precipitation from 1971–2000 baseline values, under representative concentration pathways (RCP) 2.6, 4.5 and 8.5.

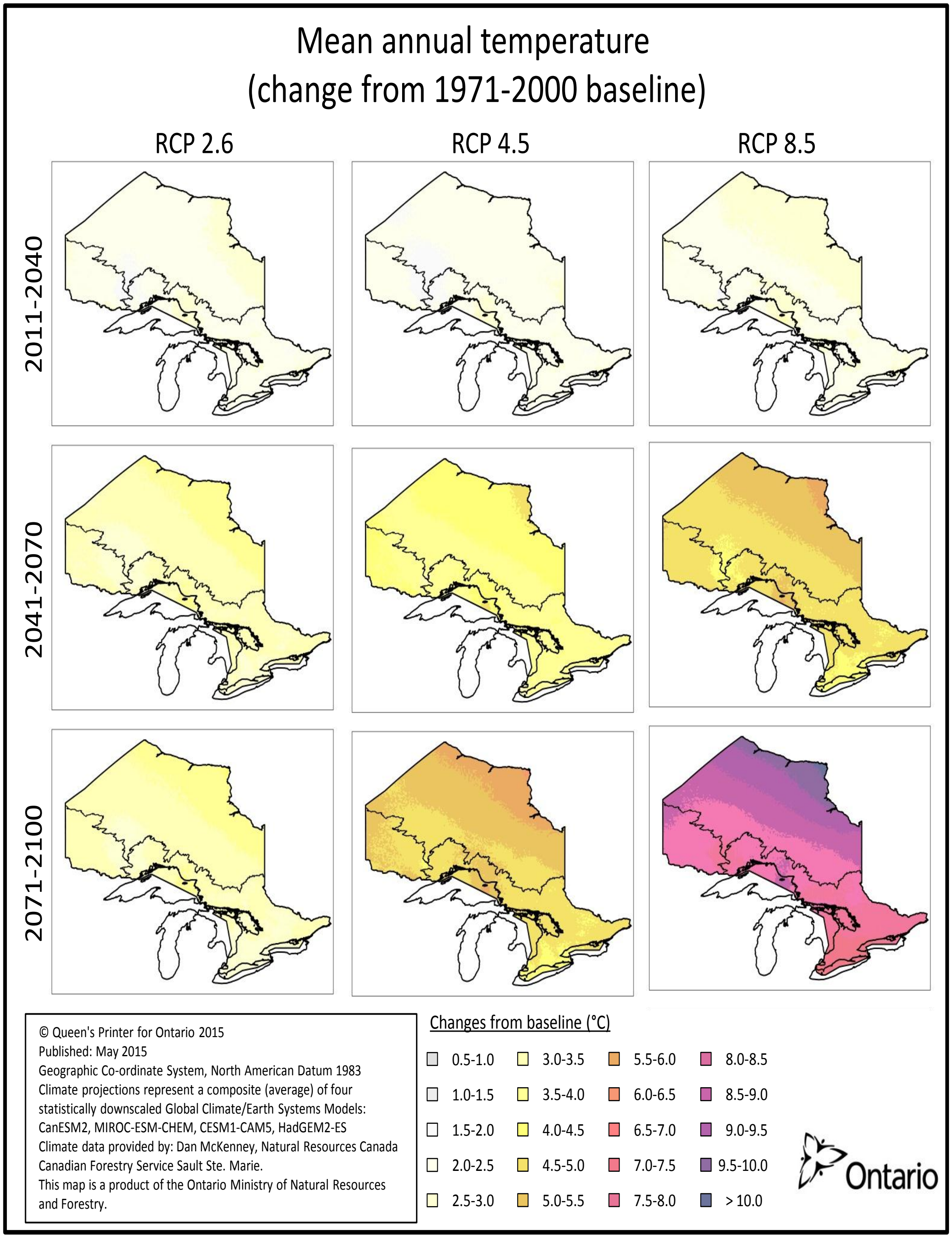

Figure 4. Projected changes in Ontario's mean annual temperature from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5, over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

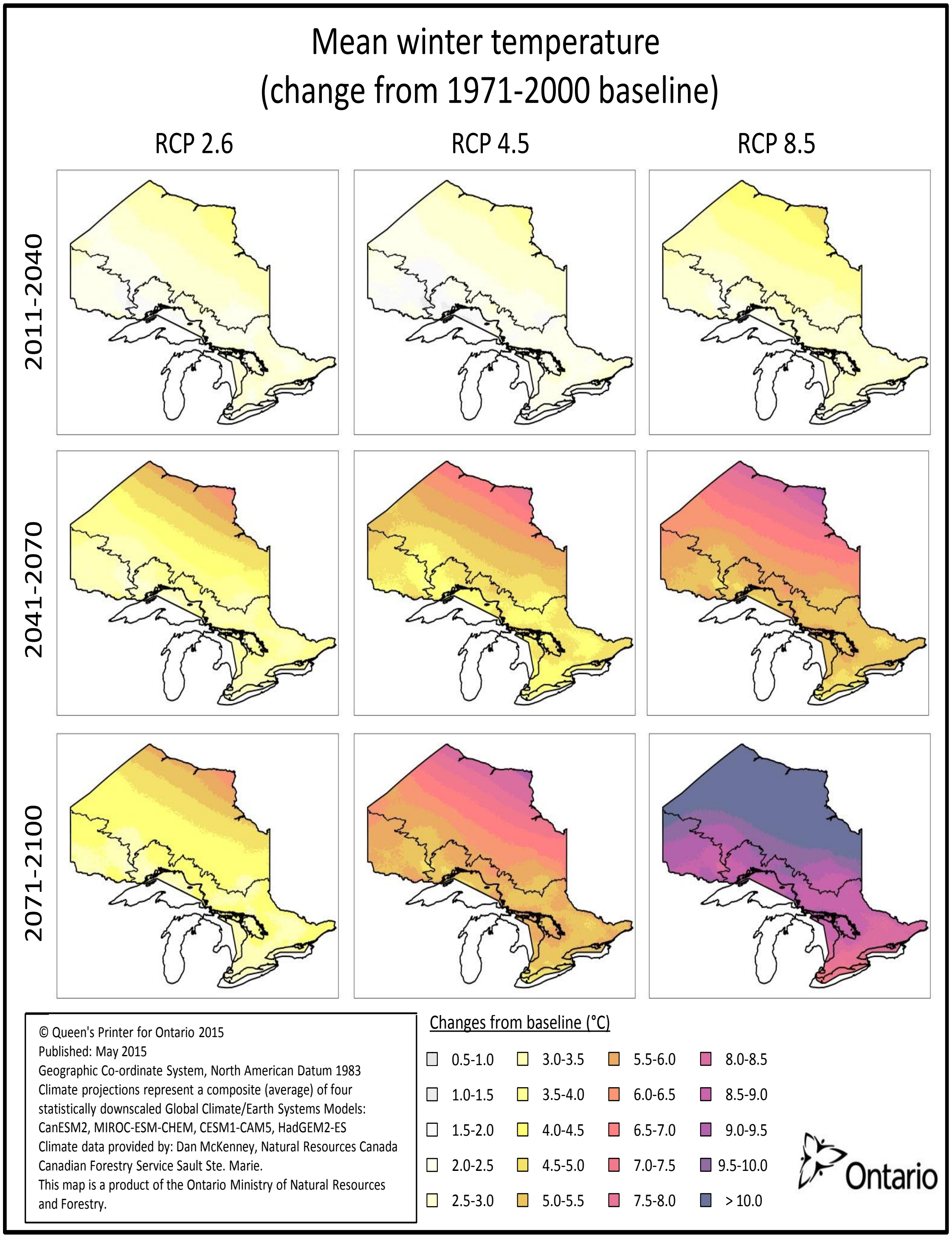

Figure 5. Projected changes in Ontario's mean winter temperatures from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5, over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

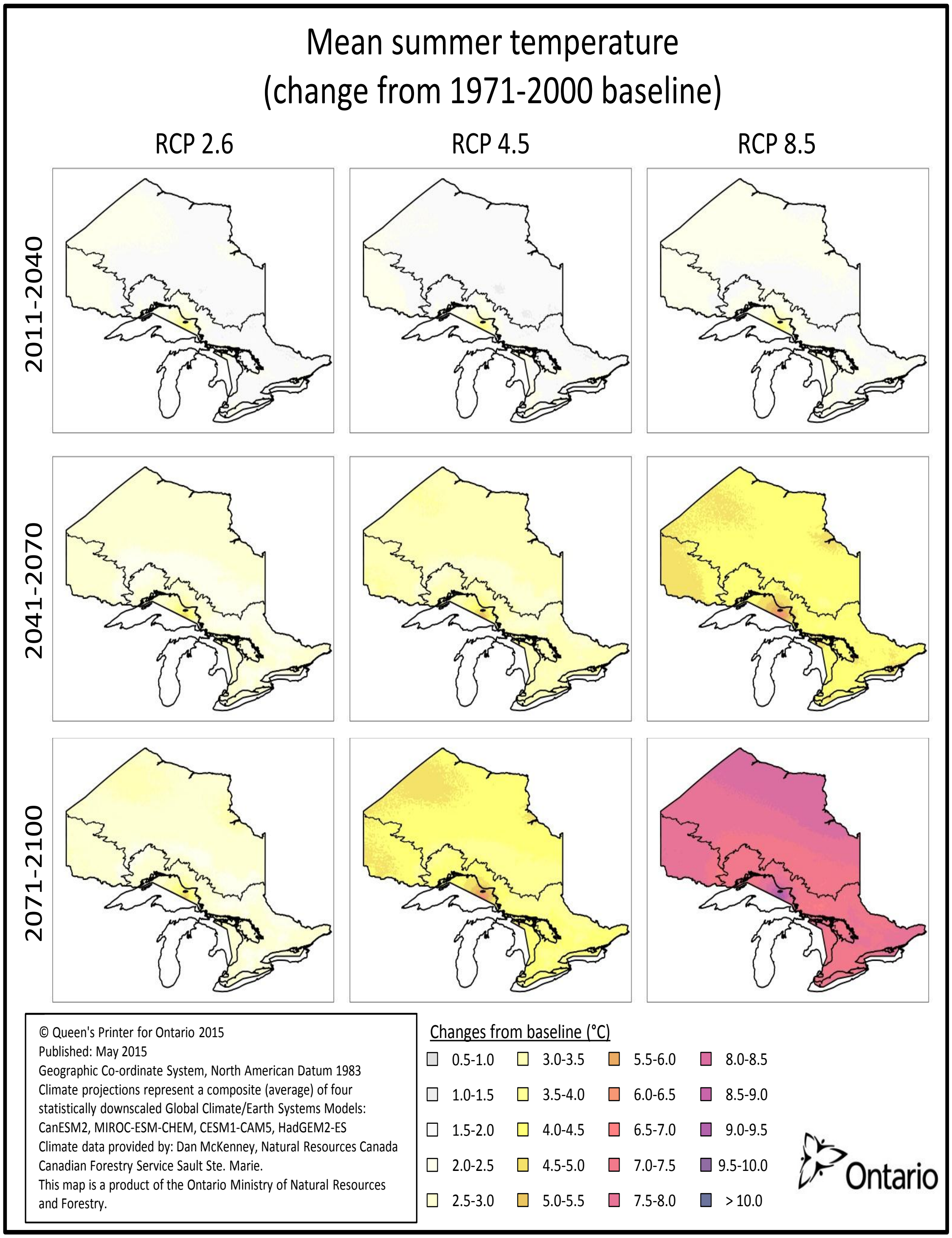

Figure 6. Projected changes in Ontario's mean summer temperatures from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5, over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

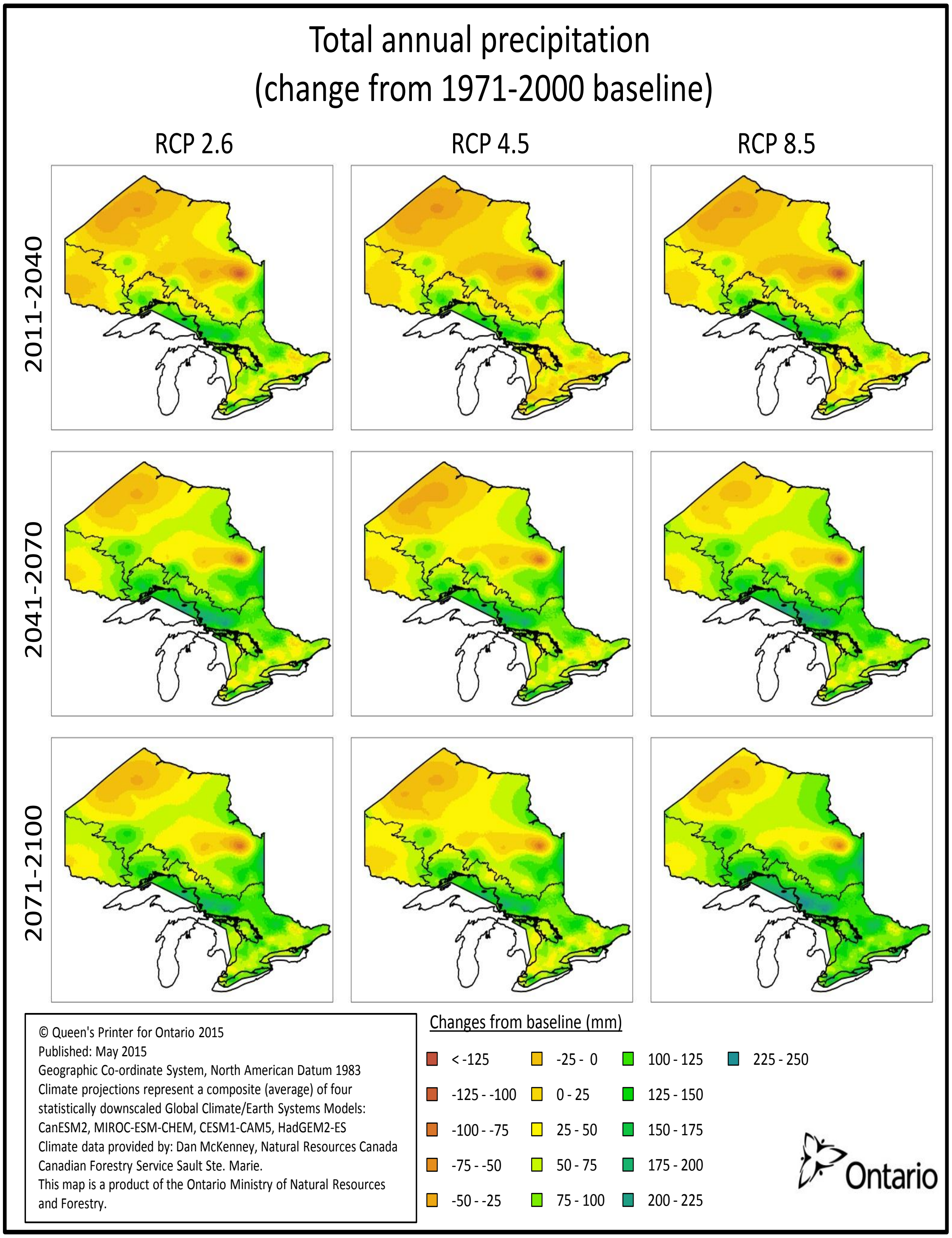

Figure 7. Projected changes total annual precipitation in Ontario from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5 over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

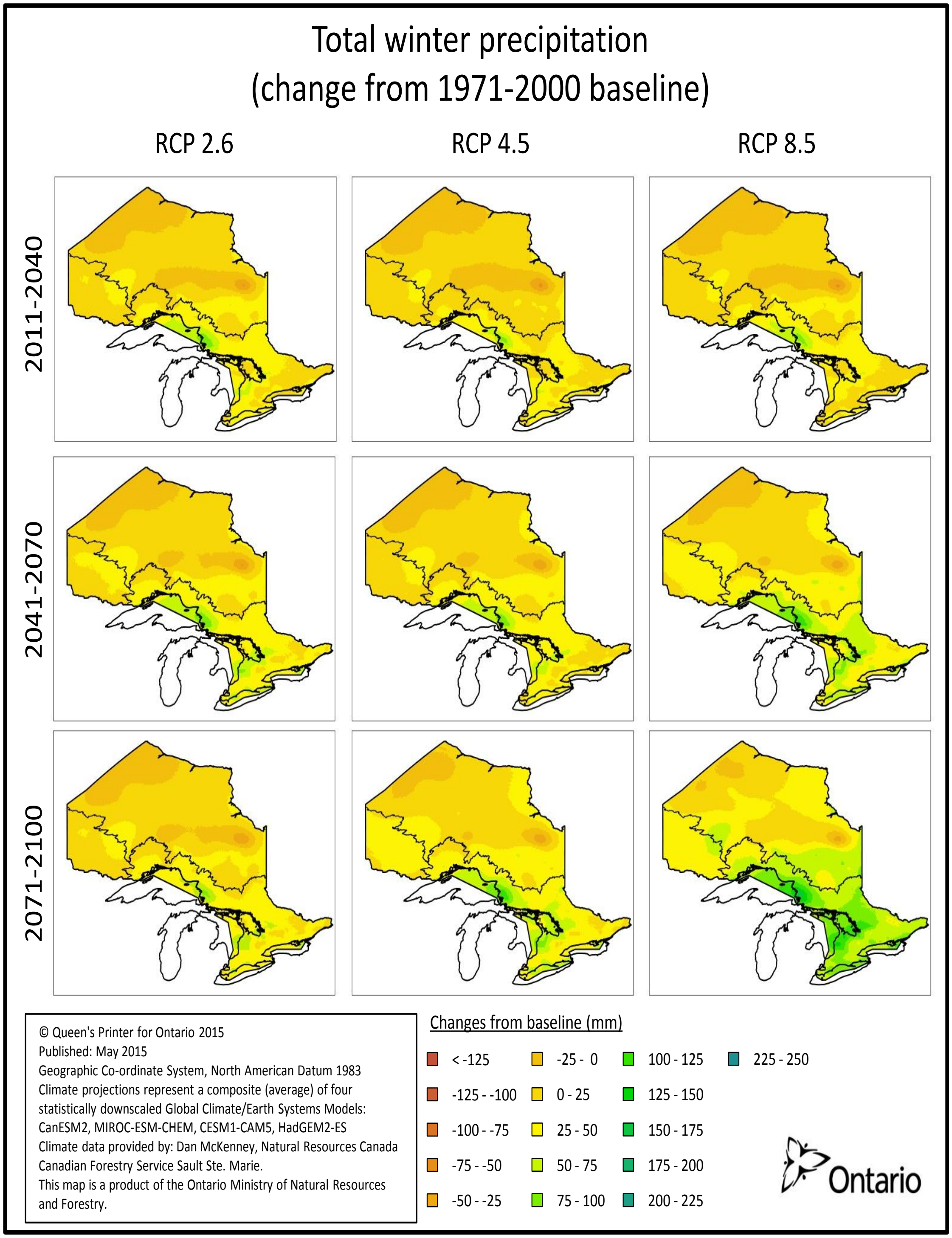

Figure 8. Projected changes in Ontario's winter precipitation from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5 over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

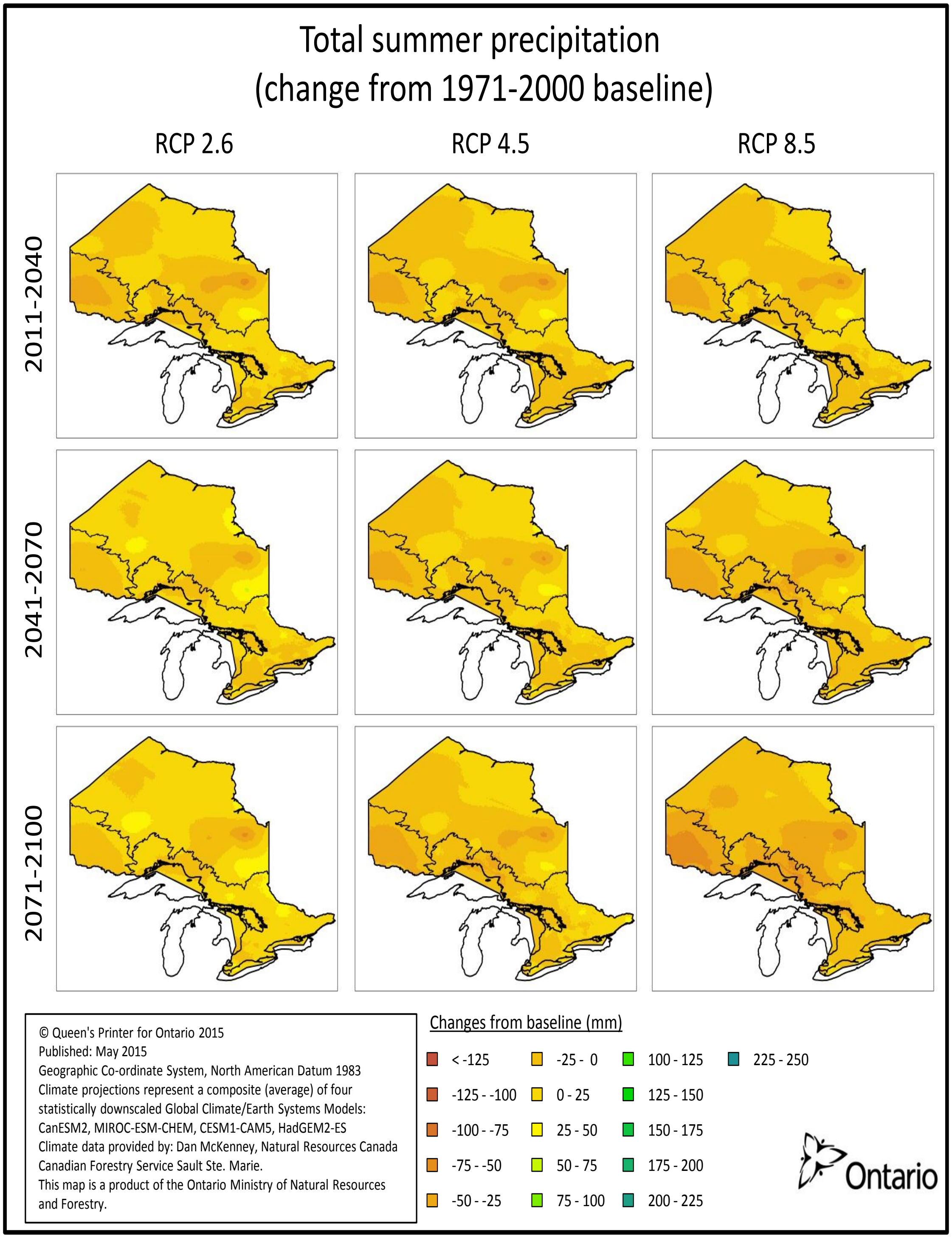

Figure 9. Projected changes in Ontario's summer precipitation from 1971–2000 baseline values for representative concentration pathways (RCP) 2.6, 4.5, and 8.5 over three 30-year time frames (2011–2040, 2041–2070, and 2071–2100). Data are derived from the composite AR5 model and statistically downscaled for the province. The three primary watersheds in Ontario are delineated on the map.

Climate projections for the Hudson Bay Basin

Annual climate

Throughout the 21st century, increases in mean annual air temperature are projected for the Hudson Bay Basin. By the 2080s, projected temperature increases range from 2.6 to 10.3 °C from historical levels across the pathways (Figure 4). Increases could be higher in the northern portion of the basin than the south (Figure 3; Table 2). On average, annual temperature could increase by 2.2 to 2.6 °C by the 2020s, 3.4 to 5.0 °C by the 2050s, and 3.4 to 8.9 °C by the 2080s (Table 2; Figure 10). Warming is projected to increase from the Great Lakes Basin boundary in a northeast gradient, peaking at the Hudson Bay/James Bay Coast (Figure 4).

Changes in precipitation differ across the Hudson Bay Basin (Figure 7). Changes in total annual precipitation are projected to be minimal, though slightly higher on average (10 to 63 mm above baseline levels; Table 2). The James Bay coast is projected to experience the greatest increase in precipitation (164 to 218 mm more precipitation than baseline levels). By the 2050s the area of increased precipitation is projected to extend diagonally across the Hudson Bay Basin towards Sioux Lookout (Figure 7; Figure 10). Along the Severn and Moose rivers, precipitation is projected to decrease; areas near Sachigo Lake, Bearskin Lake, and the Moore, Missinabi, and Mattagami rivers could become progressively drier over the century (Figure 7). It is possible, however, that some of the observed patterns are associated with the limited distribution of climate stations in the Far North.

Winter climate

Models project air temperature increases may be greater in winter months (Figure 5; Table 2). Winter warming of 1.5 to 4.4 °C by the 2020s is projected under RCP 2.6 (Figure 5; Table 2). Extreme warming upwards of 10 °C (up to a maximum of 13.9 °C; Table 2) may occur by the 2080s under RCP 8.5 across most of the Far North (Figure 5; Figure 10).

Winter precipitation is projected to remain relatively unchanged across the Hudson Bay Basin (Figure 8; Table 2). Depending on the pathway, precipitation changes may increase on average by 5 to 8 mm by the 2020s, 11 to 18 mm by the 2050s, and 9 to 29 mm by the 2080s.

Summer climate

Summer temperatures could increase more slowly than winter temperatures in the Hudson Bay Basin (Figure 3; Figure 6; Table 2). Summer warming of 1.4 to 2.4 °C is projected for the 2020s under RCP 2.6 (Figure 6; Table 2). The greatest warming may occur under RCP 8.5 in the region around Kashechewan and Fort Albany (Figure 6).

Summer precipitation could decline across the Hudson Bay Basin (Figure 9; Table 2). By the 2080s, rainfall may range from 69 mm less to 48 mm more than baseline levels. Depending on the pathway, precipitation changes may vary, ranging from 0.2 to 4 mm by the 2020s; -4 mm to 11 mm by the 2050s, and -17 mm to 6 mm by the 2080s (Table 2).

Table 2. Changes in temperature and precipitation from 1971–2000 baseline values for the Hudson Bay Basin under three representative concentration pathways (RCP 2.6, 4.5, and 8.5) and for three time periods (2011–2040, 2041–2070, and 2071–2100). For each entry, the first row is the mean (SD) and the second row is the range across the watershed (minimum to maximum).

	Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
		RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Annual	Temperature (°C)	2.3 (0.1)	2.2 (0.1)	2.6 (0.2)	3.4 (0.3)	4.1 (0.2)	5.0 (0.3)	3.4 (0.3)	5.3 (0.3)	8.9 (0.5)
		1.7 to 2.7	1.6 to 2.6	1.8 to 3	2.5 to 4.2	3.4 to 4.8	4.2 to 5.9	2.6 to 4.2	4.4 to 6.2	7.6 to 10.3
	Precipitation (mm)	17.1 (35.9)	10.4 (34.7)	15.1 (35.8)	48.6 (40.4)	37 (40.9)	54.3 (39)	47.2 (39.3)	42.7 (39.3)	62.7 (42.6)
		-125 to 164	-133 to 144	-130 to 152	-99 to 198	-100 to 193	-95 to 206	-102 to 197	-94 to 194	-81 to 218
Summer	Temperature (°C)	2 (0.1)	1.8 (0.1)	2.1 (0.1)	2.7 (0.2)	3.3 (0.2)	4.4 (0.2)	2.9 (0.2)	4.3 (0.3)	7.8 (0.3)
		1.5 to 2.3	1.4 to 2.2	1.6 to 2.4	2.1 to 3	2.6 to 3.6	3.8 to 4.7	2.2 to 3.2	3.5 to 4.7	7 to 8.6
	Precipitation (mm)	-0.2 (12.2)	-3.7 (11.9)	-4.1 (11.9)	10.5 (13)	0.7 (12)	-4.4 (12.2)	8.6 (13.8)	-3.2 (11.7)	-16.8 (13.4)
		-63 to 39	-64 to 35	-61 to 36	-53 to 52	-57 to 38	-67 to 30	-59 to 48	-60 to 33	-69 to 14
Winter	Temperature (°C)	2.3 (0.2)	2.1 (0.2)	2.7 (0.3)	3.2 (0.3)	4.7 (0.3)	5.6 (0.3)	3.6 (0.3)	5.6 (0.3)	9.3 (0.4)
		1.5 to 4.4	1.2 to 4.1	1.9 to 5.2	2.5 to 6.8	3.8 to 7.9	4.7 to 9.3	2.8 to 6.7	4.8 to 9.5	8.3 to 13.9
	Precipitation (mm)	7.6 (14.0)	4.5 (12.6)	5.6 (13.7)	10.5 (14.2)	11.7 (14.4)	17.6 (16.0)	8.8 (13.2)	18.0 (14.7)	28.9 (19.2)
		-54 to 49	-56 to 38	-55 to 44	-53 to 49	-51 to 54	-48 to 63	-53 to 45	-49 to 56	-41 to 88

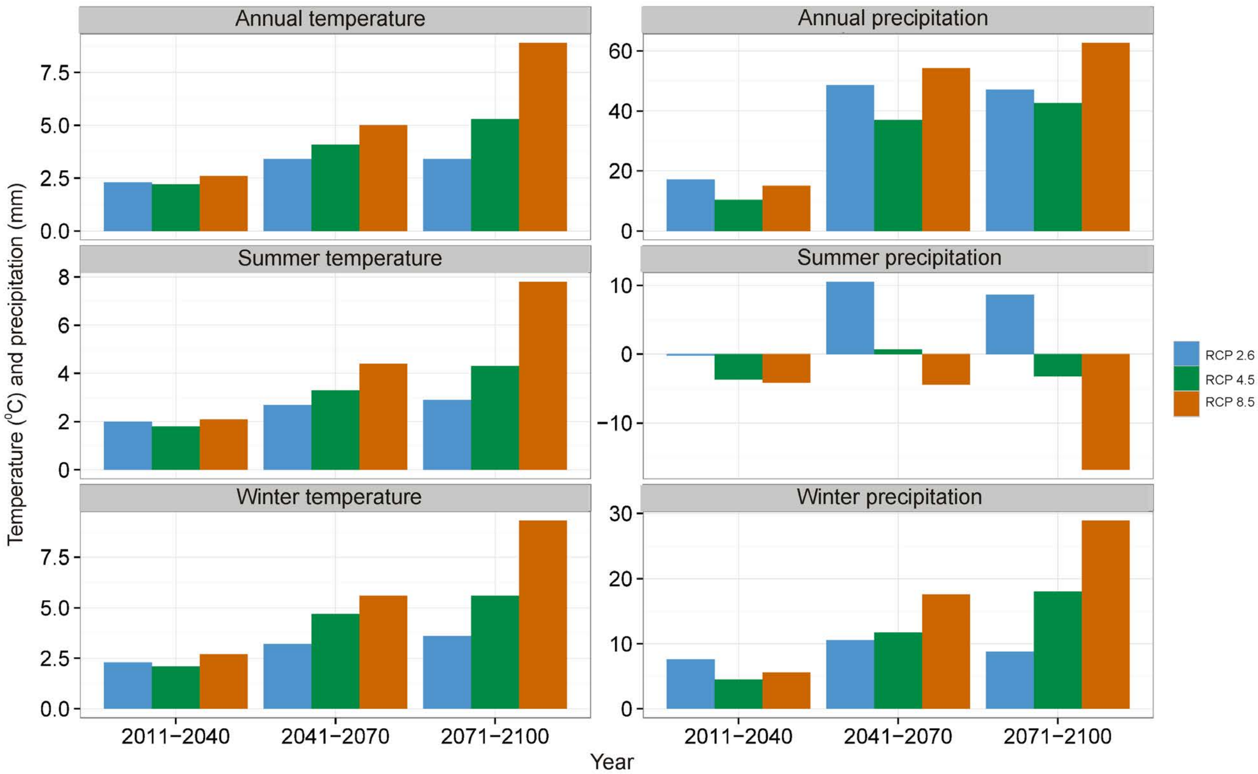

Figure 10. Projected changes in mean annual temperature, annual precipitation, summer temperature, summer precipitation, winter temperature, and winter precipitation from 1971–2000 baseline values in the Hudson Bay Basin under representative concentration pathways (RCP) 2.6, 4.5 and 8.5.

Climate projections for the Nelson River Basin

Annual climate

Increases in mean annual air temperature are projected through the 21st century in the Nelson River Basin. Models project mean annual air temperatures could increase by up to 8.8 °C by the 2080s, depending on the pathway used (Figure 4; Figure 11). Temperature increases are fairly consistent across the basin (Figure 4). On average, annual temperature may increase by 2.2 to 2.4 °C by the 2020s, 3.0 to 4.8 °C by the 2050s, and 3.1 to 8.3 °C by the 2080s (Table 3).

There is a precipitation gradient from west to east in the Nelson River Basin in the climate projections (Figure 7). Only slight increases in precipitation are projected for the western portion of the Basin, becoming progressively wetter from the Manitoba border towards the boundary with the Great Lakes Basin (Figure 7). Changes in total annual precipitation in the Nelson River Basin are likely to increase on average by up to 64 mm by the 2080s (Table 3).

Winter climate

Air temperature increases are likely to be greatest in winter months (Figure 5; Figure 11; Table 3). Projections for the 2020s indicate warming of 1.1 to 2.7 °C in the winter, 3.2 to 5.6 °C by the 2050s, and 3.6 to 9.3 °C by the 2080s, depending on the pathway (Figure 5; Table 3). Temperature increases are projected in a radiating pattern from the junction of the Nelson River Basin and the Great Lakes Basin (Figure 5).

Winter precipitation is likely to remain relatively unchanged across the Nelson River Basin (Figure 8; Table 3). Depending on the pathway, winter precipitation changes will increase slightly, on average by 19 to 22 mm above baselines by the 2020s, 22 to 31 mm by the 2050s, and 22 to 40 mm by the 2080s (Table 3).

Summer climate

Summer temperatures are projected to increase less than winter temperatures in the Nelson River Basin (Figure 6; Figure 11; Table 2). A west to east gradient of temperature warming may be observed from the Manitoba border towards the Great Lakes Basin boundary (Figure 6). Projections show summer warming of 1.4 to 2.6 °C by the 2020s, 2.7 to 4.6 °C by the 2050s, and 2.9 to 7.8 °C by the 2080s (Figure 6; Table 3), depending on the pathway used.

Summer precipitation may decline across the Nelson River Basin throughout the century (Figure 9). By the 2080s, rainfall may range from 60 mm less to 20 mm above baseline levels (Table 3). Depending on the pathway, precipitation changes may decrease on average by 19 to 21 mm by the 2020s, 7 to 27 mm by the 2050s, and 3 to 44 mm by the 2080s (Table 3; Figure 11).

Table 3. Changes in temperature and precipitation for the Nelson River Basin from 1971–2000 baseline values under three representative concentration pathways (RCP 2.6, 4.5, and 8.5) and for three time periods (2011–2040, 2041–2070, and 2071–2100). For each entry, the first row is the mean (SD) and the second row is the range across the watershed (minimum to maximum).

	Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
		RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Annual	Temperature (°C)	2.3 (0.2)	2.2 (0.1)	2.4 (0.1)	3 .0(0.1)	4.0 (0.2)	4.8 (0.2)	3.1 (0.1)	5.0 (0.2)	8.3 (0.2)
		1.7 to 2.7	1.6 to 2.6	1.8 to 2.9	2.5 to 3.5	3.4 to 4.4	4.2 to 5.2	2.6 to 3.6	4.4 to 5.4	7.6 to 8.8
	Precipitation (mm)	18.1 (19.3)	28.7 (17.2)	32.8 (18)	51.8 (21.7)	37.5 (19.9)	54.3 (22)	57.5 (19.1)	40.6 (20.2)	64 (22.4)
		-26 to 81	-6 to 91	-7 to 95	3 to 122	-9 to 103	2 to 119	12 to 116	-5 to 108	17 to 139
Summer	Temperature (°C)	2.2 (0.2)	2.1 (0.2)	2.3 (0.2)	2.7 (0.2)	3.4 (0.2)	4.6 (0.2)	2.9 (0.2)	4.4 (0.2)	7.8 (0.2)
		1.5 to 2.5	1.4 to 2.4	1.6 to 2.6	2.1 to 3.1	2.7 to 3.8	3.9 to 5	2.2 to 3.2	3.7 to 4.8	6.9 to 8.1
	Precipitation (mm)	-18.6 (10)	-19.1 (9.2)	-20.8 (9.2)	-7.4 (10.3)	-19.8 (8.8)	-27.7 (11.1)	-2.9 (9.3)	-24.1 (9.3)	-43.6 (10.6)
		-36 to 6	-35 to 8	-37 to 4	-25 to 18	-36 to 2	-46 to 4	-19 to 20	-41 to -1	-60 to -14
Winter	Temperature (°C)	2.3 (0.2)	2.1 (0.2)	2.7 (0.3)	3.2 (0.3)	4.7 (0.3)	5.6 (0.3)	3.6 (0.3)	5.6 (0.3)	9.3 (0.4)
		1.3 to 3	1.1 to 2.8	1.8 to 3.5	2.3 to 4	3.6 to 5.5	4.5 to 6.5	2.6 to 4.3	4.6 to 6.4	8.2 to 10.5
	Precipitation (mm)	21.7 (4.7)	19.4 (4.5)	18.8 (4.5)	24 (5.6)	21.6 (4.8)	30.6 (5.6)	21.9 (5)	30.6 (5.2)	39.7 (6.9)
		8 to 39	6 to 36	6 to 36	9 to 44	8 to 40	15 to 51	7 to 40	17 to 50	23 to 65

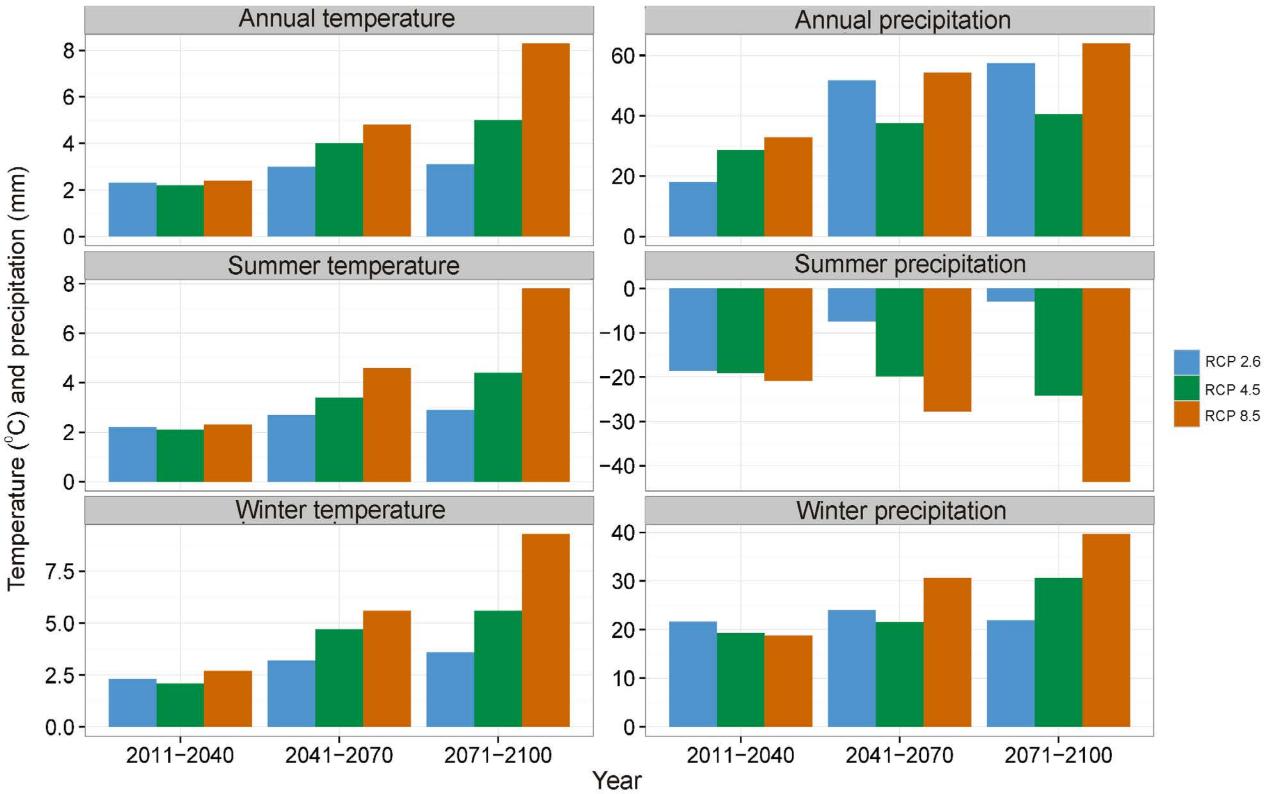

Figure 11. Projected changes in mean annual temperature, annual precipitation, summer temperature, summer precipitation, winter temperature, and winter precipitation in the Nelson River Basin from baseline values under representative concentration pathways (RCPs) 2.6, 4.5 and 8.5.

Climate projections for the Great Lakes Basin

Annual climate

Increases in mean annual air temperature are projected through the 21st century with model results showing 2.3 to 7.9 °C increases in mean annual air temperature, varying by pathway (Figure 4; Figure 12; Table 4). Mean annual air temperature is projected to increase more in the northern portion of the Great Lakes Basin compared to the southern part (Figure 4).

By the 2080s, annual precipitation is projected to increase by 99 to 123 mm or up to 20% depending on the pathway (Table 4) across the Great Lakes Basin. The greatest change will likely be in the Lake Superior basin (Figure 7). Lake effect precipitation is evident in most future projections (Figure 7), though its magnitude and spatial pattern vary greatly depending on pathway and time period.

Winter climate

Winter temperatures are projected to increase, on average by 2.5 to 2.8 in the 2020s, 3.5 to 5.3 by the 2050s, and 3.5 to 8.6 by the 2080s, depending on the pathway (Figure 5; Figure 12; Table 4). In the northern portion of the basin near Marathon warming, up to 10 °C, may occur by the 2080s under RCP 8.5, (Figure 5; Figure 12).

The Great Lakes Basin is projected to receive more precipitation adjacent to the lakes, and little change in winter precipitation in the inland areas (Figure 8). Under the RCP 8.5, the Great Lakes Basin could experience a 158 mm increase in precipitation by the 2080s, particularly near Sault Ste. Marie.

Summer climate

Across the Great Lakes Basin, mean summer temperatures could increase by 1.2 to 9.8 °C by the 2080s (Figure 5; Figure 12; Table 4), but this varies by pathway. Temperatures are projected to increase more in the eastern region of the Lake Superior sub-basin and in the Lake Huron sub-basin near Blind River (Figure 6).

For each subsequent time period, the Great Lakes Basin is projected to receive increasingly less summer rainfall (Figure 9). From the 2020s, the amount of precipitation received may not change. By the end of the century, under RCP 8.5 rainfall could decrease by as much as 75 mm in the region (Figure 9).

Table 4. Changes in temperature and precipitation from 1971–2000 baseline values for the Great Lakes Basin under three representative concentration pathways (RCP 2.6, 4.5, and 8.5) and for three time periods (2011–2040, 2041–2070, and 2071–2100). For each entry, the first row is the mean (SD) and the second row is the range across the watershed (minimum to maximum).

	Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
		RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Annual	Temperature (°C)	2.3 (0.2)	2.3 (0.2)	2.5 (0.2)	3.2 (0.2)	3.9 (0.2)	4.7 (0.2)	3.1 (0.2)	4.8 (0.2)	7.9 (0.4)
		1.7 to 3.2	1.7 to 3.1	1.8 to 3.4	2.5 to 4.1	3.1 to 4.8	4 to 5.7	2.4 to 4.1	3.9 to 5.8	6.7 to 9
	Precipitation (mm)	72.5 (31.3)	52 (34.2)	65.4 (35.6)	95.8 (37.9)	87 (34)	101.3 (38.1)	99.1 (32.7)	89 (33.6)	123.3 (35.3)
		-4 to 189	-27 to 167	-15 to 187	3 to 220	2 to 206	15 to 225	21 to 217	13 to 205	30 to 240
Summer	Temperature (°C)	2 (0.3)	2 (0.3)	2.1 (0.3)	2.6 (0.3)	3.2 (0.3)	4.4 (0.3)	2.7 (0.3)	4.1 (0.3)	7.5 (0.3)
		1.2 to 4.6	1.2 to 4.5	1.3 to 4.7	1.8 to 5.2	2.5 to 5.7	3.7 to 6.8	1.9 to 5.3	3.3 to 6.7	6.8 to 9.8
	Precipitation (mm)	2.3 (9.2)	-2.7 (8.8)	-1.7 (8.5)	4.2 (9.7)	-2.5 (9.4)	-11 (10.1)	8.4 (10.2)	-4.4 (12.3)	-21.4 (14)
		-24 to 36	-24 to 26	-23 to 32	-19 to 35	-26 to 37	-38 to 25	-19 to 42	-37 to 33	-59 to 32
Winter	Temperature (°C)	2.5 (0.3)	2.2 (0.3)	2.8 (0.2)	3.5 (0.3)	4.5 (0.3)	5.3 (0.3)	3.5 (0.3)	5.5 (0.3)	8.6 (0.6)
		1.5 to 3.2	1.3 to 3	2 to 3.5	2.6 to 4.2	3.5 to 5.2	4.2 to 6.2	2.6 to 4.3	4.3 to 6.3	6.6 to 9.9
	Precipitation (mm)	32.8 (14.7)	28.3 (12.2)	29.6 (13.7)	40.1 (14.5)	34.9 (13.4)	51 (16.5)	35 (11.7)	46.8 (16.4)	75.5 (21.6)
		-3 to 97	-3 to 85	-3 to 94	5 to 99	0 to 92	9 to 121	3 to 87	6 to 116	21 to 158

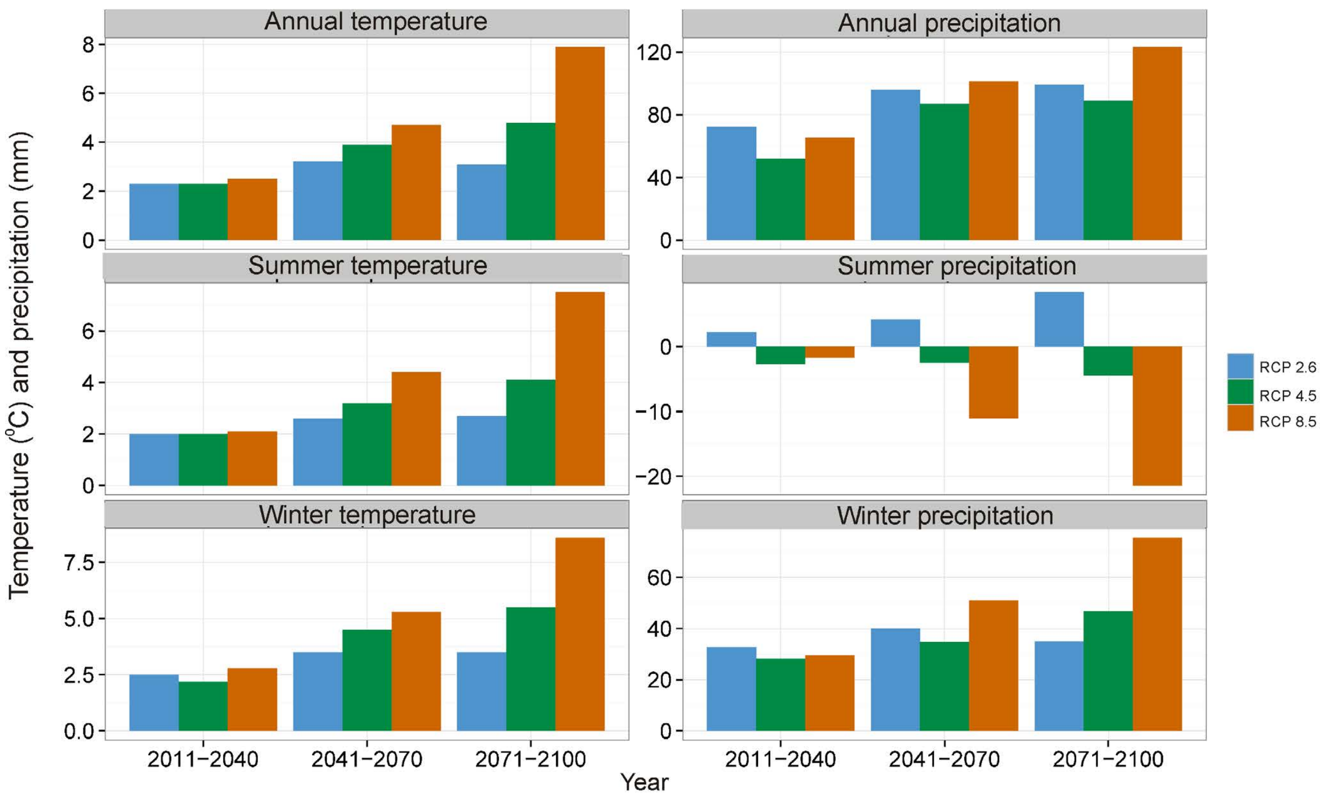

Figure 12. Projected differences in mean annual temperature, annual precipitation, summer temperature, summer precipitation, winter temperature, and winter precipitation from 1971–2000 baseline values in the Great Lakes Basin under representative concentration pathways (RCPs) 2.6, 4.5 and 8.5.

Comparison of Great Lakes sub-basin climates

Projected increases in mean annual air temperature are highest by the 2080s for the Lake Superior sub-basin (3.2 to 8.3 °C above 1971–2000 baselines), followed by the Lake Huron sub-basin (3.1 to 7.9 °C), the Ottawa River sub-basin (3.1 to 7.9 °C), the Lake Ontario sub-basin (3 to 7.6 °C) and the Lake Erie sub-basin (2.8 to 7.2 °C) (Table 5). Though increases are comparable across the sub-basins, a greater increase in mean annual air temperature may occur in the northern sub-basins.

Mean annual precipitation may increase across all five sub-basins (Table 5). By the 2080s, annual precipitation is likely to increase most in Lake Superior (103 to 131 mm above baseline levels across the three pathways), followed by Lake Huron (105 to 125 mm), Ottawa River (97 to 111 mm), Lake Erie (81 to 109 mm), and Lake Ontario (74 to 102 mm). The maximum potential difference in annual precipitation is also greatest for Lake Superior (up to 240 mm), and smallest in the Ottawa River (179 mm) by the 2080s under RCP8.5.

There may be little variation to changes in summer air temperature across the five sub-basins (Table 5). By the 2080s, the average air temperature across the emission scenarios is projected to be 3 to 7.6 °C above 1971–2000 baselines for Lake Ontario, 2.9 to 7.5 °C for Lake Superior, 2.5 to 7.5 °C for Ottawa River, 2.7 to 7.4 °C for Lake Huron, and 2.6 to 7.4 °C for Lake Erie. Greater variation in winter air temperatures, however, is possible between sub-basins. The Lake Superior sub-basin may experience the greatest warming by the 2080s (up to 9.2 °C greater than 1971–2000 baselines under RCP8.5), followed by Lake Huron (up to 8.7 °C), Ottawa River (up to 8.6 °C), Lake Ontario (up to 8.1 °C), and Lake Erie (up to 7.5 °C).

Summer may be drier on average across all five sub-basins (Table 5). While Lake Erie is likely to have 3 to 9 mm less rainfall by the 2080s across the pathways, more sizable changes in summer precipitation are projected in the other sub-basins, to a maximum of 16 to 34 mm less precipitation than baselines in Lake Superior. Across the sub-basins, winter is most likely to experience more drastic changes in precipitation patterns than summer. Lake Superior is projected to have the lowest average increase by the 2080s (33 to 66 mm above baselines), though variability will be highest in this watershed; some areas of the sub-basin may experience up to 158 mm more winter precipitation than baseline levels. Lake Huron may have the greatest changes in mean winter precipitation (37 to 85 mm above baselines), followed by Lake Erie (38 to 76 mm), Lake Ontario (34 to 72 mm), and Ottawa River (30 to 66 mm).

Table 5. Changes in temperature and precipitation for the five Great Lakes Sub-Basins from 1971–2000 baseline values under three representative concentration pathways (RCP 2.6, 4.5, and 8.5) and for three time periods (2011–2040, 2041–2070, and 2071–2100). For each entry, the first row is the mean (SD) and the second is the range across the watershed (minimum to maximum).

		Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
			RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Lake Superior Basin	Annual	Temperature (°C)	2.3 (0.3)	2.2 (0.3)	2.5 (0.3)	3.2 (0.3)	4 (0.2)	4.8 (0.3)	3.2 (0.3)	5 (0.2)	8.3 (0.2)
			1.7 to 3.2	1.6 to 3.1	1.8 to 3.4	2.5 to 4.1	3.4 to 4.8	4.2 to 5.7	2.6 to 4.1	4.4 to 5.8	7.6 to 9
		Precipitation (mm)	68.8 (36.3)	67.5 (33.2)	76.5 (37.4)	112.3 (36.3)	93 (36.4)	112.6 (40)	102.8 (33.5)	95.3 (35.4)	131.4 (41.2)
			0 to 175	-4 to 165	5 to 183	44 to 215	26 to 199	40 to 223	31 to 203	26 to 196	54 to 240
	Summer	Temperature (°C)	2.2 (0.5)	2.1 (0.5)	2.3 (0.5)	2.8 (0.5)	3.3 (0.5)	4.5 (0.4)	2.9 (0.5)	4.3 (0.4)	7.5 (0.4)
			1.5 to 4.6	1.4 to 4.5	1.7 to 4.7	2.1 to 5.2	2.7 to 5.7	3.9 to 6.8	2.2 to 5.3	3.7 to 6.7	6.9 to 9.8
		Precipitation (mm)	-2.7 (8.5)	-1.6 (7.8)	-3.2 (7)	5.6 (8.6)	-6.4 (8.4)	-16 (8.4)	4.4 (10)	-14 (9.5)	-34 (11.1)
			-24 to 22	-20 to 14	-22 to 13	-18 to 25	-26 to 13	-38 to 3	-19 to 29	-37 to 6	-59 to -12
	Winter	Temperature (°C)	2.3 (0.3)	2 (0.3)	2.8 (0.3)	3.4 (0.3)	4.5 (0.3)	5.5 (0.3)	3.6 (0.3)	5.6 (0.3)	9.2 (0.3)
			1.5 to 3	1.2 to 2.8	1.9 to 3.5	2.5 to 4.2	3.8 to 5.2	4.7 to 6.2	2.8 to 4.3	4.8 to 6.3	8.3 to 9.9
		Precipitation (mm)	35 (19.3)	28.4 (16.3)	32.8 (18.3)	39.2 (18.8)	35.8 (17.4)	48.5 (22.6)	32.9 (14.9)	45.8 (21.3)	66.1 (28.8)
			-4 to 97	-7 to 85	-5 to 94	1 to 99	1 to 92	6 to 121	-1 to 87	6 to 116	16 to 158
Lake Huron Basin	Annual	Temperature (°C)	2.3 (0.1)	2.3 (0.1)	2.5 (0.1)	3.2 (0.1)	3.9 (0.1)	4.7 (0.1)	3.1 (0.1)	4.8 (0.1)	7.9 (0.2)
			1.9 to 2.7	1.9 to 2.6	2 to 2.8	2.7 to 3.5	3.4 to 4.2	4.2 to 5.1	2.6 to 3.5	4.3 to 5.1	7.2 to 8.3
		Precipitation (mm)	80.2 (28.7)	51.4 (32.3)	67.5 (34.2)	97.6 (35.7)	88.2 (33.4)	103 (37.1)	105.1 (31.7)	91.2 (33.3)	125 (31.6)
			18 to 189	-18 to 167	1 to 187	23 to 220	18 to 206	31 to 225	39 to 217	24 to 205	59 to 235
	Summer	Temperature (°C)	1.9 (0.2)	1.9 (0.2)	2.1 (0.2)	2.6 (0.2)	3.2 (0.2)	4.4 (0.2)	2.7 (0.2)	4.1 (0.2)	7.4 (0.2)
			1.5 to 2.8	1.5 to 2.8	1.6 to 3	2.2 to 3.5	2.7 to 4	3.9 to 5.2	2.2 to 3.6	3.6 to 4.9	6.9 to 8.2
		Precipitation (mm)	5.6 (7.3)	-3.9 (8.3)	-2.8 (8)	4.7 (9.2)	-2.2 (7.1)	-11.3 (8.3)	10.3 (8.3)	-3.9 (7.1)	-20.2 (6)
			-14 to 28	-24 to 18	-23 to 22	-19 to 28	-22 to 22	-31 to 15	-10 to 35	-23 to 27	-37 to 4
	Winter	Temperature (°C)	2.6 (0.2)	2.3 (0.2)	2.9 (0.1)	3.5 (0.1)	4.6 (0.1)	5.4 (0.2)	3.6 (0.1)	5.5 (0.2)	8.7 (0.3)
			2.1 to 3.2	1.9 to 2.9	2.5 to 3.3	3.2 to 4	4.2 to 5	4.9 to 5.9	3.2 to 4	5.1 to 6	7.7 to 9.3
		Precipitation (mm)	35.2 (10.2)	28.7 (9.8)	31.4 (9.1)	42.6 (12.9)	37.9 (10)	56 (13)	36.7 (11.2)	52.8 (12.1)	85.2 (17.8)
			2 to 73	1 to 64	2 to 70	9 to 81	5 to 69	21 to 96	4 to 68	18 to 89	39 to 133

Table 5. Con't.

		Change from 1971–2000 baseline	2011–2040			2041–2070			2071–2100		
			RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5	RCP 2.6	RCP 4.5	RCP 8.5
Lake Erie Basin	Annual	Temperature (°C)	2.2 (0.1)	2.2 (0.1)	2.3 (0.1)	2.9 (0.1)	3.6 (0.1)	4.4 (0.1)	2.8 (0.1)	4.4 (0.1)	7.2 (0.2)
			1.8 to 2.5	1.7 to 2.5	1.9 to 2.7	2.5 to 3.4	3.1 to 4	4 to 4.9	2.4 to 3.2	3.9 to 4.9	6.7 to 7.8
		Precipitation (mm)	68.1 (28.7)	31.1 (28.7)	46.7 (29.6)	70.1 (29.5)	83 (31.4)	77.1 (29.3)	81.3 (27.9)	68.2 (29.6)	109.3 (29)
			24 to 182	-10 to 148	5 to 165	22 to 182	35 to 205	29 to 190	35 to 192	20 to 183	57 to 222
	Summer	Temperature (°C)	1.9 (0.1)	2 (0.1)	2.1 (0.1)	2.6 (0.1)	3.2 (0.1)	4.4 (0.1)	2.6 (0.1)	4.1 (0.1)	7.4 (0.1)
			1.6 to 2.2	1.6 to 2.3	1.8 to 2.4	2.3 to 2.9	2.8 to 3.5	4 to 4.7	2.3 to 2.9	3.7 to 4.4	7 to 7.7
		Precipitation (mm)	1.5 (8.9)	-8.5 (9.6)	-3.9 (10.2)	-1.8 (9.7)	-1 (10.6)	-9.4 (10)	7.6 (9.2)	-0.8 (10.5)	-4 (10.7)
			-14 to 36	-24 to 26	-20 to 32	-18 to 33	-18 to 37	-25 to 25	-9 to 42	-22 to 33	-23 to 32
	Winter	Temperature (°C)	2.5 (0.2)	2.1 (0.2)	2.6 (0.2)	3.2 (0.2)	4.1 (0.3)	4.8 (0.3)	3.1 (0.2)	5 (0.3)	7.5 (0.4)
			2 to 3.2	1.6 to 2.9	2.1 to 3.3	2.6 to 4	3.5 to 5	4.2 to 5.8	2.6 to 3.9	4.3 to 5.9	6.6 to 8.8
		Precipitation (mm)	32 (8.7)	32.6 (8.3)	22.8 (7.8)	43 (9.2)	32 (8.9)	49.8 (9.5)	37.7 (8)	46.4 (9.5)	75.9 (11.2)
			10 to 60	12 to 60	4 to 49	20 to 69	11 to 59	27 to 74	18 to 65	24 to 72	48 to 105
Lake Ontario Basin	Annual	Temperature (°C)	2.3 (0.1)	2.3 (0.1)	2.4 (0.1)	3.1 (0.1)	3.8 (0.1)	4.6 (0.2)	3 (0.1)	4.6 (0.1)	7.6 (0.2)
			1.8 to 2.6	1.8 to 2.6	1.9 to 2.7	2.6 to 3.4	3.3 to 4.1	4 to 4.9	2.4 to 3.3	4.1 to 4.9	6.9 to 8
		Precipitation (mm)	55.1 (18.4)	22.9 (17.7)	36.3 (17.5)	62.5 (19.8)	61 (19.8)	72.6 (19.9)	74.3 (18.6)	66.7 (18.9)	102 (20.8)
			16 to 121	-16 to 96	-2 to 105	23 to 142	20 to 141	33 to 154	35 to 143	26 to 144	62 to 186
	Summer	Temperature (°C)	1.9 (0.2)	2 (0.2)	2.1 (0.2)	2.6 (0.2)	3.2 (0.2)	4.4 (0.2)	2.6 (0.2)	4.1 (0.2)	7.6 (0.2)
			1.4 to 2.3	1.5 to 2.4	1.6 to 2.5	2.1 to 3	2.8 to 3.7	3.9 to 4.9	2.1 to 3.1	3.7 to 4.6	6.9 to 8.1
		Precipitation (mm)	-0.1 (5.2)	-7.5 (4)	-3.3 (4)	-3 (4.5)	-4.8 (4.4)	-9.5 (4.3)	5.2 (5)	2.7 (3.9)	-10.6 (6)
			-11 to 17	-16 to 6	-12 to 10	-13 to 12	-14 to 10	-18 to 5	-5 to 21	-6 to 18	-23 to 7
	Winter	Temperature (°C)	2.7 (0.1)	2.4 (0.2)	2.8 (0.2)	3.5 (0.2)	4.5 (0.2)	5.2 (0.2)	3.5 (0.2)	5.4 (0.2)	8.1 (0.2)
			2.2 to 3	1.9 to 2.8	2.3 to 3.2	3 to 3.9	4 to 4.9	4.6 to 5.6	2.9 to 3.9	4.8 to 5.7	7.3 to 8.6
		Precipitation (mm)	22.2 (7.7)	25 (7.8)	20.9 (6.9)	35.5 (9)	26.4 (8.1)	44.3 (9.1)	33.7 (7.9)	38.5 (8.9)	72 (10.9)
			1 to 46	3 to 48	2 to 40	12 to 62	5 to 49	22 to 71	13 to 57	17 to 65	50 to 105
Ottawa River Basin	Annual	Temperature (°C)	2.3 (0.1)	2.2 (0.1)	2.4 (0.1)	3.2 (0.1)	3.9 (0.1)	4.7 (0.1)	3.1 (0.1)	4.7 (0.1)	7.9 (0.2)
			1.7 to 2.6	1.7 to 2.6	1.8 to 2.8	2.6 to 3.6	3.2 to 4.3	4.1 to 5.1	2.4 to 3.6	4.1 to 5.2	7.3 to 8.6
		Precipitation (mm)	66.6 (26.2)	43.2 (24.6)	55.9 (25.9)	82.6 (28.3)	79.9 (27.2)	94.8 (27.9)	96.5 (28.7)	87.7 (26.2)	111.4 (26.9)
			-4 to 137	-27 to 116	-15 to 128	3 to 161	2 to 156	15 to 171	21 to 171	13 to 157	30 to 179
	Summer	Temperature (°C)	1.8 (0.2)	1.8 (0.2)	1.9 (0.2)	2.5 (0.2)	3.1 (0.2)	4.3 (0.2)	2.5 (0.2)	3.9 (0.2)	7.5 (0.2)
			1.2 to 2.2	1.2 to 2.3	1.3 to 2.3	1.8 to 2.9	2.5 to 3.6	3.7 to 4.7	1.9 to 2.9	3.3 to 4.4	6.8 to 8
		Precipitation (mm)	9.9 (7.8)	6.1 (7)	8.3 (6.3)	12.2 (10.7)	9.1 (7.4)	2.1 (7.2)	19.4 (9.3)	12 (7.5)	-9.8 (6.8)
			-8 to 33	-12 to 24	-8 to 29	-8 to 35	-9 to 29	-14 to 22	0 to 42	-5 to 33	-25 to 10
	Winter	Temperature (°C)	1.9 to 3.2	1.8 to 3	2.2 to 3.5	2.9 to 4.3	3.9 to 5.3	4.6 to 6.1	2.8 to 4.3	4.8 to 6.3	7.8 to 9.6
			2.6 (0.2)	2.4 (0.2)	2.9 (0.2)	3.6 (0.2)	4.6 (0.2)	5.3 (0.2)	3.6 (0.2)	5.5 (0.2)	8.6 (0.3)
		Precipitation (mm)	23.6 (10.1)	21.5 (7.2)	22.4 (8.7)	31.3 (7.8)	27.7 (9.3)	42.4 (9.1)	30.1 (7.3)	34.8 (9.4)	66.3 (9.8)
			-3 to 55	-2 to 46	-3 to 51	5 to 55	0 to 57	13 to 69	6 to 52	6 to 62	34 to 95

Conclusions

Increases in mean annual temperature are expected across all three primary watersheds in Ontario throughout the 21st century. The projections indicate that by the 2080s the Hudson Bay Basin may have the largest increases in temperature (up to 10.3 °C) as compared to the Nelson River Basin (up to 8.8 °C) and the Great Lakes Basin (up to 7.9 °C).

This report presents a subset of climate variables that introduce readers to climate projections in Ontario. Additional climate variables are readily available (e.g., growing degree days, frost free days, minimum and maximum air temperatures) and may be important to consider depending on the analysis being conducted. For example, other research indicates that minimum air temperatures are projected to increase more than the maximum air temperatures (Colombo et al. 2007; Hayhoe et al. 2010; McKenney et al. 2011; Price et al. 2011; Zhang et al. 2000), a trend already observed in past weather observation station analysis (Vincent et al. 2012). Similarly, winter warming is projected to be higher than summer warming. Higher temperatures in the winter may also mean fewer frost days per year (Gregg et al. 2012). This could also mean a longer growing season, which is important for plants, aquatic primary productivity, and fish whose life cycles are temperature dependent.

Changes in precipitation are more variable than changes in temperature. While the Hudson Bay Basin may experience little change to annual precipitation, the Nelson River Basin may have an increase in rain that could peak near the Great Lakes Basin boundary. The Great Lakes Basin may experience precipitation increases of up to 20%, particularly over and near the lakes, and most dramatically in winter. Large standard deviations are seen for nearly all precipitation estimates, which indicates the high variability associated with projections of precipitation and the difficulty of making accurate projections of precipitation.

The purpose of this report is to summarize the trends in temperature and precipitation under projected AR5 climate scenarios for the province, and to highlight how patterns may change across the province. For more in-depth investigations into possible climate scenarios in Ontario, some additional methods of analysis may be considered:

- We have only shown the trends in winter and summer; information for spring and fall is also available for analysis. Other climate variables are also available for those interested in exploring specific climate change effects.
- The statistical downscaling method used in this report is only one approach for turning broad climate projections intended for global scales into regional climate projections. As the science progresses, other more complex methods may prove more precise and may provide more accurate projections of precipitation variables.
- Similarly, standard deviation is only one way to show the variability in temperature and precipitation projected for Ontario. Other methods may be used to perform statistical analyses of the values.

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Appendix C. Hydrologic Model Input Parameters: Alternative 1

Project	GFL EOWHF Surface Water Quantity EA	No.		--
By	J. Look	Date		24-Jun-2022
Checked	S. Kashi	Checked		--

TABLE 2

PC-SWMM Input Parameters

ALTERNATIVE METHOD 1 - Conceptual Design

Subcatchments

Name	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Zero Imperv (%)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)
1.00	501356.99	5018391.07	9	3.78	251.99	150	2	10	0.015	0.300	1.9	5.08	25	290.50	0.509	0.23
1_1	501563.10	5017893.12	17	1.50	751.55	20	2	10	0.015	0.300	1.9	5.08	25	290.07	0.510	0.23
1_4	501545.52	5017353.53	8	4.90	489.80	100	2	10	0.015	0.300	1.9	5.08	25	290.07	0.510	0.23
1_5	501720.44	5017612.25	8	0.69	344.10	20	2	10	0.015	0.300	1.9	5.08	25	290.07	0.510	0.23
20.00	501045.59	5017064.31	13	6.14	614.16	100	2	10	0.015	0.300	1.9	5.08	25	292.06	0.493	0.23
21.00	500286.75	5018146.47	15	1.75	873.85	20	2	10	0.015	0.300	1.9	5.08	25	299.99	0.424	0.22
23.00	500370.28	5017735.46	14	1.24	618.55	20	2	10	0.015	0.300	1.9	5.08	25	315.17	0.292	0.21
6.00	500811.40	5018750.66	11	11.96	797.24	150	2	10	0.015	0.300	1.9	5.08	25	290.07	0.510	0.23
7.00	500271.09	5018432.66	19	22.37	1118.70	200	2	100	0.015	0.300	1.9	5.08	25	291.58	0.497	0.23
S19_2	501238.36	5018635.55	10	5.79	386.03	150	2	10	0.015	0.300	1.9	5.08	25	290.07	0.510	0.23
S29_5	500579.85	5017358.26	18	1.30	649.60	20	2	10	0.015	0.300	1.9	5.08	25	320.04	0.250	0.21
S29_6	500733.46	5017082.05	13	0.63	315.00	20	2	10	0.015	0.300	1.9	5.08	25	320.04	0.250	0.21

Conduits

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Inlet Offset (m)	Outlet Offset (m)	Cross-Section	Geom1 (m)	Geom2 (m)	Geom3	Geom4	Barrels	Slope (m/m)
9.00	9	10	430.09	0.035	0.00	0.00	TRAPEZOIDAL	1.00	9.00	3	3	1	0.0007
1.00	10	11	319.87	0.035	0.00	0.00	TRAPEZOIDAL	1.10	11.00	3	3	1	0.0007
3.00	11	16	824.45	0.035	0.00	0.00	TRAPEZOIDAL	1.10	11.50	3	3	1	0.0007
4.00	16	12	257.85	0.035	0.00	0.00	TRAPEZOIDAL	1.10	11.50	3	3	1	0.0007
6.00	14	15	430.17	0.035	0.00	0.00	TRAPEZOIDAL	1.00	8.00	3	3	1	0.0010
2_1	8	17	183.94	0.035	0.00	0.00	TRAPEZOIDAL	1.00	8.00	3	3	1	0.0007
2_2	17	9	454.51	0.035	0.00	0.00	TRAPEZOIDAL	1.00	8.00	3	3	1	0.0007
5_1	13	18	202.31	0.035	0.00	0.00	TRAPEZOIDAL	1.00	8.00	3	3	1	0.0010
5_2	18	14	432.35	0.035	0.00	0.00	TRAPEZOIDAL	1.00	8.00	3	3	1	0.0010
2.00	12	19	15.66	0.035	0.00	1.20	TRAPEZOIDAL	1.00	7.00	3	3	1	0.0128
7_1	15	22	223.82	0.035	0.00	0.00	TRAPEZOIDAL	1.10	10.00	3	3	1	0.0010
7_2	22	12	396.29	0.035	0.00	0.00	TRAPEZOIDAL	1.10	11.00	3	3	1	0.0010

Junctions

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)	Depth (m)	Initial Depth (m)	Surcharge Depth (m)
8.00	501759.39	5017534.96	67.53	68.53	1.00	0.00	0.00
9.00	501449.05	5018092.61	67.09	68.09	1.00	0.00	0.00
10.00	501240.11	5018468.33	66.78	67.78	1.00	0.00	0.00
11.00	501084.88	5018747.87	66.56	67.56	1.00	0.00	0.00
12.00	500501.70	5018313.54	65.80	65.80	0.00	0.00	0.00
13.00	500783.88	5016994.72	67.49	68.49	1.00	0.00	0.00
14.00	500474.28	5017548.45	66.85	67.85	1.00	0.00	0.00
15.00	500264.70	5017923.92	66.42	67.42	1.00	0.00	0.00
16.00	500594.70	5018477.64	65.98	66.98	1.00	0.00	0.00
17.00	501669.98	5017695.62	67.41	68.41	1.00	0.00	0.00
18.00	500685.19	5017171.24	67.29	68.29	1.00	0.00	0.00
22.00	500156.28	5018119.62	66.20	66.84	0.64	0.00	0.00

Appendix D. Hydrologic Model Input Parameters: Alternative 2

TABLE 3

PC-SWMM Input Parameters

ALTERNATIVE METHOD 2 - Conceptual Design

Subcatchments

Name	X-Coordinate	Y-Coordinate	Outlet	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (mm)	Dstore Perv (mm)	Zero Imperv (%)	Suction Head (mm)	Conductivity (mm/hr)	Initial Deficit (frac.)
22_2	501088.43	5017087.83	13	7.10	710.08	100	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22.00	500379.55	5018575.17	19	20.44	1022.04	200	2	100	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_20	501607.28	5017506.62	8	10.31	343.77	300	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_14	501060.83	5018798.58	11	8.94	596.30	150	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_31	500642.30	5017247.89	13	1.87	932.90	20	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_32	500395.00	5017692.17	14	1.14	571.80	20	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
1.00	500230.59	5018221.07	15	2.37	1185.00	20	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_3	500651.42	5018583.09	16	1.05	525.00	20	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_9	501306.25	5018514.68	10	6.63	442.27	150	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23
22_10	501498.62	5018007.90	8	1.97	984.00	20	2	10	0.015	0.300	1.9	5.08	25	290.79	0.504	0.23

Conduits

Name	Inlet Node	Outlet Node	Length (m)	Roughness	Inlet Offset (m)	Outlet Offset (m)	Cross-Section	Geom1 (m)	Geom2 (m)	Geom3	Geom4	Barrels	Slope (m/m)
1.00	10	11	401.33	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
4.00	16	12	428.66	0.035	0.00	0.00	TRAPEZOIDAL	1.10	9.00	3	3	1	0.0008
6.00	14	15	430.17	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
2_1	8	17	218.15	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
5_1	13	18	202.31	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
5_2	18	14	432.35	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
11.00	4	5	201.14	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0012
12.00	3	4	399.07	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0012
13.00	5	12	253.59	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0012
14.00	20	7	644.27	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0008
15.00	7	6	403.92	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0008
10_1	21	23	200.77	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0012
10_2	23	3	396.19	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0012
16_1	6	24	368.70	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0008
16_2	24	16	239.50	0.035	0.00	0.00	TRAPEZOIDAL	1.00	6.00	3	3	1	0.0008
9.00	17	10	388.48	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
7_1	15	9	454.98	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
7_2	9	12	436.29	0.035	0.00	0.00	TRAPEZOIDAL	1.10	9.00	3	3	1	0.0009
3_1	11	25	207.67	0.035	0.00	0.00	TRAPEZOIDAL	1.00	5.00	3	3	1	0.0009
3_2	25	16	254.98	0.035	0.00	0.00	TRAPEZOIDAL	1.10	9.00	3	3	1	0.0009

Junctions

Name	X-Coordinate	Y-Coordinate	Invert Elev. (m)	Rim Elev. (m)	Depth (m)	Initial Depth (m)	Surcharge Depth (m)
8.00	501641.74	5017746.07	67.47	68.47	1.00	0.00	0.00
10.00	501347.39	5018276.23	66.92	67.92	1.00	0.00	0.00
11.00	501152.17	5018626.70	66.56	67.56	1.00	0.00	0.00
12.00	500454.45	5018476.48	65.80	66.80	1.00	0.00	0.00
13.00	500783.88	5016994.72	67.56	68.56	1.00	0.00	0.00
14.00	500490.96	5017518.64	66.99	67.99	1.00	0.00	0.00
15.00	500296.16	5017867.55	66.60	67.60	1.00	0.00	0.00
16.00	500828.76	5018685.02	66.14	67.14	1.00	0.00	0.00
17.00	501535.82	5017936.69	67.27	68.27	1.00	0.00	0.00
18.00	500685.19	5017171.24	67.38	68.38	1.00	0.00	0.00
3.00	500870.46	5017731.30	66.83	67.83	1.00	0.00	0.00
4.00	500675.94	5018079.56	66.35	67.35	1.00	0.00	0.00
5.00	500577.90	5018255.09	66.10	67.10	1.00	0.00	0.00
6.00	501125.76	5018154.55	66.63	67.63	1.00	0.00	0.00
7.00	501322.69	5017802.08	66.96	67.96	1.00	0.00	0.00
20.00	501538.79	5017415.29	67.47	68.47	1.00	0.00	0.00
21.00	501161.44	5017210.34	67.54	68.54	1.00	0.00	0.00
23.00	501063.58	5017385.55	67.30	68.30	1.00	0.00	0.00
24.00	500945.72	5018476.13	66.34	67.34	1.00	0.00	0.00
9.00	500073.68	5018264.20	66.19	67.19	1.00	0.00	0.00
25.00	501051.48	5018808.22	66.37	67.37	1.00	0.00	0.00