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Dear Agency, Minister and Eastern Power Inc:

Re: Eastern Power Inc Proposed Gas-Powered Electricity Plant (IAA Ref # 83696)
Impact Assessment Planning Phase

We are legal counsel to the Pembina Institute for Appropriate Development ("Pembina") and write to highlight the need for an impact assessment of Eastern Power Inc.'s proposed Hydrogen Ready Power Plant Project (the "Project").

The Project is a large fossil fuel electricity generating station being proposed in a region of Canada that has been burdened by large amounts of environmental pollutants. At 614 MW of generating capacity, it is over three times higher than the 200 MW threshold level in the *Physical Activities Regulations* for projects that are presumptively subject to an impact

assessment.[1] While sold as a "hydrogen-ready" facility, Eastern Power Inc. (the "Proponent") plans to burn a significant amount of natural gas well past Canada's 2035 proposed timeline for a net zero electricity grid, which will require primarily carbon-neutral generating sources. The Proponent's assertions and plans to incorporate hydrogen as a fuel source are largely speculative and lack any concrete assessment of feasibility.

Importantly, the Project also has numerous likely and demonstrable potential adverse impacts on areas of federal jurisdiction. As set out in these comments, the assertions from the Proponent that such impacts are not likely are based on information that is incomplete, dated, and, in several cases, erroneous. The Agency cannot reasonably conclude that the project is not likely to cause adverse effects on areas of federal jurisdiction and thus, in Pembina's submission, must order an impact assessment.

Whether the Project ultimately proceeds or not, there is absolutely *no* reason that a such a large project, in such an environmentally sensitive area, should not be weighed based on science and fact through the best means available to the federal government: a thorough impact assessment.

1. Scope and Timing of Comments

These comments are addressed to the Impact Assessment Agency of Canada (the "Agency"), the Minister of Environment and Climate Change (the "Minister") and the Proponent.

Pembina provides these comments to draw the Agency's attention to information and issues that are relevant to the Agency's obligatory considerations under s. 16(2)(b), (c), and (g) of the *Impact Assessment Act* (the "Act").[2] These comments also provide a number of relevant studies to the Agency for its consideration under s. 16(2)(f) of the Act as one of the obligatory factors for consideration. While these comments are not being provided during the Agency's specified public comment period[3] on the Initial Project Description ("IPD"), they are nonetheless relevant to the Agency's s.16 determination.

Not only are these comments relevant to the Agency's s. 16 determination, but Pembina provides these comments with the legitimate expectations that public comments are to be received by the Agency during the Planning Phase beyond the comment period on the Initial Project Description. The Agency's *Impact Assessment Process Overview* guidance document states that the public will be provided with an opportunity to provide "input and

[1] *Physical Activities Regulations,* SOR/2019-285, s 30.
[2] *Impact Assessment Act,* SC 2019, c 28, ss 16(2)(b), (c), (g) [*IAA*].
[3] Pembina was not able to provide comments during the 30 day comment period as they were not aware of the comment period, nor were they aware that the comment period would be the only engagement opportunity during the Planning Phase.

comment on key documents, including the…Detailed Project Description, Summary of Issues, Response to Summary of Issues…"[4]

Pembina recently learned that the Agency is *not* intending to provide a formal comment period to receive input or comments specific to these documents during the Planning Phase. These comments, which relate to the Agency's Summary of Issues and the Initial Project Description, are therefore provided now in light of the absence of an additional formal comment period of these documents. Given the apparent lack of any forthcoming opportunity to consider and comment on the Response to the Summary of Issues and the Detailed Project Description prior to the Agency's s. 16 determination, these comments also address matters relating to those as well.

These comments are being provided to the Minister to inform any potential determination he may make under s. 17(1) of the *Impact Assessment Act* ("*IAA*") as well as any other determinations the Minister may need to make with regards to the potential effects of this project, such as under s. 166 of the *Canadian Environmental Protection Act,* SC 1999, c 33 ("*CEPA*").[5]

Finally, these comments are being provided to the Proponent as a part of their ongoing obligations to engage with the public during the Planning Process and to inform the Proponent's pending Detailed Project Description and Response to the Summary of Issues.

2. An Impact Assessment is Required to Assess Whether the Project will Cause Adverse Effects on Areas of Federal Jurisdiction

As detailed below, there are a number of factors which have yet to be raised by the Proponent, the Agency, Indigenous groups or the public that are pertinent to the Agency's obligatory considerations under s. 16 of the Act. Pembina submits that individually, and cumulatively, these factors strongly favour requiring an impact assessment.

2.1 As a Large Fossil Fuel Electricity Project in one of Canada's Most Polluted Areas, the Project Should Presumptively be Subject to an Impact Assessment

Apart from the numerous potential adverse impacts on areas of federal jurisdiction detailed below, the nature of this project and its location necessitate an impact assessment.

The significant potential for greenhouse gas ("GHG") emissions from the Project, and the interplay of such emissions on federal policies and laws, weighs heavily in favour of an

[4] Impact Assessment Agency of Canada, "Impact Assessment Process Overview: Phase 1" (last modified 14 February 2022), online: *Government of Canada* <https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/impact-assessment-process-overview/phase1.html>. See "Roles and Responsibilities – Public".

[5] See pages 24-25 of these comments for further details on the potential for a determination under a 166 of *CEPA*.

impact assessment. The IPD claims the Project will take advantage of low GHG carbon emitting hydrogen fuel as they become progressively more available over the life of the Project.[6] However, even the Proponent's most optimistic projections indicate that the Project intends to burn 80% natural gas for the first 15 years of operations, then 35% natural gas up for years 16-24 of operation only converting to 100% hydrogen in the final year of the Project.[7] The expectation that the Project will burn natural case for the first 24 years of operations raises the likelihood that the facility could run afoul of the federal government's proposed *Clean Electricity Regulations*.[8] Secondly, there is a very credible risk that this Project will result in GHG emissions beyond 2050, the date of Canada's net-zero emissions target, if the Project operates longer than 2050.

This Project also risks frustrating the goals of the federal government's Emissions Reduction Plan for 2030 ("ERP").[9] Achieving a 40-45% reduction in GHG emissions is a key objective of the federal government to combat climate change and its potentially catastrophic impacts on, among other things, areas of federal jurisdiction. However, through new electricity projects relying in large part on natural gas such as the Proponent's, Ontario is actually set to see a 375% increase in electricity GHG emissions by 2030, and 600% increase by the late 2030's. This could frustrate the ERP which specifically points to efforts underway in Ontario that would assist in achieving the ERP's emissions reduction targets including the evaluation of "a moratorium on the procurement of new natural gas generation and develop an achievable pathway to phase-out contracted natural gas generation and move to zero emissions in the electricity system".[10]

In addition to the incongruity of new fossil fuel electricity with federal policy and regulations, the location of the Project poses serious risks of harm from cumulative effects. The need to address the cumulative effects and reduce the environmental and human health risks in the Sarnia area is well acknowledged and recognized by both the federal and provincial governments. The Project is being proposed within the study area of the Sarnia Area Environmental Health Project, a region that has been subject to an almost unprecedented burden of environmental pollution. The Sarnia Area Environmental Health Project was developed in 2017 by the Ontario Ministry of Environment, Conservations and Parks ("MECP") to help understand and address concerns of Sarnia area communities about

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[6] Eastern Power Inc, "Hydrogen Ready Power Plant Project: Initial Project Description for a Designated Project under the Impact Assessment Act" (24 May 2022) at 14, online (pdf): *Impact Assessment Agency of Canada* https://iaac-aeic.gc.ca/050/documents/p83696/144109E.pdf [IPD].
[7] *Ibid* at 39.
[8] "Clean Electricity Regulations" (last modified 26 July 2022), online: *Government of Canada* <https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/clean-electricity-regulation.html>.
[9] Environment and Climate Change Canada, *2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy,* (Quebec: Environment and Climate Chance Canada, 2022), online (pdf): *Government of Canada* <https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf>.
[10] *Ibid* at 119.

air pollution and other environmental stressors from local industries in the area.[11] Further, there are two designated Federal Contaminated Sites in the Sarnia region[12]; these are areas in which substances occur at concentrations that are above background levels and pose or are likely to pose an immediate of long-term hazard to human health or the environment or exceed the levels specified in policies and regulations.[13]

The construction of a large gas plant, especially without a thorough impact assessment, would disregard the geographical context in which it is being proposed. As mentioned by the Chippewas of Kettle and Stony Point First Nation ("CKSPFN") in their comments on the IPD, the Project will contribute to the already significant cumulative effects of oil and gas infrastructure within their traditional territory. This has impacted their rights to hunt, fish and trap in the area, and supports the need for a federal impact assessment to ensure issues such as cumulative effects and protection of Aboriginal rights are evaluated.[14]

The federal government has recognized the disproportionate number of people who live in environmentally hazardous areas are members of an Indigenous, racialized or other marginalized community. The establishing of environmentally hazardous sites, including landfills and polluting industries, in areas inhabited primarily by members of those communities could be considered a form of racial discrimination.[15] Given that the proposed Project is to occur near the traditional territories of various First Nations, in an area known to bear a disproportionate burden of pollution, approving the Project without conducting a thorough impact assessment risks perpetuating racial discrimination against Indigenous peoples.

Finally, the Project is a designated activity for Agency review because it is a fossil fuel-fired power generating facility with a production capacity or 200MW or more.[16] According to the Agency, designated projects are those that are determined to have the greatest potential

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[11] "Sarnia Area Environmental Health Project", online: *Clean Air Sarnia and Area* <https://www.cleanairsarniaandarea.com/>.
[12] "Action plan for contaminated sites" (last modified 9 April 2021), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/federal-contaminated-sites/action-plan.html>.
[13] Treasury Board of Canada Secretariat, "Federal Contaminated Sites Inventory", online: *Government of Canada* <https://www.tbs-sct.gc.ca/fcsi-rscf/home-accueil-eng.aspx>.
[14] Chippewas of Kettle and Stony Point First Nation, "Comment Form: Information to Inform the Summary of Issues" (12 July 2022) at 3 & 7, online (pdf): *Impact Assessment Agency of Canada* <https://registrydocumentsprd.blob.core.windows.net/commentsblob/project-83696/comment-58658/CKSPFN%20-%20Enclosure%201%20-%20Comment%20Form%20-%20Hydrogen%20Ready%20Power%20Plant%20Project_FINAL_for%20transmittal%20(002).pdf> [CKSPFN].
[15] Bill C-230, *An Act respecting the development of a national strategy to assess prevent and address environmental racism and to advance environmental justice,* 2nd Sess, 43rd Parl, 2020-2021, Preamble (consideration in committee in the House of Commons 22 June 2021), online: *Parliament of Canada* <https://www.parl.ca/DocumentViewer/en/43-2/bill/C-230/second-reading>.
[16] IPD, *supra* note 6 at 14.

for adverse and complex effects in areas of federal jurisdiction.[17] At over 600 MW, the Project is three times higher than the threshold at which a Project is presumed to have a potential for adverse and complex effects. There is nothing in the materials provided by the Proponent that guarantees that such presumptive impacts will not be caused by the Project.

2.2 Potential for Adverse Effects Within Federal Jurisdiction

When determining whether an impact assessment is required, the Agency is required to take into account "the possibility that the carrying out of the project may cause adverse effects within federal jurisdiction or adverse direct or incidental effects."[18] As expanded on in this section, the project is likely to cause adverse effects with federal jurisdiction, warranting a full impact assessment.

Further, the Agency cannot determine with any level of certainty that an impact assessment is *not* required based on the incomplete information provided by the Proponent. The majority of the information provided by the Proponent in the IPD is not tailored to this specific Project and is over ten years old. Specifically, the Proponent relies predominantly on a Natural Resources Baseline Report and Environmental Impact Study ("EIS") to assess its potential impacts, including those on fish and fish habitat, migratory birds and species at risk.[19] This EIS was not developed for the Project, but rather was prepared in 2012 for a different project - the Green Electron Power Project[20] - despite the fact that, among other things, environmental and regulatory conditions are likely to have changed over the last ten years.

2.2.1 Location of the Project and Proximity to Migratory Bird and Fish Habitats

The potential for this Project to cause impacts on migratory birds and fish and fish habitat is compounded due to its close proximity to environmentally sensitive areas. The proposed Project site is to take place on the Greenfield South Power Corporation's property (an

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[17] Impact Assessment Agency of Canada, "Operational Guide: Designating a Project under the *Impact Assessment Act*" (revised 19 May 2022), online: *Government of Canada* <https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/designating-project-impact-assessment-act.html>.

[18] *IAA,* s 16(2)(b).

[19] AMEC Environment & Infrastructure, "Green Electron Power Project (East Site), Township of St. Clair, Lambton County, Ontario: Natural Resources Baseline Report and Environmental Impact Study" (November 2012), online (pdf): *Impact Assessment Agency of Canada* <https://iaac-aeic.gc.ca/050/documents/p83696/144117E.pdf> [EIS]. Please note that the East Site is the site of the proposed Project; the Proponent for the Green Electron Power Project was Greenfield South Power Corporation, which is affiliated with Eastern Power Inc. The EIS was attached to the IPD as Appendix 7.8. A full list of Appendices attached to the IPD can be found here.

[20] Greenfield South Power Corporation, "Green Electron Power Project: Project Description" (20 November 2012) at 27, online (pdf): *Impact Assessment Agency of Canada* <https://iaac-aeic.gc.ca/050/documents/p80023/83799E.pdf>.

affiliate of Eastern Power Inc.). The location of the proposed Project facility can be seen in **Figure 1**, and the property boundary can be seen in **Figure 2**. **Figure 2** demonstrates that the property boundary overlaps with the interwoven Bickford Oak Wetland Conservation Reserve ("Conservation Reserve") and the Clay Creek Woodlands Area of Natural Scientific Interest ("ANSI"); specifically, 6.1 hectares of the ANSI lies within the southern portion of the Property.[21] Figure 1 demonstrates that the proposed facility is immediately adjacent to the Conservation Reserve and ANSI. Both the Conservation Reserve and ANSI are valued ecosystems that provide habitat for various migratory bird and aquatic species.[22]

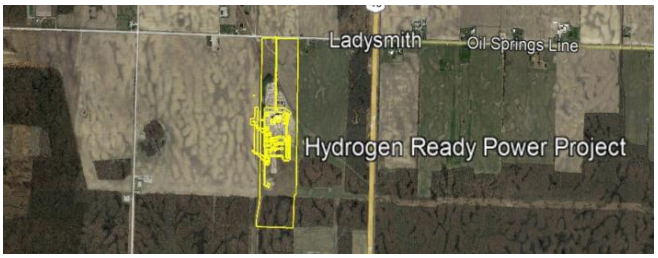

Figure 1: Location of the proposed facility[23]

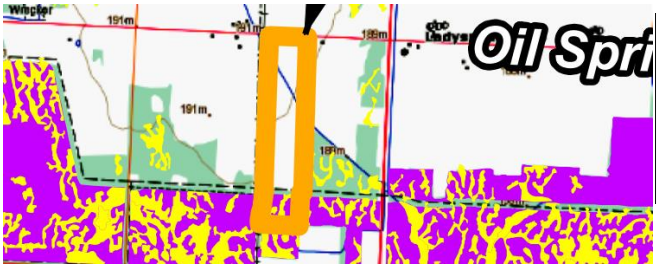

Figure 2: Property boundary of the Project[24]

The Conservation Reserve is a provincially significant wetland and designated conservation reserve under the *Provincial Parks and Conservation Reserves Act,* SO 2006, c 12[25] and is the largest protected Carolinian clay plain forest in Canada.[26] Industrial activities, including generation of electricity, within the Conservation Reserve are prohibited by provincial legislation.[27] As expanded on in Ontario's Management Plan for the Conservation Reserve, protection of this interior Carolinian forest is highly important to the conservation of biological diversity and natural heritage in southern Ontario.[28] Further, according to the

[21] EIS, *supra* note 19 at 6.
[22] *Ibid* at 7.
[23] IPD, *supra* note 6 at 2.
[24] EIS, *supra* note 19 at 3.
[25] *Designation of Conservation Reserves,* O Reg 315/07, s 1 Schedule 294: Bickford oak woods conservation reserve.
[26] Ministry of Natural Resources, "Bickford Oak Woods Conservation Reserve Management Plan" (2009) at 2, online: *Government of Ontario* <https://www.ontario.ca/page/bickford-oak-woods-conservation-reserve-management-plan> [Conservation Reserve Management Plan]. Please note that the page number refers to the PDF version of this document, attached as **Appendix A** in **Schedule II**.
[27] *Ibid* at 14.
[28] *Ibid* at 3.

comments submitted by the CKSPFN and the Caldwell First Nation, all Carolinian habitat and its species in Southwestern Ontario are of direct cultural heritage value to the community, including endangered deciduous tree species that only occur in the Conservation Reserve. The Conservation Reserve is also relied on by various First Nations for hunting, fishing and trapping.[29,30] Due to the ecological, biological and cultural significance of the Conservation Reserve, we are appending the Ontario Ministry of Natural Resources' Bickford Oak Woods Conservation Reserve Management Plan as **Appendix A** in **Schedule II** of these comments for the Agency's consideration under s. 16(2)(f).

The Project site and portions the Conservation Reserve and the ANSI all fall within the St. Clair River Tributaries Subwatershed ("St. Clair River Subwatershed")[31]: one of the 14 subwatersheds within the St. Clair Region Watershed (**see Figure 3**).[32] The St. Clair Region Watershed was designated as an Area of Concern under the Canada-United States Great Lakes Water Quality Agreement in 1987.[33] As such it is a geographic area designated by the Parties where significant impairment of beneficial uses has occurred as a result of human activities at the local level.[34] The area's designation was in response to years of industrialization, urbanization, and agricultural land use activities which have severely degraded water quality and ecosystem health.[35] In particular the St. Clair Region Watershed's fish and wildlife habitat have been significantly impaired.[36]

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[29] CKSPFN, *supra* note 14 at 1.
[30] Caldwell First Nation, "Comment Form: Information to Inform the Summary of Issues" (13 July 2022), online: *Impact Assessment Agency of Canada* <https://iaac-aeic.gc.ca/050/evaluations/proj/83696/contributions/id/58612>.
[31] St. Clair Region Conservation Authority, "St. Clair Region Watershed Report Card" (2018) at 68, online (pdf): *Government of Ontario* <https://www.scrca.on.ca/wp-content/uploads/2018/12/2018-SCRCA-WRC-Report.pdf> [SCRCA].
[32] *Ibid* at 27.
[33] "St. Clair River: Area of Concern" (last modified 25 March 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/areas-concern/st-clair-river.html>.
[34] *Great Lakes Water Quality Agreement Between Canada and the United States of America,* 1978, as amended on 16 October 1983 and on 18 November 1987, signed 7 September 2012 and entered into force 12 February 2013 at 21, online (pdf): *Government of Canada* <https://www.canada.ca/content/dam/eccc/migration/main/grandslacs-greatlakes/a1c62826-72be-40db-a545-65ad6fceae92/1094_canada-usa-20glwqa-20_e.pdf>.
[35] "St. Clair River: Area of Concern" (last modified 25 March 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/great-lakes-protection/areas-concern/st-clair-river.html>.
[36] Ministry of Environment, Conservation and Parks and Environment and Climate Change Canada, "Canada-Ontario Agreement of Great Lakes Water Quality and Ecosystem Health" (2021) at 42, online (pdf): *Government of Ontario* <https://files.ontario.ca/mecp-coa-great-lakes-en-2021-05-26.pdf>.

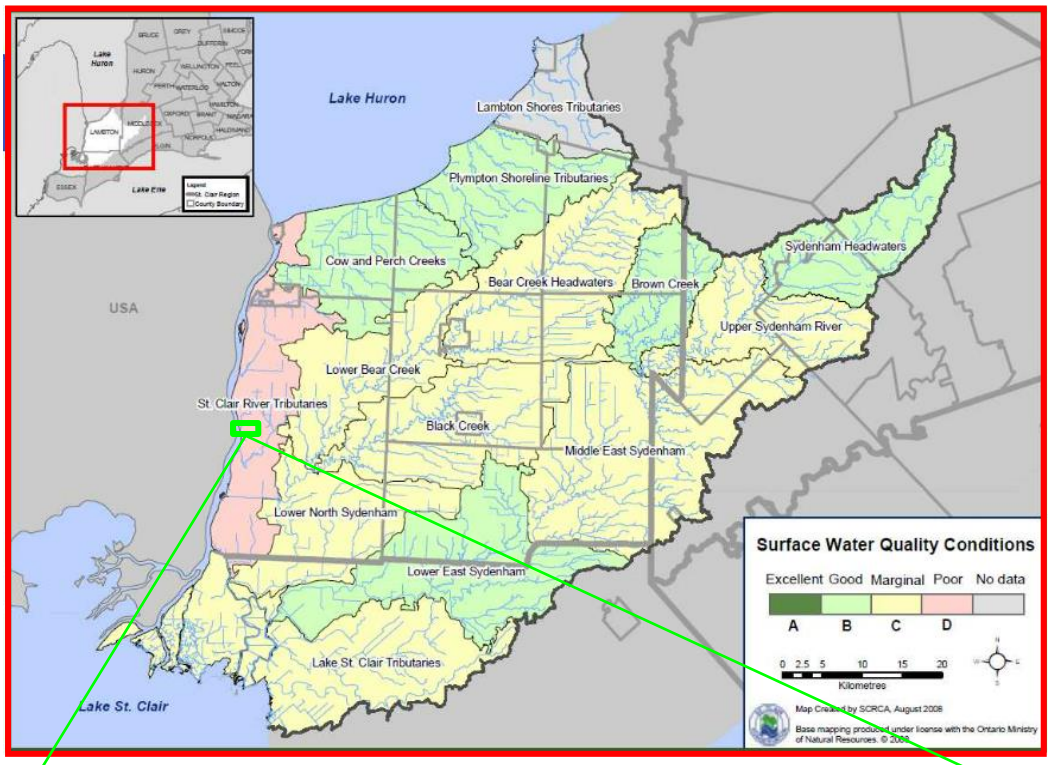
The 2021 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health, which is intended to assist Canada in meeting its obligations under the Canada-United States Agreement[37], outlines Canada's and Ontario's obligations regarding the restoration of the St. Clair Region Area of Concern. One of these obligations is to undertake remedial actions to address the loss of fish and wildlife habitat.[38] Restoration of the St. Clair Region Watershed is an ongoing effort. The construction and operation of the Project within the Area of Concern raises concerns about whether it is consistent with these restoration objectives.

According to the St. Clair Region Watershed Report Card from 2018, wetlands provide habitat for a diverse range of plant and animal species, however overall wetland cover (which is an indicator of environmental health) is very poor across the St. Clair Region Watershed.[39] This demonstrates the fragility of the St. Clair River Watershed ecosystem and highlights the need for further information regarding potential impacts of the Project on the health of the watershed. The St. Clair Region Watershed Report Card, as it is from 2018, offers more current information regarding the known and potential occurrences of various fish and migratory bird species (in the subwatershed in which the Project site is located) and regarding the status of the wetland. For these reasons we are appending the St. Clair Region Watershed Report Card as **Appendix B** in **Schedule II** of these comments for the Agency's consideration under s. 16(2)(f).

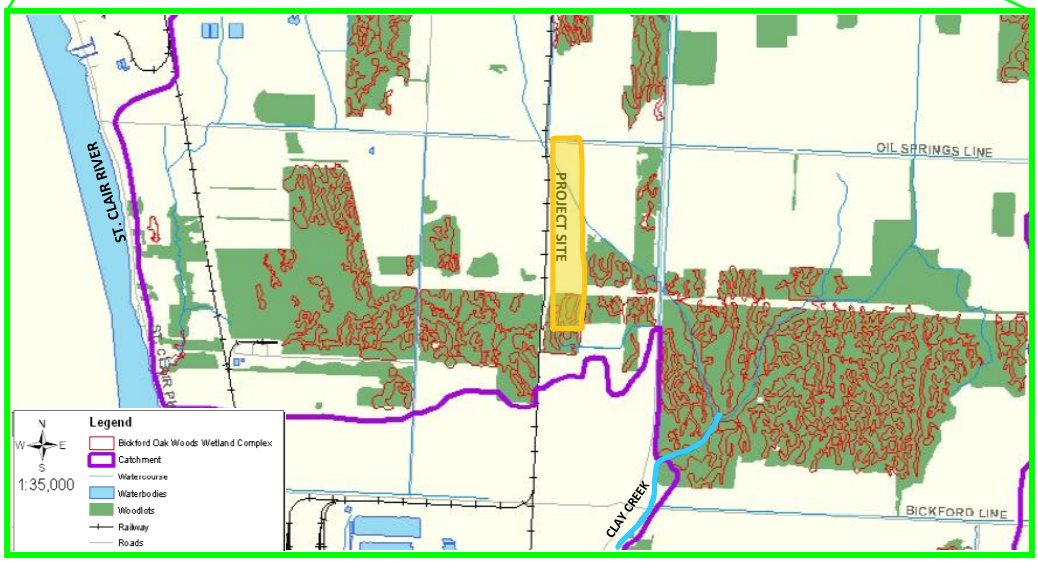
In addition to the existing environmental stress on wetland environments in Ontario, the Ontario government's recent proposal to lessen environmental protections in favour of development puts these environments at further risk.[40] Ontario's announcement on October 25, 2022 to restrain the role of the conservation authorities (who oversee and protect vital and deteriorating watersheds) further erodes any confidence that provincial regulatory mechanisms are sufficient to ensure the Project won't have adverse effects on areas of federal jurisdiction.

[37] *Ibid* at 9.
[38] *Ibid* at 42.
[39] SCRCA, *supra* note 31 at 6.
[40] Ministry of Natural Resources and Forestry, "Proposed updates to the regulation of development for the protection of people and property from natural hazards in Ontario" (25 October 2022), online: *Environmental Registry of Ontario* <https://ero.ontario.ca/notice/019-2927>.

Figure 3: The first map shows the St. Clair Region Watershed (which is a designated Area of Concern) and its 14 subwatersheds. The enlarged map below demonstrates Project site's proximity to the provincially significant interwoven Conservation Reserve and ANSI, Clay Creek and St. Clair River, all of which overlap with the St. Clair River Subwatershed.



St. Clair Region Conservation Authority, 2008



Ministry of Natural Resources, 2007. Please note that this map has been altered by adding labels for Clay Creek and St. Clair River and identifying the Project site.

2.2.2 Potential Adverse Impacts on Migratory Birds

It is possible, and indeed probable, that the carrying out of the designated Project will cause adverse effects on migratory birds protected under the *Migratory Birds Convention Act,* SC 1994, c 22 ("*MBCA*"). According to the Proponent's materials the Project is being proposed in an area where at least 73 migratory bird species are present, 13 of which are listed species under the *Species At Risk Act,* SC 2002, c 29 ("*SARA*"). The potential for adverse effects of such a large industrial facility in this area is thus significant.

Importantly, the Proponent's assertion that the Project will have no net impact on migratory birds contains a fatal flaw. By basing its materials on an EIS from 2012 the Proponent has mischaracterized the *SARA* status of no less than ten bird species present in the Project area. The Proponent has not provided any update to the types of species present in the area. The Agency should thus give the Proponent's assertions little weight. Pembina has not been able to undertake a detailed analysis of each of the potentially impacted *SARA* species but sets out how the potential impacts of the Project on one such species, the Cerulean Warbler, are emblematic of that of the other 12 species at risk in the area. This evidence, set out below, strongly weighs in favour of requiring an impact assessment.

Migratory Birds and SARA Species in Project Area

The federal government has jurisdiction over migratory birds under the *MBCA* and has additional obligations under *SARA* to protect migratory bird species at risk. Various bird species are known to frequent the area in and around the proposed Project site, as evidenced by the IPD, the EIS, and many public submissions to the Agency.

The EIS notes that a total of 91 bird species were recorded in the 10km^2 Block (the "Block") around the Project site. 73 of which are migratory bird species protected under the *MBCA* (see **Table 1** attached in **Schedule I** to these comments).[41] The EIS specified that there was confirmed breeding evidence in the Block for 38 of these species, probable breeding evidence in the Block for 20 species, and possible breeding evidence in the Block for 16 species. Of the 73 migratory bird species, 13 species are now listed under *SARA:* four are Endangered; five are Threatened; and three are of Species Concern.[42] Of the 13 migratory bird species at risk, at least six have known or potential occurrences within the St. Clair River Subwatershed as of 2018 (**see Table 2** attached in **Schedule I** to these comments).[43]

[41] "Birds Protected in Canada" (last modified 16 August 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/migratory-birds-legal-protection/list.html>.
[42] *SARA* at Schedule 1: List of Wildlife Species at Risk.
[43] SCRCA, *supra* note 31 at 70.

Dated EIS Mischaracterizes the Nature of Potential Impacts on Migratory Birds and SARA Species

As previously noted, the EIS relied on by the Proponent is from 2012; specifically, the sections of the IPD on which the Proponent draws its conclusion that the Project will not cause adverse effects on migratory birds solely references the 2012 EIS. The Proponent's materials were not updated to reflect any environmental, regulatory or climatic changes over the last ten years. Alarmingly, the EIS fails to account for the changes in the *SARA* listings of 10 migratory bird species at risk (see **Table 2** attached in **Schedule I** to these comments).

The mischaracterization of *SARA* species is significant for the federal government's obligations in relation to potentially impacted species. The listing of species of Special Concern requires the federal government to develop a Management Plan that sets out the goals and objectives for maintaining sustainable population levels.[44] The listing of Endangered or Threatened species requires stricter obligations on the federal government and the development of a Recovery Strategy and Action Plan (which set out the goals and objectives for arresting or reversing a decline of a species population[45]), and subjects these species to ss. 32 and 33 of *SARA*.[46] The mischaracterization of these species' *SARA* status explains why the EIS (and subsequently, the IPD) has failed to consider or comment on the existence or implication of any Management Plans or Recovery Strategies for the mischaracterized *SARA* protected species.

The Recovery Strategies of threatened and endangered species are a critical piece to *SARA*'s regulatory regime. Omitting any consideration as to whether such Recovery Strategies exist, are in draft form, or create barriers to the Project, is a significant omission from these materials. Recovery Strategies are intended to, among other things, identify the threats to survival of the species, identify the species' critical habitat, and set out approaches for species recovery.[47]

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[44] "Species at Risk Act: Management Plans" (last modified 25 February 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/management-plans.html>.

[45] "Species at Risk Act: Recovery Strategies" (last modified 23 February 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/recovery-strategies.html>.

[46] *SARA* at ss. 32-33. Section 32 prohibits the killing, harming, harassing, capturing, taking, possession, collection, buying, selling or trading of an individual of a wildlife species that is listed as an extirpated, endangered, or threatened species. Section 33 prohibits the damage or destruction of the residence of one more individuals of a wildlife species that is listed as an endangered or threatened species, or extirpated species if a recovery strategy has recommended the reintroduction of the species into the wild in Canada.

[47] "Species at Risk Act: Recovery Strategies" (last modified 23 February 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/recovery-strategies.html>.

The mischaracterization of these species' *SARA* status also suggests that the Proponent has not considered whether any critical habitat of an endangered or threatened species intersects with the Project area or the Block surrounding it. Without considering the Management Plans or Recovery Strategies of the species, it is unclear how the Proponent could conclude that the Project will have no net impacts on migratory birds. An impact assessment is therefore necessary to determine whether the carrying out of the Project will negatively impact any of these species, whether it will risk violating *SARA*, and whether it is aligned with the relevant Management Plans or Recovery Strategies.

Project's Negative Impacts on Migratory Birds and SARA Species

The Proponent's materials concede that the Project is expected to have negative effects on air quality, due to emissions of pollutants, dust, odour and noise, and negative effects due to the creation of waste materials requiring disposal.[48] Additionally, there are possible specific impacts on wildlife and wildlife habitat including potential contamination from construction equipment malfunctions, localized dust generation, soil erosion and sedimentation, and sensory disturbances due to noise and light.[49]

While the Proponent's materials identify some limited proposed mitigation measures, much of this proposed mitigation is qualified and unspecified, for example, that Project construction and maintenance will primarily (not exclusively) occur during daylight hours and that further compliance with the *MBCA* regulations and guidelines with be complied with "if required."[50] The IPD does not specify how and to what extent this mitigation will address these potential impacts, apart from a blanket statement that the Project will have no net impacts on migratory birds. Further, none of the mitigation measures are in regard to the potential adverse impacts from the various emissions from the facility.

Among the ecologically relevant emissions arising from the Project are nitrogen oxides and carbon monoxide. There is no discussion in the IPD about the impacts of nitrogen oxide and carbon monoxide emissions on migratory birds, which raises concerns because there is ample evidence of adverse impacts faced by bird species attributable to exposure to gas-phase and particulate air pollutants including carbon monoxide.[51]

According to the IPD, the land area for the proposed Project has been maintained free of any returning naturalizing vegetation to the present and is ready to develop for the Project[52], and this has precluded any potential for chance nesting activity of migratory

[48] IPD, *supra* note 6 at 8.
[49] EIS, *supra* note 19 at 30.
[50] IPD, *supra* note 6 at 42.
[51] Olivia V Sanderfoot & Tracey Holloway, "Air pollution impacts on avian species via inhalation exposure and associated outcomes" (2017) 12 Environ. Res. Lett. 1 at 2 (IOP), online (pdf): *IOP Science* <https://iopscience.iop.org/article/10.1088/1748-9326/aa8051/pdf>.
[52] IPD, *supra* note 6 at 40.

birds[53]. However, the EIS states that smaller remnant naturalized features remain on the site that have not been disturbed in the recent past, which provide some potential habitat opportunities.[54] The EIS also includes observations of several species of birds flocking in the Project study area including Horned Larks, Mourning Doves and American Goldfinch, all of which are migratory bird species.[55]

Finally, reliance on the EIS, which was prepared for the previous Green Electron Power Project means that there is no consideration of cumulative effects of the Project with this previous development. This indicates a need for additional information regarding the potential habitat available to migratory birds in and around the Project site.

Given the potential threats to migratory bird species and their habitat, the limited mitigation measures identified by the Proponent, and the Proponent's reliance on an EIS with inaccurate information regarding species at risk, there is insufficient information for the Proponent to conclude that there would be no net impacts on migratory birds. Additional research is required to fully clarify the potential impacts the Project may cause to migratory bird species, and this necessitates an impact assessment.

Adverse Effects on the Cerulean Warbler

The Cerulean Warbler is an endangered species with a declining population that is known to occur and possibly breed near the Project site. This, coupled with the fact that the EIS was not updated to reflect the change in *SARA* status from Special Concern to Endangered (which implies that any Recovery Strategy was not considered in the development of the IPD) raises concerns as to whether the potential impacts of the Project on this species were adequately considered. The risks to this species from the Project are emblematic of other bird species and highlight the need for an impact assessment and warrant consideration by the Agency under s. 16(2)(b).

The Cerulean Warbler has been identified in the Conservation Reserve Management Plan as a species whose habitat is protected in the Conservation Reserve and ANSI.[56] The Cerulean Warbler has known or potential occurrences within the St. Clair River Subwatershed as of 2018.[57] Further, the Conservation Reserve intersects with or is immediately adjacent to the proposed Project site, and there is evidence to suggest that the Cerulean Warbler uses this land during part of its life cycle, including breeding. This area could qualify as the

[53] *Ibid* at 45.
[54] EIS, *supra* note 19 at 19.
[55] *Ibid* at 11.
[56] Conservation Reserve Management Plan, *supra* note 26 at 6.
[57] SCRCA, *supra* note 31 at 70.

residence[58] of the Cerulean Warbler that cannot be damaged or destructed under s. 33 of *SARA*.

The EIS acknowledges that there is possible breeding evidence of the Cerulean Warbler within the Block around the proposed Project site and that the Conservation Reserve supports this species.[59] Moreover, the general location of the Green Electron Power Project and the Project (**see Figure 4**) intersects with/is immediately adjacent to possible breeding grounds for the species and areas where the species have been known to occur (**see Figures 5 and 6**). Further, there have been various observations of the species in the Conservation Reserve as recently as May 2020, as documented in eBird (one of the world's largest biodiversity-related science projects that tracks bird sightings and is managed by the Cornell Lab of Ornithology)[60], which indicates that the Cerulean Warbler still relies on this habitat. Accordingly, there is sufficient information to establish that the Project location and surrounding area is relied on by the Cerulean Warbler for its residence, and this raises the possibility that the Project may cause adverse effects to its residence. This should be further explored in an impact assessment.

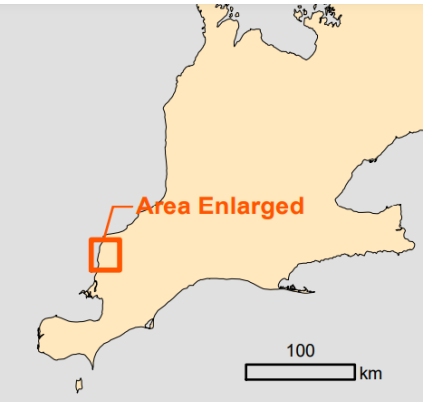

Figure 4: Key map from which enlarged map of Green Electron Power Project location (Figure 2) was derived

[58] Residence is defined in s 2(1) of *SARA:* a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating.
[59] EIS, *supra* note 19 at 7, 9-10.
[60] The Cornell Lab of Ornithology, "Species: Cerulean Warbler – *Setophaga cerulea*", online: *eBird* <https://media.ebird.org/catalog?taxonCode=cerwar&sort=rating_rank_desc&regionCode=L682473&view=list>.

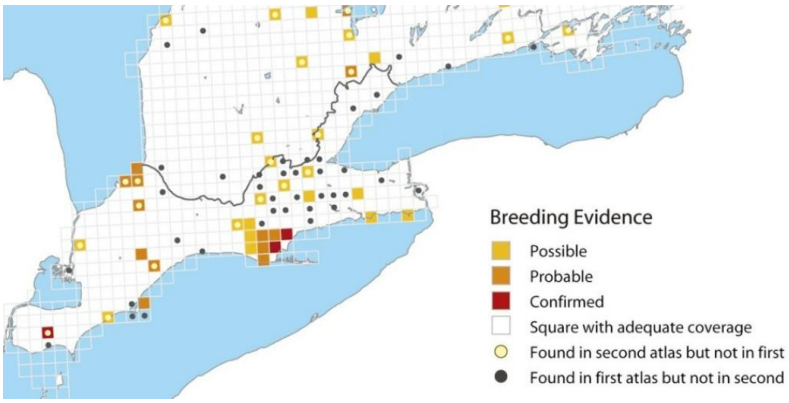

Figure 5: Distribution of the Cerulean Warbler's breeding areas in Ontario between 2001-2005[61]

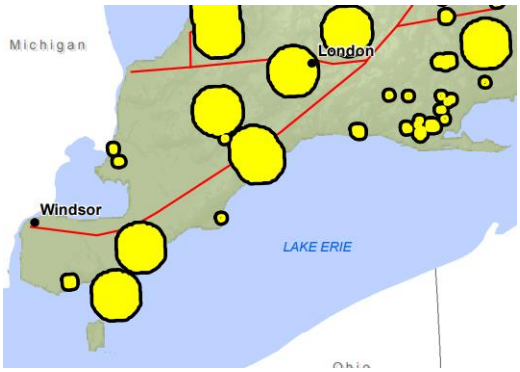

Figure 6: Cerulean Warbler species occurrences in Ontario, as of February 2012[62]

The EIS recognizes the Cerulean Warbler as a federal species of special concern as well as a provincial species of special concern, but states that there is no potential presence of the Cerulean Warbler in the Project study area because there is no continuous forest with interior habitats present or adjacent to the Project study area.[63] The EIS does not acknowledge that the Cerulean Warbler was reassessed by the Committee on the Status of Endangered Wildlife in Canada in 2010 as endangered and was reclassified from Special Concern to Endangered on Schedule 1 of *SARA* in 2017.[64] This indicates that any Recovery Strategy for this species was not considered. The conclusion in the EIS that there is no

[61] Environment and Climate Change Canada, "Recovery Strategy for the Cerulean Warbler (*Setophaga cerulea*) in Canada (2021) at 4, online (pdf): *Government of Canada* <https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/plans/rs_cerulean_warbler_e_final.pdf> [Recovery Strategy for the Cerulean Warbler].
[62] Ontario Natural Heritage Information Centre, "Cerulean Warbler in Ontario" (29 February 2012), online (pdf): *Government of Ontario* <https://files.ontario.ca/environment-and-energy/species-at-risk/cerulean_warbler_map_eng.pdf>.
[63] EIS, *supra* note 19 at 21.
[64] *Critical Habitat of the Cerulean Warbler (Setophaga cerulea) Order*, SOR/2022-97, online: *Government of Canada* <https://www.gazette.gc.ca/rp-pr/p2/2022/2022-05-25/html/sor-dors97-eng.html>.

potential presence of the species due to lack of continuous forest[65] is inconsistent with the federal Recovery Strategy for the Cerulean Warbler, which states that the minimum patch size needed to support viable local populations in Canada is not well understood and may vary.[66] Further, the potential presence of the species in and around the Project site is supported by the fact that the Canadian range of the Cerulean Warbler is concentrated in only two main areas in Ontario, one of which is the Carolinian forests between lower Lake Huron and Lake Ontario (in which the Project site is located).[67]

The EIS also does not acknowledge the ecological importance of the Cerulean Warbler: according to the Committee on the Status of Endangered Wildlife in Canada, the Cerulean Warbler can be considered an effective umbrella species for the maintenance of populations of other species that require mature deciduous forest habitats, and effective management of their habitat will likely have a positive effect on other species of interest.[68] While the Project site does not fall specifically within the critical habitat identified in the Recovery Strategy, the Recovery Strategy states that the identified critical habitat is likely not sufficient to meet the population and distribution objectives.[69] The inaccurate information about the Cerulean Warbler in the EIS, which is not the only migratory bird species at risk whose *SARA* status was out of date in the EIS, raises concerns as to the adequacy of the Proponent's assessment of potential adverse effects of the Project on migratory birds. An impact assessment is required to ensure that these potential effects are meaningfully considered.

2.2.3 Potential Adverse Impacts on Fish and Fish Habitat

The Project area and its surroundings include several fish bearing habitats. It is possible that the carrying out of the proposed Project will have adverse effects on fish and fish habitats. These effects require a thorough assessment through a fulsome impact assessment.

The Agency is required to consider the possible effects of this Project. According to the federal Department of Fisheries and Oceans ("DFO"), s. 35 (harmful alteration, disruption or destruction of fish habitat is prohibited without prior authorization) and s. 36 (no person may pollute water frequented by fish) of the *Fisheries Act,* RSC 1985, c F-14 apply to all Canadian freshwater and marine fisheries waters, including rivers, streams, ditches, lakes, estuaries, salt marshes, coastal waters and marine offshore areas. These provisions also apply to works or undertakings on areas that are not normally under water such as

[65] EIS, *supra* note 19 at 21.
[66] Recovery Strategy for the Cerulean Warbler, *supra* note 61 at 7.
[67] *Ibid* at 3.
[68] *Critical Habitat of the Cerulean Warbler (Setophaga cerulea) Order,* SOR/2022-97, online: *Government of Canada* <https://www.gazette.gc.ca/rp-pr/p2/2022/2022-05-25/html/sor-dors97-eng.html>.
[69] Recovery Strategy for the Cerulean Warbler, *supra* note 61 at iv.

shorelines, riverbanks, seasonally inundated flood plains and on privately owned land.[70] Ontario wetlands provide an extraordinarily fertile environment for innumerable species, including fish, and are more vulnerable to human activities than other types of fish habitats.[71] Accordingly, the Agency must consider the impacts of the Project on fish and fish habitat in Clay Creek, the St. Clair River, the wetlands within the Conservation Reserve and Government Drain #10.

The EIS identified 91 diverse species of resident and migrant fish within the St. Clair River, (with at least 46 species using the river for spawning and nursery habitat) and 16 species known to be present in the Clay Creek system.[72] The EIS has however only named 33 of these 91 species. Out of these 33 species, the St. Clair Region Watershed Report Card confirmed occurrences of 27 species in the St. Clair River Subwatershed as of 2018 (see **Table 1** attached in **Schedule I** to these comments).[73] Further, various of the fish species named in the EIS are mentioned in DFO documents as species that rely on Ontario wetlands as part of their habitat (ex. for spawning or feeding).[74] Aside from the 33 listed species, the Proponent's materials do not list the remaining 58 species or their status under the *SARA*. As noted below, the Proponent's dated materials have mischaracterized the *SARA* status of upwards of ten bird species. The Agency should thus cautiously review the *SARA* status of the 91 fish within the St. Clair River.

The wetland areas of the Conservation Reserve and Government Drain #10 (an open municipal ditch drain) both intersect the Project property. Government Drain #10 drains directly into Clay Creek, which drains directly into the St. Clair River.[75]

The EIS notes that Government Drain #10 is classified as a Type C Drain by DFO. While the IPD notes that Government Drain #10 is "likely" to freeze during the winter and thus provides no potential for overwintering fish habitat, there is no consideration for how or whether climate change will impact this conclusion.[76] Further, while the IPD notes that "no aspect" of Government Drain #10 is on the Project land, it acknowledges its close proximity to the Project and the potential for impacts on this fish habitat from the Project.[77] The

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[70] "Canada's *Fisheries Act:* The Habitat Protection and Pollution Prevention Provisions of the *Fisheries Act*" at 2, online (pdf): *Department of Fisheries and Oceans* <https://waves-vagues.dfo-mpo.gc.ca/library-bibliotheque/272733.pdf>.
[71] Department of Fisheries and Oceans, "The Fish Habitat Primer: A Guide to Understanding Freshwater Fish Habitat in Ontario" (March 2008) at 15, online (pdf): *Credit Valley Conservation* <https://cvc.ca/wp-content/uploads/2011/02/habitat-on_e.pdf> [The Fish Habitat Primer].
[72] EIS P 13-14; note that the EIS named 33 species
[73] SCRCA, *supra* note 31 at 78-82.
[74] The Fish Habitat Primer, *supra* note 71 at 15.
[75] EIS, *supra* note 19 at 4; this map demonstrates where Drain #10 traverses the Project site.
[76] IPD, *supra* note 6 at 43.
[77] *Ibid.*

Project itself would be located approximately 200m from Clay Creek, which includes a riparian corridor through the Conservation Reserve, and as the Conservation Reserve is of significant ecological importance to the CKSPFN, they claim that the Project has the potential to create adverse impacts on their waters and constitutionally protected Aboriginal and Treaty rights.[78]

The interconnection of potentially impacted waterways (the wetlands, Drain #10, Clay Creek and the St. Clair River) highlights the range of potential downstream effects from the Project as a result of sediment loading or contaminant spills. As mentioned in the EIS, construction of access roads, Project infrastructure and power lines have the potential to lead to a temporary increase in surface water turbidity, with an increased risk of siltation in adjacent aquatic environments of Drain 10 due to runoff during construction activities.[79] Further, spills and leaks during construction and operation could allow contaminants to enter Drain 10, and thus Clay Creek and the St. Clair River, both of which are relied on by the Caldwell First Nation for fishing.[80] The EIS also notes that riparian habitat (occurs adjacent to watercourses and contributes to fish habitat) is sensitive to disturbance from overhead line construction and may be impacted by the aboveground installation of power cables for the Project.[81] Therefore, there is potential that the carrying out of the Project may cause adverse incidental effects to the health of fish or fish habitat, and this potential should be further explored in an impact assessment.

The Agency should scrutinize the potential for spills and accidental discharges, the impacts of construction and operation and other likely impacts of the operation of this facility in such close proximity to Drain #10 and the adjacent wetland areas of the Conservation Area.

2.2.4 Potential effects on transboundary pollution

The Agency is required to consider the effects of air pollution on neighboring jurisdictions under s. 2(b)(iii) of the *IAA*. The Proponent is required to outline changes that may occur outside of Canada, such as transboundary air pollution.[82] Finally, as set out below, such information is relevant to any determination made by the Minister under s. 166(1) of *CEPA*.

Despite there being serious concerns arising from the construction of a major fossil fuel plant adjacent to an international border, the Proponent's materials downplay the potential impacts of the Project on transboundary air pollution.

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[78] CKSPFN, *supra* note 14 at 2.
[79] EIS, *supra* note 19 at 26.
[80] Caldwell First Nation, "Comment Form: Information to Inform the Summary of Issues" (13 July 2022), online: *Impact Assessment Agency of Canada* <https://iaac-aeic.gc.ca/050/evaluations/proj/83696/contributions/id/58612>.
[81] EIS, *supra* note 19 at 26.
[82] *Information and Management of Time Limits Regulations* (SOR/2019-283) at s. 20 of Schedules 1 and 2.

Proponent has not adequately assessed potential effect of nitrogen oxides emissions on bordering American regions

In the IPD, the Proponent states that the Project will have "insignificant environmental/ transboundary impact across the St. Clair River to Michigan." The only apparent basis for this claim is that "the prevailing winds are southwesterly."[83] The Proponent provides no modelling setting this out, and appears to ask the Agency to trust that because the winds usually blow away from the United States ("US") that there will be *no* significant transboundary impacts. This claim does not withstand even basic scrutiny.

"Prevailing" means "usual" [84] – i.e., winds usually blow in Ontario's direction, but not always. In fact, as set out in the paragraphs below, there *is* concern that ozone pollution from Ontario industry can contribute to serious environmental and health effects to the neighbouring jurisdiction of Michigan.

A key transboundary concern is ozone causing air pollution, specifically nitrogen oxides (NOx) emissions. As the Proponent identified, this Project will cause significant levels of NOx emissions. Ozone is created when NOx, primarily nitrogen dioxide (NO_2), reacts with sunlight to produce ozone and NO.[85]

The Proponent's claim that the Project presents no potential significant transboundary impacts is directly contradicted by the Michigan-Ontario Ozone Source Experiment ("MOOSE") in their Michigan-Ontario Zone Source Experiment Science Plan ("MOOSE Plan") of May 25, 2021**.** This MOOSE Plan sets out the known fact that ozone from Ontario industry can have impacts on ozone levels in the United States, particularly Michigan. For this reason, we have appended the MOOSE Plan as **Appendix C** in **Schedule II** to these comments for the Agency's consideration under s. 16(2)(f).

MOOSE is a series of field studies being led by the Michigan Department of Environment, Great Lakes and Energy by many collaborating governmental and scientific organizations, such as Environment and Climate Change Canada, Ontario's MECP, the US Environmental Protection Agency and the National Aeronautics and Space Administration, among others,[86]

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[83] IPD, *supra* note 6 at 33.
[84] "Prevailing wind" is defined as "the usual wind in an area or region used to refer to the direction of the wind", online: *Merriam-Webster* https://www.merriam-webster.com/dictionary/prevailing%20wind.
[85] Francis C Itliong, Bruce Holbein & Raman Raghavan, "Hydrogen Ready Power Plant Project Environmental Screening and Review Report: Appendix 17.2 Air Quality Impact Assessment Report" (23 March 2022) at 18 & 56, online (pdf): *Impact Assessment Agency of Canada* <https://iaac-aeic.gc.ca/050/documents/p83696/144111E.pdf> [Air Quality Impact Assessment Report]. This document was attached to the IPD as Appendix 7.2.
[86] "Michigan-Ontario Ozone Source Experiment Science Plan" (25 May 2021) at 10-11, online (pdf): *National Aeronautics and Space Administration* <https://www-air.larc.nasa.gov/missions/moose/docs/MOOSE%20Science%20Plan%20052521.pdf> [MOOSE Plan].

whose purpose is to "ensure a viable ozone attainment strategy, both in the short and long term".[87] The MOOSE Plan found that exceedances of American air quality standards "can sometimes occur during periods of easterly winds, when Canadian sources are likely to contribute to [Southeast Michigan] ozone design values."[88] The Canadian sources specifically identified are from around Windsor and Sarnia, near the location of this proposed Project. This is not surprising, since the Grand Bend monitoring station, just north of the Project, has recently exceeded ozone standards in Ontario more than any other monitoring location in the province.[89]

These periods when winds blow into Michigan from southwest Ontario may add additional ozone pollution into an area already often saturated with it, raising ozone pollution to higher, harmful exceedances of American air quality standards. MOOSE indicates that the seven Michigan counties directly adjacent to the proposed Project location are often already in exceedance of the US National Ambient Air Quality Standard for Ozone of 70 parts per billion ("ppb"). This makes this region a "non-attainment zone", which is an issue of importance to both the Government of Michigan and the US Environmental Protection Agency.[90] With current ozone pollution emanating from Ontario contributing to already excessive ozone levels in nearby Michigan, this Project's potential to additionally heightening the risk of adverse cumulative effects from ozone necessitates serious consideration by the Agency. Cumulative effects of project are a critical focus of any impact assessment.[91]

The potential harm that could be caused by this Project's additional contribution of transboundary ozone pollution in an ozone "non-attainment zone" is significant. Excess ozone exposure can cause breathing complications and more serious effects, including mortality, in persons with asthma and other lung diseases.[92] In their submissions, the CKSPFN expressed concern that potential increases in ground level ozone downwind of this facility due to NOx emissions interacting with sunlight is of great respiratory health concern for any humans, animals or plants exposed to its path.[93]

The Agency cannot credibly discount the findings of such highly reputable scientific bodies that sources of air pollution from the Project area can cause transboundary impacts, in

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[87] *Ibid* at 10.
[88] MOOSE Plan, *supra* note 86 at 4.
[89] "Air Quality in Ontario 2016 Report: Ground-level ozone" (2016), online: *Government of Ontario* <https://www.ontario.ca/document/air-quality-ontario-2016-report/ground-level-ozone>.
[90] MOOSE Plan, *supra* note 86 at 3-4.
[91] *IAA* at s 6(1)(m): A purpose of the *IAA* is to encourage the assessment of the cumulative effects of physical activities" in a region set to be affected by any given project.
[92] "Health Effects of Ozone Pollution" (last modified 14 June 2022), online: *United States Environmental Protection Agency* <https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution#:~:text=Inflame%20and%20damage%20the%20airways,the%20frequency%20of%20asthma%20attacks>.
[93] CKSPFN, *supra* note 14 at 2.

favour of the Proponent's bald assertion that "prevailing winds" will protect from any significant transboundary impacts. An Impact Assessment is necessary to determine the extent of the possible transboundary impacts from ozone pollution. The MOOSE Plan appended shows clear concern for the potential role excess Canadian ozone can play in causing exceedances in northeast Michigan. The Agency must consider these potential transboundary environmental effects pursuant to ss. 16(2)(b) and 2(b)(iii) of the *IAA*.

As indicated above, Pembina has appended the MOOSE Plan to these comments for the Agency's consideration as a "plan" or "study" that must be considered pursuant the Agency's obligations to s. 16(2)(f) of the *IAA*. This plan was prepared collaboratively by several agencies and ministries both Canadian and American, at the Federal, provincial and state jurisdictions, with particular concern for ozone levels in the very region where this Project is proposed to be established. The views of these jurisdictions must be taken into account by the Agency. The consideration of the MOOSE Plan is all the more critical in light of the cursory analysis of this issue by the Proponent. Considering the clear potential harm posed by excess ozone to Canada's transboundary neighbours in Michigan from the additional ozone emissions from this Project, an impact assessment is merited.

2.2.5 Concerns over choice of NOx control Technology

The potential levels of ozone created from the Project's NOx emissions could be increased due to the Proponent's choice of NOx reduction technology. The Proponent plans to use "low NOx" technology rather than "selective catalytic reduction" ("SCR") technology. The Agency needs to seek further detail on the impact of this choice, whether it will result in greater NOx emissions (and thus a greater potential for ozone impacts), and whether SCR technology would be preferable to minimize impacts on areas of federal jurisdiction.

In a region already often exceeding safe levels of ozone air quality on both sides of the border, adding any amount of additional ozone causing pollutants in the region could negatively affect federal areas of jurisdiction. The Proponent determined that this Project could emit 395.2 tonnes of NOx annually, amounting to 0.14% of Ontario's annual NOx emissions in 2018.[94] While this contribution may be a fraction of the total province-wide NOx emissions, the fact that this increase is occurring in a single location with already high levels of ozone suggests clear potential cumulative impacts. Marginal increases in ozone in this region may have outsized impacts, since the region is already often exceeding recommended levels at nearby Grand Bend station,[95] and in nearby Michigan counties, as outlined in the section above.

In light of the existing high levels of ozone in the region, the Agency should ensure that the Proponent plans to do all that it can to reduce the NOx emissions produced by this Project, and the subsequent ozone those emissions can create. Unfortunately, the "low NOx"

[94] Air Quality Impact Assessment Report, *supra* note 85 at 57.
[95] "Air Quality in Ontario 2016 Report: Ground-level ozone" (2016), online: *Government of Ontario* <https://www.ontario.ca/document/air-quality-ontario-2016-report/ground-level-ozone>.

technology the Proponent plans to use is likely to be less effective in preventing NOx emissions than the alternative option, namely SCR. This choice could contribute to higher levels of local NOx emissions, and subsequent ozone concentrations, that could push exceedances even higher above recommended levels, leading to potential harms to humans, fauna and flora.

The Proponent justifies its decision to use "low NOx" technology on the basis that SCR technology would co-produce more emissions of other forms, such as ammonium compounds.[96] The Proponent does not provide any further details or justification for this choice in any of the documents it submitted to the Agency.[97] In fact, the Proponent's Air Quality Impact Assessment Report does not mention SCR technology at all.[98] This lack of analysis is problematic considering there are credible sources which suggest that SCR technology, capable of reducing NOx emissions by 70-90%,[99] is preferrable to "low NOx" technology, which reduces "NOx emissions by a much smaller amount".[100] The Proponent has not detailed a precise percentage of NOx emissions that it expects will be mitigated by the "low NOx" technology, and until it does so, the Agency should assume that the SCR alternative could be substantially more effective at mitigating NOx emissions and subsequent ozone pollution. The potential for additional NOx emissions from the Project due to this technology choice is relevant to the cumulative NOx levels being produced in the Project's region. This is particularly true given that similar "low NOx" technology is already being used at the adjacent Green Electron Power Project facility.[101]

The potential for heightened NOx emissions and subsequent ozone pollution from the Project may cause unnecessary human and environmental impacts, both transboundary, as detailed above, and to Indigenous communities on the Ontario side of the border. With ozone pollution already saturating much of the areas of Michigan near this Project up to and exceeding maximum American health guidelines, any additional ozone created due to the choice of low NOx technology being used over SCR could cause unnecessarily higher exceedances of maximum ozone thresholds set across the US border, leading to more profound serious respiratory health impacts.

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[96] IPD, *supra* note 6 at 30.
[97] Bruce E Holbein, Francis Itliong & Raman Raghavan, "Hydrogen Ready Power Plant Project: Environmental Screening and Review Report" (30 March 2022) at 21, online (pdf): *Impact Assessment Agency of Canada* https://iaac-aeic.gc.ca/050/documents/p83696/144110E.pdf [Environmental Screening and Review Report]. This document is attached to the IPD as Appendix 7.1.
[98] Air Quality Impact Assessment Report, *supra* note 85.
[99] "Air Pollution Control Technology Fact Sheet", online: *United States Environmental Protection Agency* <https://www3.epa.gov/ttncatc1/dir1/fscr.pdf>.
[100] Bruce Biewald et al, "Use of Selective Catalytic Reduction for Control of NOx Emissions from Power Plants in the US: Prepared for The Ont*AIR*io Campaign" (February 2000) at 3, online (pdf): <https://www.synapse-energy.com/sites/default/files/SynapseReport.2000-02.OntAIRio.Control-of-NOx-Emissions..99-40.pdf>.
[101] IPD, *supra* note 6 at 30.

The potential for higher ozone concentrations in the Project region may also have significant impacts on Indigenous communities in Ontario near to the Project. While Pembina does not claim to represent any Indigenous communities, Pembina has read the concerns expressed by the CKSPFN in their comments submitted to the Agency, where they detail their concern that this Project will add ozone pollution to a region already saturated with it.[102] As the CKSPFN sets out, not only is the American air quality standard of 70ppb for ozone often exceeded, but Ontario's 80ppb standard has often been exceeded at the nearby Grand Bend station.[103]

With the use of low NOx technology, the concentrations of ozone in the area surrounding area could be higher than they would be with SCR use, potentially worsening these impacts on Indigenous communities. An impact assessment is necessary to garner a sufficient understanding of the differing environmental impacts that could occur under the use of low NOx or SCR technologies. Otherwise, increased harmful impacts from increased ozone to local Indigenous communities, an impact within federal jurisdiction and responsibility, may be allowed to occur.

2.2.6 An Impact Assessment would inform the Minister's considerations under s. 166 of *CEPA*

The Minister should be concerned with the possibility that this Project will exacerbate air pollution in the US.

Under s. 166(1) of *CEPA*, the Minister must act if he has "reason to believe that a substance released from a source in Canada into the air creates, or may reasonably be anticipated to contribute to…(a) air pollution in a country other than Canada". As outlined above, this Project could worsen already saturated ozone pollution levels across the border into northeast Michigan triggering s. 166(1).

When s. 166(1) is triggered, the Minister must consult with the responsible provincial government and/or take ministerial action under subsections 166(2) and (3).

This Project is situated on privately owned land in Ontario,[104] and is therefore a provincially regulated property. As set out below in these submissions, there is no indication that the Government of Ontario's Environmental Assessment process adequately assessed the Proponent's consideration for potential for harmful *transboundary* air pollution resulting from this Project. Following s. 166(2) of *CEPA*, the evidence that this Project may create harmful pollution in the US, and Ontario's inadequate assessment of that potential harm, ought to obligate the Minister to determine whether Ontario is willing to undertake further efforts to prevent, control or correct the air pollution set to emanate from the Project.

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[102] CKSPFN, *supra* note 14 at 5.
[103] *Ibid*.
[104] IPD, *supra* note 6 at 5.

However, should Ontario refuse to undertake sufficient further efforts to prevent potential transboundary air pollution impacts from this Project, the Minister must take his own action to address the pollution concerns. He could either publish a notice under s. 56(1) of *CEPA* requiring that the Proponent prepare a "pollution prevention plan" in relation to several of the Project's pollutants of concern that are found under Schedule 1 of *CEPA*,[105] or recommend regulations to control or correct the air pollution of concern. No matter the choice, action would need to be taken.

In order to properly fulfill his obligations under s. 166 of *CEPA*, the Minister requires a fulsome understanding of the potential pollutant impacts this Project is set to present. An impact assessment is the best available tool the federal government has to inform its decision making on projects that can cause environmental and other impacts. Considering the clear gaps in the Proponent's existing assessment of several pollutants of concern, an impact assessment would be beneficial in informing the Minister's opinion in relation to his s.166 obligations.

2.2.7 Potential effects on federal methane targets

The lack of information provided by the Proponent relating to methane emissions from the Project, particularly the lack of any meaningful analysis on potential fugitive emissions, weighs in favour of conducting an impact assessment.

The *Information and Management of Time Limits Regulations* require the Proponent to provide an "estimate of any greenhouse gas emissions associated with the project".[106] The federal impacts of greenhouse gas emissions are also a change to the environment relevant to the Agency's s.16 determination.

Despite these obligations, the Proponent has failed to provide an adequate accounting of methane emissions. In the IPD, the Proponent only briefly touches on methane emissions, providing rough estimates of tonnes of emissions from the operation of the plant.[107] This calculation appears to be based solely on unburned methane. There does not appear to be any calculation of potential fugitive emissions from the facility's operation, supply or new pipeline infrastructure associated with the Project.

The federal government's concerns related to methane emissions are evident, and for good reason. The global warming potential from methane is over 80 times than carbon dioxide in a 20-year period and 25 times greater in a 100-year period. Because of methane's global warming potential, at the 26th Conference of the Parties to the United Nations Framework

[105] Schedule 1 of *CEPA* lists substances that have been designated as toxic, for example, see ozone (substance number 61), nitrogen oxide and dioxide (substance numbers 62, 63), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/substances-list/toxic/schedule-1.html>.
[106] *Information and Management of Time Limits Regulations,* SOR/2019-283, Schedules 1 and 2 at s 23.
[107] Air Quality Impact Assessment Report, *supra* note 85 at 21, Table 3.

Convention on Climate Change ("UNFCCC") in November 2021, the federal government pledged to reduce Canada's methane emissions by 30% by 2030 economy-wide, and 75% below 2012 levels by 2030 in the oil and gas sector specifically.[108] This pledge has been backed up by federal policy and regulation,[109] and is set to be strengthened in early 2023 with new regulatory measures.[110]

The federal government's commitments to account for and reduce methane emissions include improving Canada's accountability for fugitive emissions in Canada's National Inventory Reports submitted to the UNFCCC.[111] As explained by Environment and Climate Change Canada, among Canada's next steps to meet its target of 75% reduction in oil and gas sector methane emissions relative to 2012 by 2030 is Canada's intention to "expand coverage and increase the stringency of the methane reduction obligations in the existing federal oil and gas methane regulations", including "expanded fugitive emissions requirements".[112]

There is no clear indication that the Proponent here has meaningfully attempted to account for potential fugitive methane emissions in the operation of the Project or delivery of gas to the plant, and without an impact assessment, no indication that any further detailed accounting of fugitive emissions sources will be undertaken. It is well known, as referenced by Environmental Defense in their submissions, that upstream fugitive methane emissions can nearly double the combustion product for any given natural gas site over a 20-year

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[108] Environment and Climate Change Canada, "Reducing methane emissions from Canada's oil and gas sector: discussion paper", March 2022, at 4, online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/consultation-reducing-methane-emissions-oil-gas-sector.html> [ECCC 2022 Oil and Gas Methane Emissions Discussion Paper].

[109] For example, this policy is a core directive in the 2021 Mandate Letter sent to ECCC Minister Guilbeault, setting out the policy to further reduce methane emissions across the economy, particularly "oil and gas" methane emissions by 75% below 2012 levels by 2030: Office of the Prime Minister, "Minister of Environment and Climate Change Mandate Letter", 16 December 2021, online: https://pm.gc.ca/en/mandate-letters/2021/12/16/minister-environment-and-climate-change-mandate-letter; efforts to reduce methane emissions have also been translated into regulatory measures, such as the *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*, SOR/2018-66, in an effort to reach Canada's initial target of 40-45% reduction in methane emissions compared to 2012 by 2025: Environment and Climate Change Canada, "Review of Canada's Methane Regulations for the Upstream Oil and Gas Sector: December 2021" at iii, online: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/review-methane-regulations-upstream-oil-gas-sector.html [ECCC 2021 Upstream Oil and Gas Methane Regulation Review].

[110] ECCC 2022 Oil and Gas Methane Emissions Discussion Paper, *supra* note 108 at 12; ECCC 2021 Upstream Oil and Gas Methane Regulation Review, *supra* note 109 at iii.

[111] ECCC 2022 Oil and Gas Methane Emissions Discussion Paper, *supra* note 108 at 7.

[112] *Ibid* at 10.

period.[113] The uncertainty around the full scope of methane emissions in the reporting by this Proponent to date should motivate the Agency to follow through with a thorough impact assessment.

2.2.8 Ontario's environmental assessment is not an adequate substitute for a federal impact assessment

Pembina endorses the comments made by Environmental Defense that the Agency should not rely on Ontario's Environmental Assessment ("EA") process as an adequate substitute for a federal impact assessment.[114] Further to Environmental Defense's comments, Pembina sets out further details below of the inadequacy of Ontario's EA process. Given the numerous potential effects on federal areas of jurisdiction set out above, the Agency cannot rely on this inadequate provincial process.

Ontario does not require a full EA of the Project

Electricity generation projects in Ontario are presumptively subject to a "streamlined environmental assessment" under Ontario's *Environmental Assessment Act,* RSO 1990, c E. 18 ("*EAA*"). They are not subject to the more thorough Comprehensive Environmental Assessment ("Comprehensive EA") under the *EAA*.[115]

As the Proponent explains at page five of the IPD, this Project is a Category B project under Ontario's *EAA*. According to Ontario's guidance, cited by the Proponent in Appendix 7.1 to their IPD,[116] proponents of Category B projects "are not required to prepare a Comprehensive EA 'on the condition that they complete the Environmental Screening Process'" ("ESP").[117] While the Proponent did 'self-elevate' Air pollution, Noise pollution and stormwater management to a slightly more in-depth "Environmental Review",[118] this did not bring about meaningful, impartial assessment by government actors or other parties.

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[113] Environmental Defense, "Comments on the Initial Project Description for the Gas Plant Project, IAAC File Number 83696" (13 July 2022) at 4, online (pdf): *Impact Assessment Agency of Canada* <https://registrydocumentsprd.blob.core.windows.net/commentsblob/project-83696/comment-58607/IAAC%20File%2083696%20-%20Comments%20on%20Initial%20Project%20Description%20of%20Environmental%20Defence.pdf>; citing Juan Sotes, "Fugitive Methane: New guidelines determine need to curb natural gas emissions in Ontario" (May 2022) at 7, online (pdf): *The Atmospheric Fund* <https://taf.ca/wp-content/uploads/2022/05/TAF_Fugitive-methane-guidelines_2022-2.pdf>.

[114] Environmental Defense, *ibid* at 6-7.

[115] *EAA* at Part II.4; "Preparing environmental assessments" (updated 6 June 2022), online: *Government of Ontario* <https://www.ontario.ca/page/preparing-environmental-assessments#section-5>. See the "Streamlined Environmental Assessments" section.

[116] Environmental Screening and Review Report, *supra* note 97 at 41.

[117] "Guide to Environmental Assessment Requirements for Electricity Projects" (last revised January 2011), online: *Government of Ontario* <https://www.ontario.ca/page/guide-environmental-assessment-requirements-electricity-projects>.

[118] Environmental Screening and Review Report, *supra* note 97 at 3-4.

Rather, the Environmental Review merely required the Proponent to produce slightly more detailed and updated reports on the listed effects, appended to their ultimate Environmental Screening and Review Report.[119] A more detailed self-assessment is, ultimately, still a self-assessment.

The ESP and Environmental Review process did not involve meaningful review by the public or government authorities resembling anything near Ontario's Comprehensive EA process, or a federal impact assessment. For example, under the ESP and Environmental Review, if a member of the public takes issue with an environmental effect they identify in any given project, they can only apply for a more in-depth, Comprehensive EA study on the matter if it is related to existing Aboriginal or treaty rights.[120] No other basis allows for such a review request by the public. Further, under the ESP and Environmental Review, the Minister of MECP does not need to make a decision approving any step of the process, or its final product – projects are by default either "pre-approved or exempt" from Ministerial oversight and substantive review.[121]

Clearly, the Ontario EA regime has been specifically designed to allow natural gas electricity projects like this avoid meaningful, accountable assessment. After all, there does exist a more thorough type of environmental assessment in Ontario – the Comprehensive EA. Where Ontario has made Comprehensive EA largely inapplicable to this Project, the Agency must ensure a federal impact assessment fills the gaps left by Ontario.

If the Ontario EA process had allowed for a Comprehensive EA, many of the assessment gaps identified might have been filled. Under a Comprehensive EA, MECP and the Minister of MECP would have been *required* to decide whether this Project adequately prevents or mitigates environmental harms. The Proponent would have needed to create a Terms of Reference to scope and detail many aspects of the Project before even beginning the Comprehensive EA.[122] That Terms of Reference would have faced a mandatory review by the Minister of MECP, who could only approve it if they found it to be in the public interest.[123] The Proponent would have had to submit a Comprehensive EA, setting out in detail the potential environmental effects of the Project.[124] The Director of MECP, and ultimately the Minister of MECP, would have been required to determine whether the Comprehensive EA adequately addressed any environmental concerns.[125] Further, this review by the MECP and the Minister of MECP would have needed to consider "any" public comments submitted in relation to the content of the Comprehensive EA when making

[119] Environmental Screening and Review Report, *supra* note 97 at 4.
[120] *EAA* at s 17.31(7).
[121] "Preparing environmental assessments" (updated 6 June 2022), online: *Government of Ontario* <https://www.ontario.ca/page/preparing-environmental-assessments#section-5>. See the "Streamlined Environmental Assessments" section.
[122] *EAA* at s 17.4(1).
[123] *EAA* at s. 17.4(10).
[124] *EAA* at s 17.6(2).
[125] *EAA* at s 17.11(4)-(7).

their mandatory decisions.[126] Finally, the Minister of MECP would have had to decide whether to approve the Project in full[127], approve it with conditions[128], refuse the Project,[129] or refer the application to the Ontario Land Tribunal to make the ultimate decision.[130] Clearly, this process would have allowed for far more impartial, thorough checks and balances on the Proponent's self-assessment.

The Agency should be concerned that Ontario's streamlined EA regime cut out the Comprehensive EA process, especially considering the many federal impacts identified above that are still of concern even after the Proponent's self-assessment. Much of the Comprehensive EA gap could be filled by the similar federal impact assessment. For example, under a federal impact assessment, the Agency would have a chance to impartially assess and approve an Impact Statement provided by the Proponent against Tailored Impact Statement Guidelines.[131] This step by the Agency would help ensure that the Proponent has collected adequate information and studies, and properly consulted the public and Indigenous groups. The Agency would further provide further checks on the environmental sufficiency of the Proponent's Project by considering all of the factors under s. 22(1) of the *IAA* in an impact assessment.[132] Finally, the Minister would provide another important check, making a final public interest determination on the Project informed by the Agency's impact assessment.[133]

With the Ontario EA process reaching completion without a Comprehensive EA, the Agency must take this opportunity to fill the assessment gap with a federal impact assessment. Beyond the basic lack of accountability inherent in the self-assessment performed to date, the many outstanding environmental effects of concern, particularly those touching on federal jurisdiction as outlined in these submissions, should compel the Agency to order an impact assessment so that those concerns are properly and transparently examined.

[126] *EAA* at ss 17.9(2), 17.11(1).
[127] *EAA* at s 17.15(1)(a).
[128] *EAA* at s 17.15(1)(b).
[129] *EAA* at s 17.15(1)(c).
[130] *EAA* at s 17.16(1).
[131] Impact Assessment Agency, "Impact Assessment Process Overview: Phase 1" (last modified 8 November 2019), online: *Government of Canada* <https://www.canada.ca/en/impact-assessment-agency/services/policy-guidance/impact-assessment-process-overview/phase2.html>. See "Roles and Responsibilities – The Agency".
[132] *IAA* at s 28(2).
[133] *IAA* at s 60(1).

3.0 Conclusion

For the reasons set out in these comments detailing the potential adverse impacts and the gaps in the information, Pembina submits that the Eastern Power Inc Project be required to undergo an impact assessment. The gaps in the scope, detail and currency of the information on the nature of potential adverse impacts on areas of federal jurisdiction detailed above are significant. It would be unreasonable for the Agency to conclude that the Project should not be required to undertake an impact assessment given these deficiencies.

Yours truly,

<Original signed by>

Reid Gomme
Staff Lawyer

Encl.:

Schedule I: Tables
- Table 1
- Table 2
- Table 3

Schedule II: Appendices
- Appendix A: Bickford Oak Woods Conservation Reserve Management Plan, 2009
- Appendix B: St. Clair Region Watershed Report Card, 2018
- Appendix C: MOOSE Plan, May 25, 2021

Cc: Binnu Jeyakumar, Pembina Institute for Appropriate Development (<email address removed>)
Karambir Singh, Pembina Institute for Appropriate Development (<email address removed>)

SCHEDULE I: TABLES

Table 1: Cross-reference between Table 2.2 of the EIS (Summary of Bird Species occurring within the 10km^2 Block around the Proposed Project Site and their Potential for Occurrence within the Proposed Project Site[134]) against list of protected bird species under the *MBCA*[135] and endangered or threatened species under *SARA*[136]

Common Name	Scientific Name	Breeding Evidence[1]	Potential Breeding Occurrence in the Study Area
Acadian Flycatcher*	*Empidonax virescens*	Possible	--
Alder Flycatcher	*Empidonax alnorum*	Possible	--
American Crow	*Corvus brachyrhynchos*	Probable	--
American Goldfinch	*Spinus tristis*	Probable	--
American Kestrel	*Falco sparverius*	Confirmed	--
American Redstart	*Setophaga ruticilla*	Possible	--
American Robin	*Turdus migratorius*	Confirmed	--
American Woodcock	*Scolopax minor*	Probable	--
Baltimore Oriole	*Icterus galbula*	Confirmed	--
Bank Swallow	*Riparia riparia*	Possible	--
Barn Swallow*	*Hirundo rustica*	Confirmed	--
Belted Kingfisher	*Ceryle alcyon*	Possible	--
Black-billed Cuckoo	*Coccyzus erythropthalmus*	Probable	--
Black-capped Chickadee	*Poecile atricapillus*	Confirmed	--
Blue Jay	*Cyanocitta cristata*	Confirmed	--
Blue or Golden-winged Warbler*	*Vermivora sp.*	Possible	--
Blue-gray Gnatcatcher	*Polioptila caerulea*	Confirmed	--
Blue-winged Warbler	*Vermivora cyanoptera*	Probable	--
Bobolink*	*Dolichonyx oryzivorus*	Probable	--
Brown Creeper	*Certhia americana*	Confirmed	--
Brown Thrasher	*Toxostoma rufum*	Probable	--
Brown-headed Cowbird	*Molothrus ater*	Confirmed	Y
Canada Goose	*Branta canadensis*	Confirmed	--
Carolina Wren	*Thryothorus ludovicianus*	Possible	--
Cedar Waxwing	*Bombycilla cedrorum*	Confirmed	--

[134] EIS, *supra* note 19 at 9.
[135] "Birds Protected in Canada" (last modified 16 August 2022), online: *Government of Canada* <https://www.canada.ca/en/environment-climate-change/services/migratory-birds-legal-protection/list.html>.
[136] *SARA* at Schedule 1: List of Wildlife Species at Risk.

Cerulean Warbler*	*Setophaga cerulea*	Possible	--
Chipping Sparrow	*Spizella passerina*	Confirmed	--
Cliff Swallow	*Petrochelidon pyrrhonota*	Confirmed	--
Common Grackle	*Quiscalus quiscula*	Confirmed	--
Common Yellowthroat	*Geothlypis trichas*	Confirmed	--
Cooper's Hawk	*Accipiter cooperii*	Confirmed	--
Downy Woodpecker	*Picoides pubescens*	Confirmed	--
Eastern Bluebird	*Sialia sialis*	Confirmed	--
Eastern Kingbird	*Tyrannus tyrannus*	Probable	--
Eastern Meadowlark*	*Sturnella magna*	Probable	--
Eastern Phoebe	*Sayornis phoebe*	Possible	--
Eastern Screech-Owl	*Megascops asio*	Possible	--
Eastern Towhee	*Pipilo erythrophthalmus*	Possible	--
Eastern Wood-Pewee	*Contopus virens*	Probable	--
European Starling	*Sturnus vulgaris*	Confirmed	--
Field Sparrow	*Spizella pusilla*	Confirmed	--
Gray Catbird	*Dumetella carolinensis*	Confirmed	--
Great Blue Heron	*Ardea herodias*	Confirmed	--
Great Crested Flycatcher	*Myiarchus crinitus*	Confirmed	--
Great Horned Owl	*Bubo virginianus*	Possible	--
Green Heron	*Butorides virescens*	Possible	--
Hairy Woodpecker	*Picoides villosus*	Probable	--
Herring Gull	*Larus argentatus*	Possible	--
Horned Lark	*Eremophila alpestris*	Confirmed	--
House Finch	*Carpodacus mexicanus*	Probable	--
House Wren	*Troglodytes aedon*	Confirmed	--
Indigo Bunting	*Passerina cyanea*	Probable	--
Killdeer	*Charadrius vociferous*	Confirmed	--
Least Flycatcher	*Empidonax minimus*	Probable	--
Mallard	*Anas platyrhynchos*	Confirmed	--
Mourning Dove	*Zenaida macroura*	Confirmed	--
Northern Cardinal	*Cardinalis cardinalis*	Confirmed	--
Northern Flicker	*Colaptes auratus*	Confirmed	--
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*	Confirmed	--
Northern Waterthrush	*Parkesia noveboracensis*	Possible	--
Orchard Oriole	*Icterus spurius*	Confirmed	--
Ovenbird	*Seiurus aurocapillus*	Probable	--

Pileated Woodpecker	*Dryocopus pileatus*	Probable	--
Prothonotary Warbler*	*Protonotaria citrea*	Probable	--
Purple Martin	*Progne subis*	Possible	--
Red-bellied Woodpecker	*Melanerpes carolinus*	Confirmed	--
Red-eyed Vireo	*Vireo olivaceus*	Probable	--
Red-headed Woodpecker*	*Melanerpes erythrocephalus*	Probable	--
Red-tailed Hawk	*Buteo jamaicensis*	Confirmed	--
Red-winged Blackbird	*Agelaius phoeniceus*	Confirmed	Y
Rock Pigeon	*Columba livia*	Confirmed	--
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	Confirmed	--
Ruby-throated Hummingbird	*Archilochus colubris*	Possible	--
Savannah Sparrow	*Passerculus sandwichensis*	Probable	Y
Scarlet Tanager	*Piranga olivacea*	Possible	--
Song Sparrow	*Melospiza melodia*	Confirmed	Y
Spotted Sandpiper	*Actitis macularia*	Confirmed	--
Swamp Sparrow	*Melospiza georgiana*	Possible	--
Tree Swallow	*Tachycineta bicolor*	Confirmed	--
Tufted Titmouse	*Baeolophus bicolor*	Confirmed	--
Turkey Vulture	*Cathartes aura*	Possible	--
Veery	*Catharus fuscescens*	Confirmed	--
Vesper Sparrow	*Pooecetes gramineus*	Possible	--
Warbling Vireo	*Vireo gilvus*	Confirmed	--
White-breasted Nuthatch	*Sitta carolinensis*	Confirmed	--
Wild Turkey	*Meleagris gallopavo*	Confirmed	--
Willow Flycatcher	*Empidonax traillii*	Confirmed	--
Wood Duck	*Aix sponsa*	Confirmed	--
Wood Thrush	*Hylocichla mustelina*	Confirmed	--
Yellow Warbler	*Setophaga petechia*	Confirmed	--
Yellow-throated Vireo	*Vireo flavifrons*	Probable	--

Source: Cadman et al., 2007

[1]See http://www.birdsontario.org/atlas/codes.jsp?lang=en for information on evidence definitions.

* Listed under the provincial *Endangered Species Act, 2007*

Table 2: Comparison of the *SARA* statuses identified in the EIS and the current *SARA* statuses of migratory bird species at risk with breeding evidence in the Block[137] and known or potential occurrences within the St. Clair River Subwatershed[138] as of 2018

Species	*SARA* listing as identified in EIS (2012)[139]	*SARA* listing as of 2022[140]	Breeding Evidence in the Block	Known and potential occurrences within the St. Clair River Subwatershed
Acadian Flycatcher	Endangered	Endangered	Possible	Yes
Bank Swallow	No Status	Threatened	Possible	Yes
Barn Swallow	No Status	Threatened	Confirmed	Yes
Golden-winged Warbler	Threatened	Threatened	Possible	
Bobolink	No Status	Threatened	Probable	
Cerulean Warbler	Special Concern	Endangered	Possible	Yes
Eastern Meadowlark	No Status	Threatened	Probable	Yes
Eastern Wood-Pewee	No Status	Special Concern	Probable	
Great Blue Heron	No Status	Special Concern	Confirmed	
Prothonary Warbler	Endangered	Endangered	Probable	Yes
Red-headed woodpecker	Threatened	Endangered	Probable	
Savannah Sparrow	No status	Special Concern	Probable	
Wood Thrush	No Status	Threatened	Confirmed	

[137] EIS, *supra* note 19 at 9.
[138] SCRCA, *supra* note 31 at 70.
[139] EIS, *supra* note 19 at 20-23.
[140] *SARA* at Schedule 1: List of Wildlife Species at Risk.

Table 3: Occurrence of fish species (named in the EIS) within St. Clair River, Clay Creek and the broader St. Clair River Subwatershed with description of potential life cycle processes occurring in the Conservation Reserve

Species named in EIS[141]	**Species identified in the Fish Habitat Primer as relying on Ontario wetland habitat**[142]	**Life cycle process according to The Fish Habitat Primer**	**Habitat identified in EIS**	**Species occurrences within St. Clair River Tributaries Subwatershed as of 2018**[143]
Northern pike	Yes	Spawning (in sedges: grasses that grow in wet areas) and nursery (leaves its eggs in the wetland, attached to standing plants from the previous growing season, which keep the eggs from sinking and suffocating and protects them from predators)	St. Clair River and Clay Creek	Yes
Longnose gar	Yes	May spend entire lives in a wetland	St. Clair River	Yes
Bluegills	Yes	Periodic feeding and protection	Clay Creek	Yes
Smallmouth Bass, Largemouth Bass and White Bass	Yes (Bass)	Periodic feeding and protection	St. Clair River	Yes, except White Bass
Black crappie	Yes	Periodic feeding and protection	Clay Creek	Yes
White Sucker	Yes (Suckers)	Feeding	St. Clair River and Clay Creek	Yes
Walleye	Yes	Feeding	St. Clair River	Yes
Lake Sturgeon			St. Clair River	Yes
Muskellunge			St. Clair River	No

[141] EIS, *supra* note 19 at 13-14.
[142] The Fish Habitat Primer, *supra* note 71 at 15.
[143] SCRCA, *supra* note 31 at 78-82.

Yellow Perch			St. Clair River	Yes
Brownfin			St. Clair River	No
Channel Catfish			St. Clair River	Yes
Rainbow Trout			St. Clair River	Yes
Brown Trout			St. Clair River	Yes
Chinook Salmon			St. Clair River	Yes
Coho Salmon			St. Clair River	No
Rainbow Smelt			St. Clair River	Yes
Pumpkinseed			Clay Creek	Yes
Green Sunfish			Clay Creek	Yes
Golden Shiner			Clay Creek	Yes
Spotfin Shiner			Clay Creek	Yes
Central Mudminnow			Clay Creek	Yes
Brown Bullhead			Clay Creek	Yes
Common Carp			Clay Creek	Yes
Common Shiner			Clay Creek	Yes
Spottail Shiner			Clay Creek	Yes
Tadpole Madtom			Clay Creek	Yes
Fathead Minnow			Clay Creek	Yes
Freshwater Drum			Clay Creek	Yes

SCHEDULE II: APPENDICES

APPENDIX A: Bickford Oak Woods Conservation Reserve Management Plan, 2009

Ontario (https://www.ontario.ca/page/government-ontario)

Bickford Oak Woods Conservation Reserve Management Plan

This document provides policy direction for the protection, development and management of the Bickford Oak Woods Conservation Reserve and its resources.

Management Plan
Final

Cette publication hautement spécialisée « Bickford Oak Woods Conservation Reserve : Management Plan » n'est disponible qu'en anglais en vertu du Règlement 411/97, qui en exempte l'application de la Loi sur les services en français. Pour obtenir des renseignements en français, veuillez communiquer avec le ministère de l'Environnement, de la Protection de la nature et des Parcs au
Toll-free: 1-800-565-4923.

Aylmer District
Ontario Ministry of Natural Resources
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Office of the Minister

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I am pleased to approve the Management Plan for Bickford Oak Woods Conservation Reserve.

Bickford Oak Woods Conservation Reserve has been designated for protection due toits biodiversity and significant natural heritage features which consist of numerous rare plant and animalspecies including many species at risk.

The intent to regulate Bickford Oak Woods as a conservation reserve was estabilshed through an amendment to the Chatham District Land Use Guidelines on March 31, 2004. Bickford Oak Woods was regulated as a conservation reserve under the Provincial Parks and Conservation Reserves Act.

The specific direction for managing this conservation reserve will be in the form of a management plan, which defines the area to which the plan applies, provides the purpose for which the conservation reserve has been proposed, and outlines the Ministry of Natural Resources' (MNR) management intent for the protected area. This management plan has been created with input from program specialists within the MNR Aylmer District and Chatham Area offices as well as the MNR Southern Region office. A number of public engagement activities and consultation periods were provided to the public during the development of this plan. Consultation occurred at the invitation to participate, issues and options and draft management plan stages.Consultation included direct mail outs, newspaper advertisements,and postings on the Environmental Bill of Rights registry. Comments from the review period have been considered in the development of this document. The Bickford Oak Woods Management Plan will provide both the foundation for the continued monitoring of activities and guidance for the management of the conservation reserve.

The management direction outlined in the management plan will be implemented by the MNR Chatham Area Supervisor. The need for an amendment or review shall be determined after 10 years.

The Honourable Donna Cansfield
Ontario Minister of Natural Resources
Date: October 1, 2009

Executive Summary

Bickford Oak Woods Conservation Reserve (BOW CR) is the largest protected Carolinian clay plain forest in Canada. Located in the County of Lambton, this 314 hectare property is predominantly forested with scattered wetland pockets that provide habitat for a diversity of Carolinian species and communities including the

provincially rare pin oak, Shumard oak, buttonbush thicket, cerulean warbler, tufted titmouse, and Carolina wren. In 2002, the first occurrence in Canada of swamp cottonwood was reported in Bickford Oak Woods Conservation Reserve. Swamp cottonwood is a tree that is a candidate for endangered species status, both provincially and nationally.

This conservation reserve is located in the Carolinian Life Zone. This zone provides habitat for species more typically found south of the Canadian border. It represents the extreme southwest region of Ontario where the eastern deciduous forest of North America has its most northern limits. Approximately 215 hectares of the site is considered interior forest, a type of habitat that is not well represented in southern Ontario due to extensive forest loss and fragmentation. Protection of this interior Carolinian forest is highly important to the conservation of biological diversity and natural heritage in southern Ontario.

Ontario's goal for Bickford Oak Woods Conservation Reserve is to:

Protect the significant natural heritage values of Bickford Oak Woods Conservation Reserve and maintain biodiversity while providing compatible recreational opportunities.

Three key objectives for Bickford Oak Woods Conservation Reserve are:

Protection: Protect biodiversity and provincially significant elements of the natural landscape of Ontario and manage the area to ensure ecological integrity is maintained.

Recreation: Provide day use recreational opportunities and permit traditional public land uses which are compatible with natural heritage protection.

Research: Facilitate scientific research and provide points of reference to support monitoring of ecological change on the broader landscape.

This management plan defines the policies that will be used to guide management to achieve the goal and meet the stated objectives for Bickford Oak Woods Conservation Reserve.

The operational policies for recreational activities are as follows:

Recreational Activities

Recreational activities and their impacts will be monitored. If a recreational activity is found to have an adverse effect on the natural heritage values of BOW CR, then the activity will be appropriately limited through an administrative amendment to this plan, as well as through the use of enforcement and mitigative measures. The property will be managed to meet the long-term goal of protecting the biodiversity and significant natural heritage values, while providing compatible recreational opportunities.

Permitted Activities

Horseback riding is permitted on MNR authorized trails designated for this use. Cross-country skiing is permitted on MNR authorized trails. Non-consumptive activities such as hiking, photography, wildlife viewing, and nature appreciation are permitted to occur.

Hunting and fishing are permitted according to provincial and federal legislation. Only temporary non-damaging tree stands, such as 'self-climbing' ones, are permitted.

Prohibited Activities

The following activities are prohibited within BOW CR:

- Overnight camping,
- Open fires,
- Private hunt camps,
- Mountain biking,
- Motorized vehicle use,
- Paint-ball activities,
- Put-and-take fish stocking, and
- Fuel wood collection.

There are no MNR authorized trails for the public to use motorized vehicles within BOW CR. Motorized recreational and utility vehicles are prohibited within BOW CR except within designated parking areas. MNR may authorize the use of motorized vehicles for enforcement, emergency, and management purposes.

Aylmer District office should be contacted in regards to other uses as identified in this plan.

Statement of Environmental Values and the Environmental Bill of Rights

The Ministry of Natural Resources' Statement of Environmental Values (SEV) under the Environmental Bill of Rights (EBR) describes how the purposes of the EBR are to be considered whenever decisions are made in the Ministry that might significantly affect the environment. This includes decisions made as a result of preparing management direction for a protected area.

The Ministry's SEV has been considered throughout the planning process. The management direction for Bickford Oak Woods Conservation Reserve will further the objectives of managing Ontario's resources on an environmentally sustainable basis.

1. Introduction

The land that comprises Bickford Oak Woods Conservation Reserve (BOW CR) was acquired through agreement between the Nature Conservancy of Canada (NCC) and Ontario Parks, a branch of the Ministry of Natural Resources (MNR). Ownership was transferred to MNR in June 2002. The Ministry's natural heritage interest in the site has been ongoing since the 1970s, culminating in its acquisition. Conservation reserves complement provincial parks as part of a system that protects representative natural areas and special landscapes in Ontario. Maintenance of ecological integrity shall be the first priority in the planning and management of BOW CR.

1.1 Size and Location

BOW CR is a 314 hectare property located in the Township of St. Clair, geographic township of Moore, in the County of Lambton (Figure 1). It is 25 kilometres south of Sarnia, just east of Highway 40 and north of Bickford Line. This site is the eastern limit of a six kilometre wooded corridor to the St. Clair River. This corridor is what remains of a larger forest complex locally known as the '1800 Block'.

1.2 Significance

BOW CR is the largest protected Carolinian clay plain forest in Canada. It is predominantly forested with scattered wetland pockets that provide habitat for a diversity of Carolinian species and communities including the provincially rare pin oak, Shumard oak, buttonbush thicket, cerulean warbler, tufted titmouse, and Carolina wren. In 2002, the first occurrence in Canada of swamp cottonwood was reported in BOW CR. Swamp cottonwood is a tree that is a candidate for endangered species status, both provincially and nationally.

This conservation reserve is located in Ecodistrict 7E2 and in the Carolinian Life Zone. This zone provides habitat for species more typically found south of the Canadian border. It represents the extreme southwest region of Ontario where the eastern deciduous forest of North America has its most northern limits. Approximately 215 hectares of the site is considered interior forest, which is defined as 100 metres or more from the forest edge. This type of habitat is not well represented in southern Ontario due to extensive forest loss and fragmentation. Protection of this interior Carolinian forest is highly important to the conservation of biological diversity and natural heritage in southern Ontario.

The '1800 Block' including BOW CR is a candidate for designation as a Life Science Area of Natural and Scientific Interest (ANSI). The conservation reserve will be managed in accordance with the ecological principles of Ontario's Biodiversity Strategy.

1.3 Site History

BOW CR lies within the Lambton Clay Plain sub-region of the St. Clair Clay Plains physiographic region. The Lambton Clay Plain is a till plain overlain with a thin layer of clay deposited by a glacial lake.

Clearing, drainage and cultivation has altered BOW CR since the turn of the last century.

The site has been explored for petroleum potential. Seven petroleum wells have been drilled within the site; all wells are plugged or inactive. One natural gas pipeline crosses the southern portions of the site and a second abuts its northern and eastern limits.

Previous owners allowed cattle to pasture the site, which was a very common agricultural practice until about the 1970s when feedlot cattle operations replaced free range pasturing. This woodland has been logged until the 1980s. An apiary exists on the south west corner.

The natural hydrology of the site has been altered by artificial drainage. Agricultural drains cross the site with the western portion of the property being most heavily impacted. The presence of heavy clay soils and wetlands has probably contributed to the majority of BOW CR not being converted to cropland.

Hunting and trapping are known to have occurred within this site historically.

1.4 Planning Process

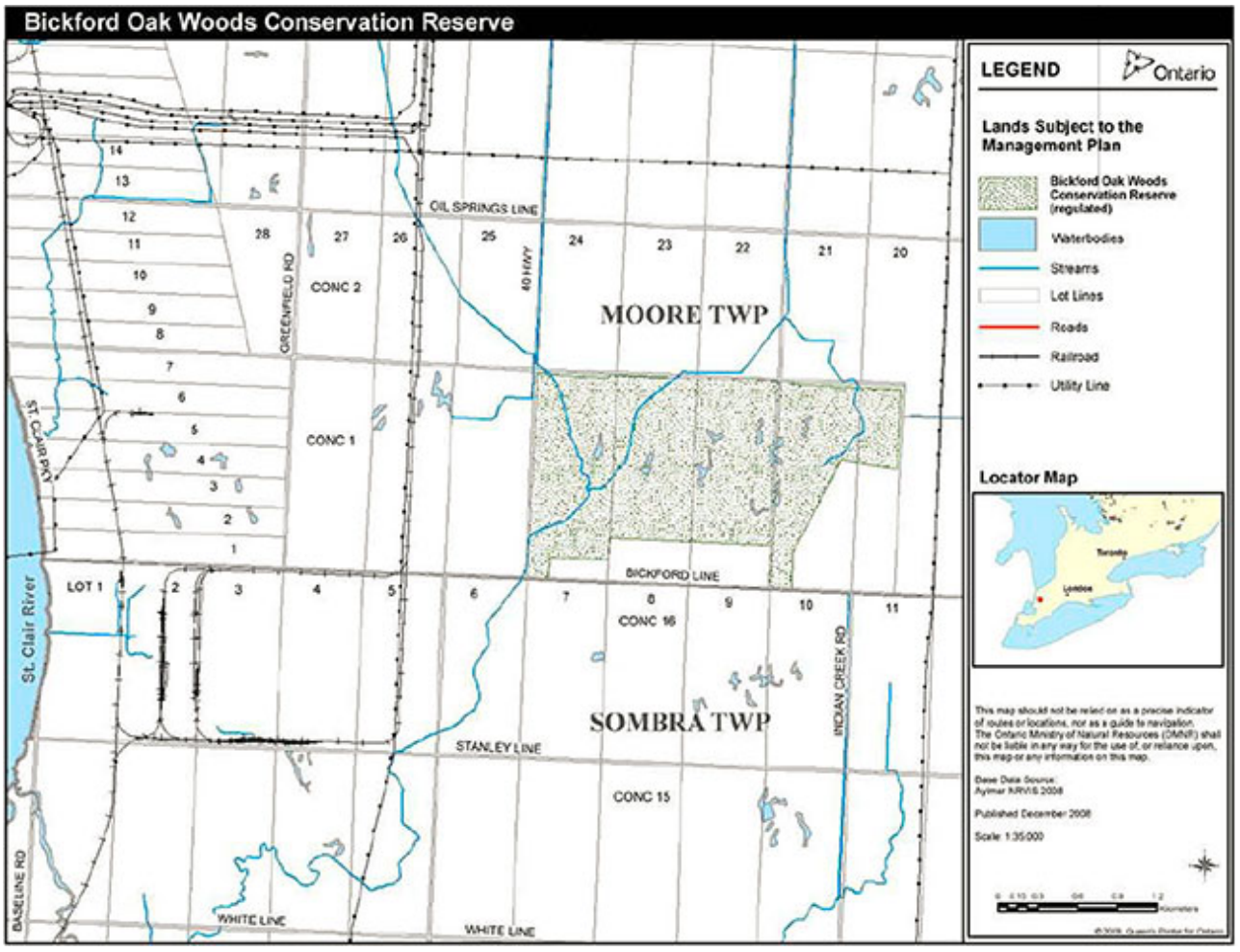
Bickford Oak Woods was designated as a conservation reserve, after public consultation, by amending the Chatham District Land Use Guidelines on March 31, 2004.

Bickford Oak Woods Life Science Inventory (Ambrose et al., 2005) provides additional information regarding the natural heritage found within BOW CR. Public and agency response to the Bickford Oak Woods Conservation Reserve: Issues and Options document and the Bickford Oak Woods Conservation Draft Management Plan were used to develop policies to conserve habitat, maintain natural heritage systems, and ensure permitted uses are compatible with the natural heritage values located within BOW CR. These sources of information assisted in the development of this management plan.

This management plan prescribes the policy direction for a 20-year period (2008 – 2028) that governs the use of the land that has been regulated as BOW CR.

This site has been regulated under the Provincial Parks and Conservation Reserves Act , by amending Ontario Regulation 199/08, to protect this important natural heritage and public recreation area.

Figure 1. Bickford Oak Woods Conservation Reserve



2. Goal

Ontario's goal for Bickford Oak Woods Conservation Reserve is to:

Protect the significant natural heritage values of Bickford Oak Woods Conservation Reserve and maintain biodiversity while providing compatible recreational opportunities.

3. Objectives

MNR has established conservation reserves to offer protection for natural heritage in specific areas of public lands, while permitting recreational public land uses that are compatible with natural heritage protection. The maintenance of ecological integrity shall be considered in decision making.

The following three objectives will guide the management planning process:

Protection: Protect biodiversity and provincially significant elements of the natural landscape of Ontario and manage the area to ensure ecological integrity is maintained.

Recreation: Provide day use recreational opportunities and permit traditional public land uses which are compatible with natural heritage protection.

Research: Facilitate scientific research and provide points of reference to support monitoring of ecological change on the broader landscape.

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4. Resource Stewardship Policies

Species at risk, vegetation, and wildlife resource stewardship policies may be further addressed in subsidiary management or implementation plans. Adaptive management principles, as defined in section 4.8 of this plan, will be used for the protection and restoration of the natural heritage values of BOW CR.

4.1 Species at Risk

Populations of species at risk (identified on the Species at Risk in Ontario list) and their habitats will be protected. Direction provided by species and ecosystem recovery strategies will be implemented where feasible.

4.2 Habitat Management

There are four main types of vegetation communities within the forested lands of this conservation reserve (as defined by the Ecological Land Classification for Southern Ontario): 1) swamp white oak mineral deciduous swamp, 2) green ash mineral deciduous swamp, 3) gray dogwood cultural thicket, and 4) a mosaic of swamp white oak mineral deciduous swamp and fresh-moist oak-sugar maple deciduous forest. The remainder of the site is composed of active agriculture fields (~8 ha).

The vegetation communities will be maintained, enhanced or restored as appropriate. Some of the communities will be managed by allowing natural ecosystems, processes and features to function normally. Where feasible and appropriate, more active

management techniques will be used to meet other policies of this plan. Over time the existing agricultural fields will be converted to a more natural state that may include an appropriate complementary matrix of woodlands, wetlands and grasslands.

Restoration projects will use only locally occurring native species. Native species that were previously known to occur in the area may be re-introduced if appropriate.

BOW CR contains, and is surrounded by agricultural land and roads, which includes the presence of tile drains and agricultural drains. Activities and projects intended to restore natural drainage will be permitted where feasible. This may include the installation of appropriate water retention and control structures and the closing, rerouting or modification of existing drains. It could also include appropriate water retention works, including the creation of ponds on the existing agricultural fields. Any works that could impact agricultural drains would require municipal approval under the Drainage Act.

4.2.1 Fire Suppression and Prescribed Burning

Special management techniques may be required to maintain and restore vegetation communities of BOW CR. If ecologically appropriate, prescribed burns may be used in accordance with the Fire Management Policy for Provincial Parks and Conservation Reserves (PL 3.03.09) and the Class Environmental Assessment for Provincial Parks and Conservation Reserves to maintain and restore vegetation communities. For all other fires, the municipality provides fire response and suppression, as needed.

4.3 Wildlife and Fish

Wildlife and fish will continue to be managed in accordance with provincial and federal policies and regulations prevailing in the area. Recreational sport hunting will be permitted.

Activities and projects that protect and enhance wildlife and their habitat will be considered, such as the installation and maintenance of nest boxes. Native species that were previously known to occur in the area may be re-introduced, if appropriate.

Appropriate management techniques will be used to address threats to human health and safety presented by wildlife (e.g. rabies control). Management approaches for the control of fish and wildlife populations that threaten natural heritage values will be

developed where feasible and appropriate. Access may be restricted to sensitive wildlife areas (e.g. heronry during breeding season).

BOW CR offers limited potential for fish habitat management; however future restoration projects that improve existing watercourses and water retention on the site may allow for the development of fish habitat and stocking of native fish species.

4.4 Insect Pests and Disease Suppression

Populations of native insects and diseases affecting vegetation or fish and wildlife within the conservation reserve will normally be allowed to develop undisturbed. Non-native insects and diseases may be controlled where feasible and necessary. Where control is undertaken, it will be directed as narrowly as possible to the specific insect or disease so as to have minimal effects on other components of the environment of the conservation reserve.

4.5 Non-native Species Introductions

Non-native species will not be deliberately introduced. Certain permitted uses within the conservation reserve disturb soil, thereby increasing the potential for invasive flora species to establish. Invasive non-native species may negatively impact native vegetation development. Management approaches for the eradication or control of non-native species that threaten natural heritage values will be developed.

4.6 Cultural Heritage

If archeological resources are discovered, appropriate steps will be taken in consultation with local First Nations and the Ministry of Culture to protect them. A Memorandum of Understanding with the Ministry of Culture requires that the cultural heritage resource screening process be implemented, should significant clearing of vegetation or soil disturbance or altering of land within this conservation reserve be considered.

Where a project involves ground disturbance in an area with archaeological potential, the project will be considered for impacts to archaeological resources. Where a project may impact on structures or cultural heritage landscapes, the project will be considered for potential effects to cultural heritage resources and appropriate mitigation measures will be considered. Staff will consult MNR's Technical Guideline for Cultural Heritage Resources.

4.7 Research and Education

Education and interpretation will be encouraged to provide a better understanding of the management and protection of the natural heritage values within BOW CR.

Scientific research by qualified individuals contributes to the knowledge of natural and cultural history and to environmental and recreational management. This type of research will be encouraged in BOW CR. All research programs will be reviewed on a case-by-case basis in the context of natural heritage protection. They will require the approval of MNR and will be subject to Ministry legislation and policy.

The local MNR office may approve the collection of specimens and/or parts of plants for an authorized research project. Specimens collected remain the property of MNR.

4.8 Inventory, Monitoring and Assessment

The Bickford Oak Woods Life Science Inventory provides the baseline inventory for the site. Additional inventories will be undertaken as necessary. For example, the site will be evaluated under the Ontario Wetland Evaluation System – Southern Manual to determine the significance of the wetlands. Inventory, monitoring and assessment will be used to determine the effectiveness of Resource Stewardship and Operational Policies. This may indicate a need to use adaptive management if expected results are not realized.

Adaptive management is a process for continually improving management policies and practices by learning from the outcomes of operational programs. Monitoring to assess whether management techniques are achieving the stated objectives is an essential component to adaptive management. All activities permitted, prohibited, or not yet identified to occur on the site will be monitored, as required, to ensure that natural heritage values and public safety are not compromised. Where monitoring indicates techniques are not effective, adjustments will be made to the operation and management of the site.

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5. Operational Policies

5.1 Recreational Activities

Recreational activities and their impacts will be monitored. If a recreational activity is found to have an adverse effect on the natural heritage values of BOW CR, then the activity will be appropriately limited through an administrative amendment to this plan, as well as through the use of enforcement and mitigative measures. The property will be managed to meet the long-term goal of protecting the biodiversity and significant natural heritage values, while providing compatible recreational opportunities.

5.1.1 Permitted Activities

Horseback riding is permitted on MNR authorized trails designated for this use. Cross-country skiing is permitted on MNR authorized trails. Non-consumptive activities such as hiking, photography, wildlife viewing, and nature appreciation are permitted to occur.

Hunting and fishing are permitted according to provincial and federal legislation. Only temporary non-damaging tree stands are permitted.

5.1.2 Prohibited Activities

The following activities are prohibited within BOW CR:

- Overnight camping,
- Open fires,
- Private hunt camps,
- Mountain biking,
- Motorized vehicle use,
- Paint-ball activities,
- Put-and-take fish stocking, and
- Fuel wood collection.

There are no MNR authorized trails for the public to use motorized vehicles within BOW CR. Motorized recreational and utility vehicles are prohibited within BOW CR except within designated parking areas. MNR may authorize the use of motorized vehicles for enforcement, emergency, and management purposes.

5.2 Commercial Activities

5.2.1 Permitted Activities

Commercial fur harvesting is permitted according to provincial legislation.

Agricultural use on existing fields will be permitted until habitat restoration projects begin.

The existing beehives will be allowed to remain in designated areas. New beehive operations or expansions are prohibited. If land use conflicts arise, this use can be limited, moved or removed from BOW CR.

5.2.2. Prohibited Activities

Industrial activities within BOW CR are prohibited by legislation, including:

- Commercial timber harvest,
- Generation of electricity,
- Prospecting, staking mining claims, developing mineral interests or working mines,
- Extracting aggregate, topsoil or peat, and
- Other industrial uses.

New transmission lines, pipelines, and transportation corridors will be discouraged.

Commercial baitfish harvesting is prohibited.

New commercial activities, including tourism developments, are prohibited.

Pasturing of livestock is prohibited.

5.3 Infrastructure

There are two parking areas located on Bickford Line. To ensure public safety, direct access from Highway 40 is prohibited.

There are no authorized existing roads within BOW CR and private access roads are prohibited from being constructed.

Existing trails will be inventoried and rationalized to determine if they are sited and aligned in an environmentally sensitive manner. Trails may be opened, closed, abandoned, seasonally restricted, or moved in accordance with the provision of recreational opportunities that do not adversely affect the natural heritage values of the conservation reserve. Subsequently, an authorized trail network will be created and adequately marked. MNR may authorize individuals to clear obstructions from trails, and the deadfall must be left on site.

The signage at the conservation reserve will be improved to clearly communicate permitted and prohibited uses, authorized trails and boundaries.

A historical water well exists and will be decommissioned.

Major infrastructure will not be considered.

5.3.1 Pipeline Easements

One natural gas pipeline crosses the southern portions of the site and a second abuts its northern and eastern limits. The pipelines and their easements are considered to be an existing use of the site and will be permitted indefinitely. MNR management activities in the easement will conform to the terms and conditions of the existing agreement. The easements should be replanted with native forbs and grasses, to reduce opportunities for noxious weeds and exotic species invasions. MNR will work with the easement holder to ensure best management practices are followed to protect conservation reserve values when maintaining the pipeline easements.

Any trails, parking lots or fences over the pipeline or in the easement will require prior approval as per the National Energy Board guidelines.

5.3.2 Abandoned Petroleum Wells

Records indicate that seven petroleum wells have been drilled. All seven have been inspected by MNR's Petroleum Resources Section and are deemed to be safe.

5.4 Land Tenure and Adjacent Lands

Any unauthorized occupation of lands within the conservation reserve will be managed in accordance with MNR policies and relevant legislation and will be removed at the occupier's expense. In addition, enforcement action may be taken.

Leasing or sale of parts or all of the conservation reserve is prohibited. Crown land dispositions (e.g. land use permit) in BOW CR will occur only in accordance with existing tenure documents, the landholding agreement with the Nature Conservancy of Canada and relevant policies and procedures. Existing land tenure may be transferred, renewed or amended as deemed appropriate.

Through municipal plan input and review, applications for large-scale development on private lands adjacent to the conservation reserve will be reviewed regarding impacts on the natural heritage values of BOW CR.

5.5 Enforcement

Enforcement will be carried out in accordance with MNR policies and relevant legislation to provide for the safety of visitors and the protection of resources.

5.6 Partnership Development

BOW CR became available to the public through partnerships. Future opportunities for partnerships and further cooperation will be encouraged in accordance with the policies of this plan. MNR may consider protecting, restoring or acquiring adjacent parcels of land.

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6. Implementation

In the implementation of the approved management plan, MNR will pursue opportunities for partnerships with other agencies and groups. Undertaking resource stewardship projects and operations will be contingent upon approval and the availability of funding. Implementation of this management plan and operation of the conservation reserve will meet the requirements of the Environmental Assessment Act, Environmental Bill of Rights, Provincial Parks and Conservation Reserves Act, Fish and Wildlife Conservation Act, Endangered Species Act, and other pertinent legislation. All projects must be screened and completed in accordance with the Class Environmental Assessment for Provincial Parks and Conservation Reserves as well as

ensure the maintenance of ecological integrity is addressed in accordance with the Provincial Parks and Conservation Reserves Act.

The following list of activities has been identified:

Stage 1

- Clean-up debris at petroleum well site
- Convert agricultural field to more suitable habitat including woodlands, wetlands and grasslands and consider viewing platform
- Restore natural hydrology where appropriate (e.g. remove tile drains)
- Control invasive and non-native species (e.g. control garlic mustard, Phragmites, Norway maple)
- Develop parking area(s) with associated trail access point(s)
- Inventory, assess and authorize trail network
- Install permitted/ prohibited use and boundary signage
- Pursue partnerships

Stage 2

- Complete application of Ontario Wetland Evaluation System to determine boundary and significance of wetlands
- Decommission water well
- Design and institute appropriate inventory and monitoring protocols
- Develop trails as appropriate
- Create educational signage and fact sheets

Ongoing

- Implement species at risk recovery strategies as appropriate
- Improve resource inventories and continue effectiveness monitoring
- Continue day-to-day maintenance (e.g. fences, signs, trails)
- Habitat management as required

7. Summary of Public Consultation

The Chatham District Land Use Guidelines (DLUG) was amended to designate Bickford Oak Woods as a conservation reserve on March 31, 2004 via Land Use Amendment (2003-09). Public consultation occurred between January 7, 2004 and February 6, 2004 regarding the designation of this site as a conservation reserve. The Environmental Bill of Rights (EBR) Environmental Registry Number was PB04E3010. Ninety-two responses were received and were considered in the development of this plan.

The management planning process has been posted on the EBR Environmental Registry as PB05E2809 (http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MjYxNTA=&statusId=MTUzMzc1&language=en (http://www.ebr.gov.on.ca/ERS-WEB-External/displaynoticecontent.do?noticeId=MjYxNTA=&statusId=MTUzMzc1&language=en)). At each stage of the process, the Ministry has notified the public of the opportunity to review. This notice has been given through mailings to First Nations communities, resource users, local and provincial interest groups, government agencies, local landowners, general public and local politicians (municipal and provincial); as well as published in local and regional newspapers and posted on the EBR Environmental Registry.

Stage I: Invitation to Participate / Commencement of Planning included a 47-day comment period from August 22, 2005 to October 6, 2005. Ten comments were received during this consultation period. All comments were supportive to the management of BOW CR and related to permitted uses.

Stage II: Review of the Issues and Options included a 47-day comment period to review the Issues and Options document from October 26, 2005 to December 12, 2005. A public open house was held on November 16, 2005. A total of 110 comments were received during this consultation period; the vast majority of comments (80%) specifically supported hunting as a permitted use while 22 comments considered other issues and options.

Stage III: Public Review of the Draft Management Plan. This stage of the management planning process included a 45-day comment period to review the Draft Management Plan. Comments were accepted from February 3, 2006 to March 20, 2006. A public

open house was held on February 15, 2006. A total of 35 comments were received. There were 29 comments in regard to permitted uses including: motorized access for the disabled, hunting, horseback riding, commercial baitfish harvesting, apiaries, fur harvesting, and ATV use.

Stage IV: Public Release of the Approved Management Plan.

Background information will be kept on file and made available as appropriate for public review at the MNR Chatham Area Office.

8. Reviews and Revisions

The Bickford Oak Woods Conservation Reserve Management Plan may be reviewed or amended to address changing issues or conditions. At ten year intervals this plan will be examined for the need for a review or amendment. A review may involve a reassessment of all or part of the plan. An amendment can be considered to address specific issues or needs.

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APPENDIX B: St. Clair Region Watershed Report Card, 2018

St. Clair Region

WATERSHED
Report Card 2018

The St. Clair Region Conservation Authority has prepared this report and a series of subwatershed report cards as a summary of the state of the forests, wetlands, and water resources in the St. Clair Region.

St. Clair Conservation

Watershed Checkup

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Executive Summary

Since 2008, the St. Clair Region Conservation Authority (SCRCA) has prepared a series of 14 Subwatershed Report Cards, a summary Watershed Report Card, and a final report every five years to help watershed residents, municipalities, agencies, and SCRCA staff and directors assess environmental health in the region. These Report Cards measure and grade surface water quality, forest conditions, and wetland cover in the St. Clair Region's 14 subwatersheds, and compares them with previous Report Card findings. Groundwater quality is also measured at eight monitoring well sites. Each Subwatershed Report Card also includes a summary of the unique features, local solutions that will improve environmental conditions, and highlights of progress since 2011.

Since the first Report Cards were produced in 2008, many environmental projects have been implemented, new issues have developed, and more information has become available. Both the 2013 and 2018 Report Cards use the updated methodologies and grading system that was developed by Conservation Ontario (2011) in order to standardize the grading of indicators used by Conservation Authorities across the province. Surface water quality indicators include total phosphorus, bacteria (*E. coli*), and benthic invertebrates. Forest condition indicators include the percent forest cover, percent forest interior, and the percent of the riparian zone that is forested. Wetland cover and groundwater quality indicators were graded for the first time in the 2018 Report Cards for the St. Clair Region. The wetland indicator is the measure the percent wetland cover and the groundwater quality indicators include nitrate and chloride concentrations.

Surface water quality grades for the St. Clair Region range from C to D. Since the 2013 Report Cards, overall surface water quality grades have shifted slightly but not enough data is available to discern a significant trend. Overall, the Middle East Sydenham, Lower East Sydenham, Lower North Sydenham and Lambton Shores Tributaries score a C grade while the remaining 10 subwatersheds score a D grade.

The eight groundwater wells all scored A grades for nitrate concentrations and the grades range from A to F for chloride concentrations. Elevated chloride could be naturally occurring in the aquifers or it could be due to human impacts. Since ground watersheds do not correlate with surface watersheds, the groundwater indicators are not reported in relation to the 14 subwatersheds in the St. Clair Region. The conditions noted at each monitoring well are specific to that location. The 2018 Report Card uses

data over a 10 year period from 2006 to 2015 for groundwater, as there is a relative lack of groundwater samples collected (usually one sample per site each year).

Forest condition grades range from C to F in the St. Clair Region, with a grade of C in the Lambton Shores Tributaries and F grades for the Lake St. Clair Tributaries and Cow and Perch Creeks subwatersheds. The remaining 11 subwatersheds scored a D grade. Changes in forest cover and forest interior since the previous Report Cards are now no longer considered to be due to improved mapping accuracy as the methodology used since the 2013 Report Card has remained unchanged. Any reported gains or losses now reflect real world changes.

Wetland cover is very poor across the St. Clair Region, with three subwatersheds scoring a D grade and the remaining 11 scoring an F. It is important to note that wetland cover in First Nations lands is not included in this assessment.

As the Conservation Ontario guidelines enable province-wide comparisons, the grades are generally low for the St. Clair Region and most of southwestern Ontario where there is intensive land use. In an effort to supplement the overall understanding of the health of the St. Clair Region, additional signals of watershed health have been considered such as significant natural areas, climate data, geologic characterizations, watercourse characterizations, and Species at Risk occurrences. By including these additional attributes, the complexity and unique characteristics of each subwatershed is better represented.

The 2018 Subwatershed Report Cards also include examples of projects contributing to improved environmental health. Highlights of these positive contributions include projects undertaken by individuals, organizations, and municipalities. Since 2011, various volunteer groups have worked to restore and enhance natural areas and engage their communities, private landowners have completed 300 stewardship projects, and almost 500,000 trees and shrubs have been planted by SCRCA staff.

Acknowledgments

The St. Clair Region Conservation Authority thanks TD Friends of the Environment Foundation, RBC Blue Water Project, Friends of the St. Clair River, Plains Midstream Canada, and the St. Clair Region Conservation Foundation for providing funds to support the aquatic sampling that produces the important data used to create the Watershed Report Cards.

Section 1: Indicators and Analysis

1.1 Introduction

The St. Clair Region Watershed Report Card presents the results of monitoring the health of the region's natural features. Grades are assigned to specific surface water quality, groundwater quality, forest condition, and wetland condition indicators using a grading system that is standardized across Ontario's Conservation Authorities. The report also includes information on features of the region. When citizens, industries, agencies and government staff understand the environmental health of their region, they can take actions to protect or enhance those features.

The first Report Card for the St. Clair Region was released in 2008, and assessed data from 2001 to 2005. It included analysis of five surface water quality and forest condition indicators for the 14 subwatersheds. It described features of the individual watersheds, actions that could be taken by individuals or agencies to improve the watershed conditions, and many stewardship activities that have been implemented by private landowners and municipalities.

The 2013 Report Card was the second released for this region, covering data from 2006 to 2010. The analysis methods and degree of accuracy evolved since the first Report Cards. For both water quality and forest condition, the guidelines were revised since 2008. Ontario's Conservation Authorities developed standardized methodologies and set the grades relative to current scientific standards. The grading system was optimized for the range of environmental conditions across the province – for a watershed to achieve an A grade for an indicator, the watershed must be healthy compared to the conditions that have been reported by other Conservation Authorities across Ontario.

The 2018 Report Card is the third Report Card to be released for the St. Clair Region. Both water quality and forest condition guidelines are the same as they were in the previous Report Card and all Geographic Information System (GIS) mapping techniques have remained the same. The groundwater quality indicator has been added to the 2018 Report Card along with the grading of wetland cover for each subwatershed.

The analysis of the main four indicators is based on water quality data collected by SCRCA staff and GIS mapping. The water quality samples are collected at sites that are judged to reflect the subject subwatershed. The forest evaluation has been completed at a landscape level from analysis of

aerial photographs.

In addition to assessing indicators of environmental health, the Report Card is an opportunity to compile information on the features of the St. Clair Region. The supplementary data on subwatershed characteristics are summarized in Section 2 and in each Subwatershed Report Card.

Recognition of local actions that improve watershed health is very important. Examples of positive contributions are included in each Subwatershed Report Card. The dozens of projects that have been completed through clean water programs and habitat stewardship are also summarized.

1.1.1 The St. Clair Region

The area covered by the St. Clair Region and this Report Card is 4,130 km^2. The largest drainage area, the Sydenham River, is subdivided into nine subwatersheds. The three large adjacent water bodies, Lake Huron, the St. Clair River, and Lake St. Clair, also have many smaller tributaries that have been grouped into five subwatersheds. The resulting 14 subwatersheds are appropriately sized for residents to identify with their local communities. They are summarized in Table 1 and illustrated in Map 1.

1.2 Indicators of Environmental Health

The indicators of subwatershed health include surface water quality, forest condition and wetland cover. Each of these indicators are graded on specific parameters over a five-year period from 2011 to 2015, these grades range from A (excellent) to F (very poor). This is the first time that groundwater quality is being assessed in the SCRCA Report Cards as there was previously an insufficient amount of data. Groundwater quality is being reported over a 10-year period from 2006 to 2015 to account for the limited number of samples (i.e., only one per year vs. eight per year for surface water) and is not reported in relation to the 14 subwatersheds.

1.2.1 Surface Water Quality

The water quality of the St. Clair Region is affected by land use, weather and soils. Surface water quality can change in response to human activities, including changes in agricultural practices, urban sewage treatment, and storm water management.

The 2018 Report Cards summarize the current water quality over a relatively short time period of five years using three parameters including concentrations of total phosphorus and bacteria, and benthic

macroinvertebrate communities. This is then compared with the five years of data from each the 2008 and 2013 Report Cards. The water quality varies from year to year and the indicators may vary independently from each other. The information presented is a general assessment of surface water quality in each subwatershed, with sampling data being collected from one monitoring station for each indicator.

1.2.2 Groundwater Quality

The Provincial Groundwater Monitoring Network (PGMN) is a partnership between the Ontario Ministry of the Environment (MOE) and Conservation Authorities. The network provides background monitoring information on groundwater levels and quality. The water analysis for the PGMN program includes basic chemistry, metals, nitrate and fluoride concentrations. As of May 2007, the SCRCA has collected samples at eight monitoring wells once a year through the program. Water level data are also collected four times a year from each of the PGMN wells.

For the purposes of the Watershed Report Cards, groundwater quality is assessed using two parameters, nitrites/nitrates and chloride concentrations. Based on the Conservation Ontario 2017 guidelines for groundwater analyses and reporting, the time period to be reported on was increased to 10 years instead of five years, to improve the statistical significance. It is important to note that the values reported for groundwater conditions at the monitoring wells are specific to those locations as the ground watershed does not correlate to the surface watershed.

There are no longer any active municipal drinking water supply systems in the St. Clair Region that are using a groundwater source.

1.2.3 Forest Condition

The forests of the St. Clair Region reflect the human impact on this landscape over the last 150 years. Surveyors' records indicate that in the early 1800s almost 70% of the Sydenham River watershed was forested. Extensive clearing for agriculture and settlements removed the majority of the woodlands. Current watershed residents are concerned that the remaining woodlands are being further reduced by mortality from invasive species, such as Emerald Ash Borer, and from warmer, drier climate conditions.

This Report Card describes the woodland layer through analysis by SCRCA staff using 2015 aerial photography. The 2008 and 2013 Report Cards considered the woodland layer analysis from the Ontario Ministry of Natural

Resources and Forestry (OMNRF) using aerial photography from 2007 and 2010, respectively.

1.2.4 Wetland Cover

Wetlands are the link between land and water and make up some of the most biologically productive ecosystems in the world. Under the OMNRF Ontario Wetland Evaluation System (OWES) definition, an area must be filled or saturated with water that is less that 2 m deep for at least part of the year and the vegetation cover must be comprised of at least 50% water-adapted plants to be considered a wetland. There are four main types of wetlands: swamps, marshes, fens, and bogs. Depending on the type of wetland, its vegetation community can be dominated by trees, grasses, shrubs, or mosses.

Wetlands offer many vital hydrological and ecological functions. They improve water quality by trapping and holding nutrients, sediments and pollutants before they reach nearby bodies of water. They reduce flooding by retaining excess water and by reducing the velocity of quick-moving floodwaters, which allows the water to enter rivers and streams at a slower, less destructive rate. Wetlands also support a diverse range of plant and animal species – they are inhabited by many of southern Ontario's species during part of or all of their life cycles. The combination of shallow water, high nutrient levels and primary productivity in wetlands are ideal for the development of organisms that form the base of the food web and feed many species including fish, amphibians, insects and other invertebrates. Many species of birds and mammals rely on wetlands for food, water, and shelter – especially during migration and breeding seasons.

Compared to pre-settlement coverage, wetland losses exceed 70% in many parts of southern Ontario (Ducks Unlimited, 2010). Environment Canada (2013) recommends that at least 10% of each major watershed and 6% of each subwatershed should be maintained or restored as wetlands.

1.3 Surface Water Quality Methods

Three select indicators are used to assess surface water quality on a watershed scale:

- Total Phosphorus;
- *Escherichia coli* (*E. coli*); and
- Benthic Macroinvertebrates

These three indicators reflect key issues related to surface water quality

across the province: nutrients, bacteria/waste, and aquatic health. These indicators can help measure the influence of factors such as urban and rural land uses, soil types, and weather on the surface water quality in the St. Clair Region.

1.3.1 Total Phosphorus

Conservation Ontario (2011) recommends total phosphorus as the key water quality indicator. Phosphorus, a nutrient commonly applied as fertilizer, adheres to soil and is readily transported to streams with eroding soil. Elevated levels of phosphorus can cause algal fouling, fish kills, taste and odour problems in drinking water, and other adverse effects.

The 75th percentile concentration of total phosphorus is calculated for all samples collected within each watershed from 2011 to 2015 inclusive. The 75th percentile is the value below which 75% of the values fall. This value reflects the water condition for the majority of the five-year time period. The 75th percentile value is converted into a score and a grade, following the Conservation Ontario guidelines (Table 2).

1.3.2 Bacteria *(E. coli)*

The second water quality indicator, *E. coli*, is a fecal bacterium found in human and animal waste. *E. coli* is broadly accepted as the key indicator of fecal contamination in rivers and the presence of potential pathogens (MOEE, 1994). Long-term ambient *E. coli* data can indicate areas with higher concentrations of fecal contamination in a watershed, and can be compared with land use activities.

The concentration of ambient *E. coli* can range from very low, less than 30 colony forming units in 100mL of water (CFU/100mL), to very high, with over 1,000 CFU/100mL. Calculating the average value would inflate the conditions that typically occur, therefore the geometric mean is used. The geometric mean is calculated as the 'nth' root of the product of 'n' numbers. Following the Conservation Ontario guidelines, the five-year geometric mean is calculated for the monitoring sites within each subwatershed.

1.3.3 Benthic Macroinvertebrates

The third surface water quality indicator, is based on the community composition of invertebrate organisms living on the bottom of the watercourse at a representative site in each subwatershed. Benthic refers to the bottom of a watercourse; macro- refers to items visible without a microscope; and invertebrates are organisms without a backbone,

such as insects, worms, and crustaceans. Benthic monitoring indices are well documented and a popular indicator of the biological health. The Family Biotic Index or FBI assigns a pollution tolerance score to each taxonomic family of benthic macroinvertebrates so the number and type of invertebrates found in each benthic sample relate to the water quality where they are collected (Hilsenhoff 1988; Mandaville 2002). The higher the score, the more polluted the watercourse. A healthy aquatic environment is dominated by pollution intolerant species. For the Watershed Report Card process, the Conservation Ontario (2011) guidelines adopt the Hilsenhoff 1988 Family Biotic Index as modified by Smith et al. 2009.

Extreme weather, stream morphology, and local site disturbance are some of the key factors beyond surface water quality that can affect the benthic macroinvertebrate assemblages from year to year. In order to account for natural year-to-year variability, it is recommended that Report Card grades are based on an average FBI value from samples taken annually over five years. Grouping data in this fashion generates an accurate estimate of surface water quality on a subwatershed basis.

1.3.4 Data Collection and Sampling

In order to accurately represent the subwatershed being graded, the Conservation Ontario guidelines recommend that the water quality conditions are reported at the outlet of each catchment area. Outlet sampling is possible for most water chemistry and bacteria stations in the Sydenham subwatersheds, but not for all benthic sampling sites due to the need to wade across the width of the river for sample collection. An exception is water chemistry and bacterial stations in the Sydenham Headwaters, which are located upstream from the town of Strathroy, therefore excluding the urban influence from the Report Card grade calculation. Another exception is the Black Creek water quality station, which is located about 20 km upstream of the outlet. In five catchments, including the Lake St. Clair Tributaries, St. Clair River Tributaries, Lambton Shores Tributaries, Plympton Shoreline Tributaries, and Cow and Perch Creeks, water chemistry is monitored in the largest watercourse. In the Cow and Perch Creeks area, Perch Creek is monitored at the second last bridge before the river flows into Lake Huron, as this location experiences less backwater dilution from the lake than the lower bridge. The location of water quality and benthic macroinvertebrate sampling sites within the St. Clair Region are shown in Map 2.

Surface water quality samples have been collected in the St. Clair Region since the 1960s under the Provincial Water Quality Monitoring Network

(PWQMN), a cooperative program between the SCRCA and the Ontario Ministry of the Environment. PWQMN sample station locations varied over the years, but since 2002 the eight existing stations have remained consistent. Starting in 2004, funding under the Canada Ontario Agreement (COA) on Great Lakes Water Quality also supported the SCRCA's water sampling program. In 2005, the COA program doubled the amount of sampling conducted in the St. Clair Region. Like the PWQMN stations, the COA sampling locations have varied. To maximize program coverage, Brown Creek and Lower North Sydenham were sampled bi-monthly rather than monthly during ice-free periods. Lambton Shores Tributaries and Plympton Shoreline Tributaries had monthly sampling financed by Lambton Shores while the COA sampling was only bi-monthly. The sites with larger sample sizes were used for this analysis (Table 3).

Bacteria analysis has occurred at eight sites in the St. Clair Region through a cooperative program with the Middlesex-London Health Unit. This data provides information for calculating grades for seven subwatersheds of the Sydenham River. Five subwatersheds did not previously have any bacterial monitoring, however, monitoring sites to represent these subwatersheds were added starting in 2010 (Table 4). These subwatersheds include Cow and Perch Creeks, St. Clair River Tributaries, Lake St. Clair Tributaries, Brown Creek, and the Lower North Sydenham.

The SCRCA has monitored aquatic benthic macroinvertebrates since 1999. Benthic communities are strongly influenced by the substrate conditions in addition to water chemistry and water flow regimes. All three variables change between, and in some cases, within subwatersheds in the St. Clair Region. There is one representative benthic sampling station for each of the 14 subwatersheds and samples are collected once each spring (Table 5). Benthics must be sampled in a wadeable watercourse (i.e., less than 1 m deep). The outlets of many subwatersheds are too deep, in these cases, the sampling stations needed to be located further upstream or in tributaries of the main watercourse. In subwatersheds with more than one watercourse (e.g., St. Clair River Tributaries) the largest watercourse (e.g., Clay Creek) is chosen for water chemistry sampling.

1.4 Surface Water Quality Results

The surface water quality values and grades are summarized in Table 6 and illustrated in Map 3. Four of the 14 subwatersheds score a C grade for their surface water quality including Middle East Sydenham, Lower East Sydenham, Lower North Sydenham, and Lambton Shores Tributaries. The

remaining 10 subwatersheds score a D grade (Table 7). At a provincial scale, there tend to be lower grades in extreme southwestern Ontario regions with intensive land use, such as the St. Clair Region.

1.4.1 Total Phosphorus

Total phosphorus concentrations exceed the provincial guidelines in all subwatersheds by between three and nine times the Provincial Water Quality Objective (PWQO) of 0.03 mg/L (Table 6). Results from the Provincial Water Quality Monitoring Network indicate similar exceedances across rural watersheds in southern Ontario, particularly the area southwest of Toronto to Goderich.

Total phosphorus is highest in St. Clair River Tributaries (0.26 mg/L), Brown Creek (0.24 mg/L), and Bear Creek Headwaters (0.20 mg/L). The lowest levels of total phosphorus are in two of the subwatersheds of the East Sydenham River, with the Sydenham Headwaters measuring 0.08 mg/L and Lower East Sydenham measuring 0.09 mg/L. The Lower North Sydenham has a relatively low value for being at the downstream end of the Sydenham River watershed but this may be due to diluting effects from the backflow of Lake St. Clair or the St. Clair River as the lower reaches of the Sydenham are at the same elevation as these larger water bodies.

Since phosphorus binds to soil particles, concentrations of phosphorus are increased in areas with erodible soils such as clay. The highest readings of phosphorus are recorded in subwatersheds in the clay plains of western Lambton County. The lower readings in the Upper Sydenham may be due to a smaller catchment area and may also reflect loam and sand soils that are less erodible than clay. It should also be noted that between 2013 and 2015 the Ministry of the Environment laboratory, which provided water chemistry analysis for the St. Clair Region, switched the analysis method for total phosphorus. This change in analysis was later found to truncate the actual range of values for total phosphorus especially at sites that had a large amount of suspended solids. As a large portion of the data used in the 2018 Watershed Report Card relating to total phosphorus is affected by this, any apparent decreases in phosphorus should be interpreted with caution.

1.4.2 Bacteria *(E. coli)*

One subwatershed scores an A grade for *E. coli* concentration and two score a B grade. Six of the subwatersheds have a C grade for *E. coli* levels and five have a grade of D (Table 6). Only the Lower North Sydenham (23 CFU/100mL), Lake St. Clair Tributaries (39 CFU/100mL), and Lower East

Sydenham (80 CFU/100mL) have values within the MOE guideline of 100 CFU/100mL for the safe recreational use of water. The lower reaches of the Sydenham River and the majority of Lake St. Clair Tributaries are at the same elevation as Lake St. Clair, consequently, backflow from the lake or the St. Clair River can dilute concentrations in these tributaries.

1.4.3 Benthic Macroinvertebrates

One subwatershed scores a B grade, which suggests that some organic pollution is probable. Seven subwatersheds have a C grade, indicating fairly substantial pollution is likely. For the remaining subwatersheds, five scored a D grade and one scored an F grade indicating substantial to very substantial organic pollution is likely. These low grades are typical of watersheds in southwestern Ontario, including the abutting Upper Thames River.

The most impacted benthic scores are recorded in the Lake St. Clair Tributaries, which scores an F grade. Land use in the area is probably one of the most significant influences on surface water quality. This subwatershed has a high percentage of organic soils, is drained and intensely cropped, and has the lowest percentage of forested riparian buffer of the 14 subwatersheds. The substrate at the benthic station has 20 to 40 cm of semi-decayed organic matter, which supports only pollution tolerant invertebrates. The subwatershed is largely tiled and drained into channelized watercourses. Some watercourses in this subwatershed are managed as pumped, municipal drains that hold standing water much of the year, allowing fine sediments to settle and release the nutrients bound to them over time.

The Middle East Sydenham reports a B grade for benthics, which is the lowest average FBI value of the 14 subwatersheds evaluated. The SCRCA's Healthy Stewardship Program has targeted this subwatershed for riparian planting, livestock exclusion fencing, and other stewardship projects for over 10 years. It is possible that stewardship efforts in the Middle East Sydenham have contributed to its improved FBI scores since the 2008 Report Cards.

1.5 Surface Water Quality Discussion

Three of the water chemistry monitoring sites (Lower East Sydenham, Lower North Sydenham, and Lake St. Clair Tributaries) appear to be influenced by lake waters. When taking these influences into account, the subwatersheds that have the best overall water quality grades for the region are the Middle East Sydenham and Lambton Shores Tributaries. These subwatersheds have the best scores for the three water quality indicators and are not influenced by lake water like the Lower East Sydenham and the Lower North Sydenham

subwatersheds. These two subwatersheds also have better than average forest cover for the St. Clair Region.

The poorest water quality conditions for benthic macroinvertebrates are found in the Lake St. Clair Tributaries, which has the second lowest amount of total forest cover as well as the lowest riparian cover. The largest watercourses in this subwatershed are municipal drains that are controlled by pump works and therefore hold standing water for much of the growing season.

The subwatersheds with the poorest water quality, based on water chemistry, are Cow and Perch Creeks, Black Creek, and Lower Bear Creek. With Sarnia located in Cow and Perch Creeks and Petrolia located upstream of Lower Bear Creek, impacts from urban areas, such as storm water and waste water, are likely contributing to the poor water quality in these subwatersheds. Cow and Perch Creeks also has among the poorest overall forest condition.

1.6 Groundwater Condition Methods

Two indicators are used to assess groundwater condition for the St. Clair Region:

- Nitrite + Nitrate (mg/L)
- Chloride (mg/L)

Surface water and groundwater move differently – one over the land surface, and the other through soil and bedrock into aquifers (underground rock formations/structures that carry water). Flowpaths are typically downward or horizontal through these aquifers, and since it is hard to see these interactions underground, the source of water for individual monitoring wells can only be inferred. Most importantly, ground watershed boundaries differ from surface watershed boundaries. Groundwater quality grades provided in this Report Card are therefore reported based on each monitoring well site, not the 14 subwatersheds, like the other indicators.

Similar to the surface water monitoring program, the Provincial Groundwater Monitoring Network (PGMN) is a partnership between the Ontario Ministry of the Environment and local Conservation Authorities. Since 2007, the SCRCA has been monitoring eight wells within the St. Clair Region watershed (Map 4). Sampling occurs once a year at all monitoring wells and samples are tested for various parameters. Conservation Ontario recommends using nitrate and chloride concentrations over a 10-year time period as indicators

of groundwater quality. The 75th percentile concentration for each indicator is calculated then converted to a point score and given a grade using the Conservation Ontario guidelines (Table 8).

1.7 Groundwater Condition Results and Discussion

Groundwater condition grades range from A to F for the eight monitoring wells in the St. Clair Region (Table 9). It is important to note that the quality of nearby private wells may differ from that of the monitoring wells.

1.7.1 Nitrites + Nitrates

Nitrites and nitrates are forms of nitrogen that can occur naturally in rocks and groundwater, however, levels can be significantly increased by human impacts such as leaky septic systems and excessive use of fertilizers and manure. High concentrations make water unsafe for drinking. The Ontario and Canadian Drinking Water Quality Standard for nitrate is 10 mg/L. The 75th percentile was calculated for nitrate as recommended in the 2017 Conservation Ontario guidelines. Nitrate concentrations at all eight monitoring wells in the St. Clair Region are lower than the drinking water guideline, and all score A grades.

1.7.2 Chloride

Chloride is a naturally occurring element that can be found in high concentrations in groundwater due to natural causes, like the type of aquifer that the groundwater originates from, or it can be an indication of human impacts such as road salt, landfills and septic systems. The Canadian Drinking Water Quality Guideline for chloride is an Aesthetic Objective of 250 mg/L. The 75th percentile was calculated for chloride as recommended in the 2017 Conservation Ontario guidelines. Concentrations of chloride at the monitoring wells range from being lower than, to exceeding the drinking water guideline – three wells score an A grade whereas two wells have a C grade and three have an F grade. In general, it is considered that these sites may have higher concentrations of chloride due to naturally occurring circumstances however, there could also be human influences.

1.8 Forest Condition Methods

Three indicators are used to assess forest condition on a subwatershed scale:

- Percent Forest Cover
- Percent Forest Interior
- Percent Forested Riparian Buffer

These indicators reflect the health of the ecosystem as they support species diversity and human health, provide terrestrial habitats for native plants and animals, and contribute to healthy water quality and aquatic habitats. They can also be measured across the province.

Using 2015 aerial photography of the St. Clair Region, SCRCA staff performed a GIS desktop review of the woodland layer to assess the three forest condition indicators.

1.8.1 Forest Cover

Percent forest cover is the percentage of the watershed area that is forested or wooded. Environment Canada (2013) recommends that a minimum of 30% of a watershed should be in forest and other natural cover to sustain native plants and animals. The terms forest, woodland, and woodlot are used interchangeably for areas that are more than 60% covered in trees and are more than 2 m in height. Woodland has been interpreted to include deciduous, coniferous, mixed, and mature plantations and does not include young plantations (less than 2 m in height), hedgerows or street trees. The minimum area that is considered a forest is 0.5 ha.

For the 2008 Report Card, woodland cover was based on the Southern Ontario Land Resource Information System (SOLRIS) woodland layer provided by OMNRF with respect to the 2000 to 2007 aerial photography. At this time, woodlands were digitized based on their precise edge boundary, and included woodland “cut-outs” where woodlands were dissected around narrow features that were less than 20 m wide. The OMNRF Natural Heritage Manual (2010) indicates woodland areas are considered continuous even if they are intersected by narrow gaps 20 m or less in width between crown edges.

For the 2013 and 2018 Report Cards, all narrow gaps, less than 20 m wide, due to watercourses, non-woody vegetation classes, and private driveways were closed and the woodland feature considered continuous in those instances. Woodland gaps due to more permanent features, such as roads or railways were retained. Using the woodland delineation standards from the OMNRF Natural Heritage Manual (2010) resulted in a more accurate assessment of the total woodland cover and woodland interior habitat for the 2013 and 2018 Report Cards compared to the 2008 Report Card.

In addition to changes to the forest delineation methods used since the 2008 Report Cards, changes have also occurred to the definition of forest area. These changes are a direct result of advancements in air photo

resolution as well as the advancement of natural heritage studies in the region. The OMNRF woodland layer used in the 2008 Report Card used only two woodland communities, treed and hedgerow, in the determination of forest area. In the 2013 and 2018 Report Cards, forest communities were classified according to heritage studies completed in Middlesex and Huron Counties, which classified forest vegetation into seven community groups. Four woodland communities are now used in the forest area calculation including deciduous, coniferous, mixed, and mature plantations. Excluded communities are wooded hedgerows that are less than 30 m in width; woody riparian buffers that are less than 30 m in width; and young plantations, where the individual trees or rows of trees are discernible at a scale of 1:2000.

These changes in methodology resulted in an apparent decrease in woodland cover between the 2008 and 2013 Report Cards. This decrease in forest cover areas is considered largely due to improved mapping accuracy rather than changes in the landscape. However, the 2013 and 2018 Report Card analyses were conducted using the same methodology, therefore, reported changes more accurately reflect changes in the landscape.

The percent forest cover calculated for each subwatershed is converted into a score and grade, following the Conservation Ontario guidelines (Table 10).

1.8.2 Forest Interior

The second forest condition indicator, forest interior, refers to the inner core area of a woodlot that is more than 100 m from the forest edge. The percent forest interior is the percentage of the watershed area that is defined as forest interior. Environment Canada (2013) recommends that more than 10% of a watershed area should be forest interior. This protected core area is required by some species to breed successfully. Area-sensitive bird species, such as the Scarlet Tanager or Pileated Woodpecker, require a relatively large forest patch within which to reproduce successfully. The outer 100 m is considered edge habitat where plants and animals are susceptible to sun and wind damage, high predation rates, the invasion of alien species, and other disturbances. Some bird species also experience increased nest parasitism when located in edge habitat.

The forest interior was calculated for the 2018 Report Card using the 2015 woodland layer. Between the 2008 and 2013 Report Cards there was an apparent increase in forest interior, this change was mainly due to changes in analytical technique rather than actual increased forest interior within the landscape. However, the methodologies were consistent between the 2013

and 2018 Report Cards so any reported changes in forest interior between the 2013 and 2018 Report Cards is based on real world changes.

The percent forest interior was converted into a score and grade, following Conservation Ontario guidelines (Table 10).

1.8.3 Riparian Buffer

The third forest condition indicator is the percentage of the forested area within a 30 m zone along both sides of all open watercourses. The Conservation Authorities target is 50% of the riparian zone in forest cover, which was derived from the Environment Canada document, "How Much Habitat is Enough? A Framework for Guiding Habitat Rehabilitation in Great Lakes Areas of Concern" (2013), which provides science-based guidelines for habitat conservation and restoration. A key recommendation of the report is that 75% of the stream length should be naturally vegetated and that streams should have a minimum 30 m wide naturally vegetated buffer on both sides (Environment Canada, 2013). To standardize the calculations and grades, the Conservation Ontario (2011) target of 50% forest cover was decided upon as not all Conservation Authorities have non-forested vegetation types mapped, such as marsh, meadow, and shrub thicket. It was estimated that two-thirds of riparian vegetation is forest, therefore, the Conservation Ontario target of the riparian zone in 50% forest cover is roughly equivalent to the Environment Canada target of the riparian zone in 75% natural vegetation cover (Conservation Ontario, 2011).

Riparian buffers provide a breeding, feeding and migration corridor for many species. In addition, they contribute to aquatic health by filtering nutrients, moderating temperatures and evaporation, and also contributing to the food web and habitat diversity of the watercourse.

For the SCRCA's 2008 Report Cards, the riparian buffer was defined more conservatively as 15 m of woody riparian buffer on both sides of an open watercourse. Conservation Authorities agreed in 2010 to adopt the Environment Canada recommendations and use the 30 m woody riparian buffer as a guideline to set targets for this decade (Table 10; Conservation Ontario, 2011).

For the 2013 and 2018 Report Cards, the percentage of the 30 m riparian buffer area that is wooded was calculated. This could include wooded riparian areas that are narrower than 30 m.

1.9 Forest Condition Results

In the St. Clair Region, forest cover is limited and is primarily constrained to land unsuitable for agriculture or development. Lambton Shores Tributaries is the only subwatershed with an overall C grade for forest conditions. Eleven watersheds have a D grade and two have an F grade including Cow and Perch Creeks and Lake St. Clair Tributaries (Table 12).

The forest condition values and grades are summarized in Table 11 and illustrated in Map 5.

The observed changes in forest condition scores between the first Report Card and the second Report Card are considered largely due to changes in analysis rather than changes in the forest condition on the landscape. Changes between the 2013 and 2018 Report Cards are due to actual physical changes to the landscape rather than being artifacts of differences in methodology.

1.9.1 Forest Cover

Environment Canada (2013) recommends a minimum of 30% forest cover for a healthy watershed. It is important to note that this number represents the minimum percent forest cover required to support one half of the native species within a watershed (Environment Canada, 2013). Forest cover for the entire St. Clair Region is 11.3% (D grade) and there was a loss of 3.28 km^2 of forest since the 2013 Report Card. This low percent forest cover is not abnormal for a highly developed portion of southern Ontario where there is intensive land use but there is opportunity for improvement. When compared with adjacent watersheds, the forest cover is similar to the Upper Thames watershed but lower than the Ausable Bayfield watershed.

Lambton Shores Tributaries has the highest percent cover in the region with 17.4% (C grade). A significant percentage of the woodland in this subwatershed, 575 ha or 26%, is within Kettle and Stony Point First Nation land. The St. Clair River Tributaries and Lake St. Clair Tributaries watersheds also have a significant portion of their woodland cover within First Nation land.

The Upper Sydenham River is the only other subwatershed that has a C grade for forest cover, with 16.1%. Three of the largest woodland patches in this subwatershed are associated with significant wetlands. There are also extensive woodlands along the Sydenham River in Southwest Middlesex.

Three of the subwatersheds (Upper Sydenham River, Middle East Sydenham, Sydenham Headwaters) with the highest forest cover are upper subwatersheds of the East Sydenham River.

Twelve subwatersheds have a D grade for forest cover. The two lowest percent forest cover values are less than 6% and are recorded in the Lower East Sydenham (5.1%) and the Lake St. Clair Tributaries (5.4%) subwatersheds. Seventy-nine percent of the woodlands in the Lake St. Clair Tributaries are on Walpole Island First Nation and, combined, all three First Nations in the St. Clair Region contain over 36 km^2 of forest cover.

1.9.2 Forest Interior

Forest interior for the entire St. Clair Region is 1.97% (F grade), due to the high number of small and narrow woodlots (Table 13). Four subwatersheds have a D grade and ten have an F grade. More than 10% interior is recommended for a healthy watershed. When compared with abutting watersheds, this region has more interior forest than the Upper Thames watershed but less than the Ausable Bayfield watershed.

The subwatersheds with the most interior forest include Lambton Shores Tributaries (3.8%) and St. Clair River Tributaries (3.7%). These subwatersheds include large tracts of forest on First Nations land. Two other subwatersheds with high forest interior values for the St. Clair Region are the Middle East Sydenham (2.6%) and Lower Bear Creek (2.6%), where the relevant woodland patches are along the river floodplain. The lowest percent forest interior is recorded in the Lower East Sydenham subwatershed (0.4%), which also has the lowest forest cover (5.1%) and over 20% of the woodlands are less than 5 ha in size (Table 13).

Developmental pressures typically create fragmented forest habitats. In the SCRCA, a measure of habitat fragmentation can be seen in the large number of woodlands smaller than 5 ha – about 50% of woodlots in the watershed are less than 5 ha in size (Table 13). These areas of smaller woodlands result in lower species diversity due to increased edge effects when compared to the same area of larger sized woodlands.

1.9.3 Riparian Buffer

The forested riparian buffer is the 30 m area that is forested on both sides of an open watercourse. The target is 50% of the riparian zone in forest cover (Conservation Ontario, 2011). The forested riparian buffer coverage for the entire St. Clair Region is 21.7%, a D grade. Five subwatersheds have a C grade

including Sydenham Headwaters, Upper Sydenham River, Lambton Shores Tributaries, Lower Bear Creek, Brown Creek. These subwatersheds are among those with the higher forest cover values for the St. Clair Region.

The two subwatersheds that received the lowest grade, F, are Lake St. Clair Tributaries (3.3%) and Cow and Perch Creeks (12.3%). These subwatersheds have the second and third lowest forest cover values for the St. Clair Region, respectively.

1.10 Forest Condition Discussion

The majority of the St. Clair Region has poor forest conditions (Table 12). The subwatershed with the best overall forest condition is Lambton Shores Tributaries, which has an overall grade of C as it has the highest percentages of forest cover and forest interior, and the third highest riparian cover. Lambton Shores Tributaries includes part of a significant woodland, wetland, and beach dune complex (approximately 20,000 ha) that extends along Lake Huron from the Kettle and Stony Point First Nation lands through the Ipperwash and Port Franks Dunes and Wetland complex to Pinery Provincial Park (Table 32).

The Upper Sydenham River has an overall D grade, with similar percentages of forest cover and riparian cover to Lambton Shores Tributaries. However, there is much less forest interior in the Upper Sydenham River subwatershed than in the Lambton Shores Tributaries, as many of the Upper Sydenham woodlands are associated with watercourses and are long and relatively narrow. The Sydenham Headwaters has the highest percentage of forested riparian buffer.

Two subwatersheds, Lake St. Clair Tributaries and Cow and Perch Creeks, have very poor forest conditions, and an overall F grade. Each of these subwatersheds have low values for all three forest condition indicators. The Lake St. Clair Tributaries subwatershed has some of the most intensely worked agricultural land in the St. Clair Region and most of the natural cover has been removed. The Cow and Perch Creeks subwatershed has been cleared for residential, commercial and industrial development associated with Sarnia, the largest urban center in the St. Clair Region. Many of the watercourses in these subwatersheds are actively maintained as municipal drains and the land within 30 m of the open water is cleared and cropped.

1.11 Wetland Cover Methods

Environment Canada recommends that at least 10% of each major watershed and 6% of each subwatershed should be wetlands, to sustain water balance and biodiversity functions (Environment Canada, 2013).

The majority of the wetlands that are known from the St. Clair Region have been evaluated by OMNRF using the Ontario Wetland Evaluation System (OWES). Since the last Report Card, SCRCA staff has completed a detailed analysis to identify any unevaluated wetlands. This required a desktop review of aerial photos, particularly examining areas where the soil types, groundwater discharge mapping or proximity to evaluated wetlands increased the likelihood of identifying previously unmapped wetlands. Sites were then ranked by the certainty of wetland presence with approximately 343 ha identified as potential wetlands by the SCRCA (Table 15).

Percent wetland cover was then calculated and scored using the Conservation Ontario guidelines (Table 14).

1.12 Wetland Cover Results and Discussion

Wetlands cover just 1.1% of the St. Clair Region (Table 15). It is important to note that the First Nations lands have not been included in the assessment of the wetland cover indicator as First Nations lands have not been evaluated under OWES. The Sydenham Headwaters, Lambton Shores Tributaries, and Upper Sydenham River have the highest wetland coverage in the St. Clair Region, with 4.5%, 2.9%, and 2.6% respectively. Seven subwatersheds have less than 0.5% wetland cover. Wetland restoration and enhancement should be strongly encouraged in all subwatersheds.

1.13 Watershed Features and Actions for Improvement

In addition to the data used to calculate grades, information on the features of each subwatershed is included in the Section 2 tables and each Subwatershed Report Card. This information may indicate why a subwatershed experiences good or poor conditions, and why there have been changes since the last Report Cards. For example, higher amounts of precipitation and of flow have been recorded, which may increase bacteria readings but improve benthic conditions. The analysis of woodlot area sizes indicates that the largest woodlot in the St. Clair Region is in the Lake St. Clair Tributaries, and 68% of the woodlot coverage in that subwatershed is concentrated in 17 woodlots. Many other features have also been

summarized to provide benchmarks for the next Report Card.

Many residents are actively working to improve the health of the watershed, recognizing that the condition of their region influences their quality of life. Actions range from volunteering to plant trees on public lands, to implementing Woodlot Management Plans and Environmental Farm Plans on their private lands, and even donating property to be restored and conserved. Tree planting projects from 2011 to 2015 are summarized in Tables 16 and 17 and a range of stewardship projects are recognized in the individual Subwatershed Report Cards.

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Section 2: Tables and Maps

Table 1. Summary of subwatershed areas in the St. Clair Region

Subwatershed	Tributary of	Area (km^2)	Area (ha)	% of St. Clair Region
Sydenham Headwaters	East Sydenham River	224	22,391	5.4
Upper Sydenham River	East Sydenham River	229	22,917	5.5
Brown Creek	East Sydenham River	155	15,525	3.8
Middle East Sydenham	East Sydenham River	538	53,843	13.0
Lower East Sydenham	East Sydenham River	397	39,670	9.6
Bear Creek Headwaters	North Sydenham River	379	37,869	9.2
Lower Bear Creek	North Sydenham River	253	25,251	6.1
Black Creek	North Sydenham River	324	32,425	7.9
Lower North Sydenham	North Sydenham River	253	25,255	6.1
Lambton Shores Tributaries	Lake Huron	127	12,665	3.1
Plympton Shoreline Tributaries	Lake Huron	239	23,863	5.8
Cow and Perch Creeks	Lake Huron	266	26,628	6.4
St. Clair River Tributaries	St. Clair River	262	26,237	6.4
Lake St. Clair Tributaries	Lake St. Clair	484	48,409	11.7
Total		**4,130**	**412,948**	**100.0**

Table 2. Surface water quality indicators scoring and grading system

Total Phosphorus (mg/L)	Bacteria (CFU *E. coli*/ 100mL)	Benthic Score (FBI)	Point Score	Grade	Overall Surface Water Quality	
					Final Points	Final Grade
< 0.020	0 – 30	0.00 – 4.25	5	A	> 4.4	A
0.020 – 0.030	31 – 100	4.26 – 5.00	4	B	3.5 – 4.4	B
0.031 – 0.060	101 – 300	5.01 – 5.75	3	C	2.5 – 3.4	C
0.061 – 0.180	301 – 1000	5.76 – 6.50	2	D	1.5 – 2.4	D
> 0.180	> 1000	6.51 – 10.00	1	F	< 1.5	F

Total phosphorus calculated using 75th percentiles

Bacteria calculated using geometric means

FBI = Modified Family Biotic Index; based on New York State tolerance values used for Benthic Invertebrates indicator.

Source: Conservation Ontario, 2017

Table 3. Number of total phosphorus samples collected and sampling station locations

Subwatershed	Site	Total Phosphorus		
		No. of Samples 2001-2005	No. of Samples 2006-2010	No. of Samples 2011-2015
Sydenham Headwaters	East Sydenham River at Hickory Drive	31	37	35
Upper Sydenham River	East Sydenham River at Shiloh Line	30	36	36
Brown Creek	Brown Creek at Rokeby Line	16	26	19
Middle East Sydenham	East Sydenham River at Lambton Line	16	25	18
Lower East Sydenham	Main Sydenham River at McNaughton Ave	31	36	36
Bear Creek Headwaters	Bear Creek at Marthaville Road	29	36	36
Lower Bear Creek	Bear Creek at Bickford Line	31	34	36
Black Creek	Black Creek at Marthaville Road	29	35	36
Lower North Sydenham	North Sydenham River at Lambton Line	16	25	18
Lambton Shores Tributaries	Shashawanda at Rawlings Road	n/d	10	17
Plympton Shoreline Tributaries	Hickory Creek at Elmsley Road	n/d	10	17
Cow and Perch Creeks	Cow Creek at Lakeshore Road	16	33	36
St. Clair River Tributaries	Clay Creek at White Line near C&O railroad	8	36	36
Lake St. Clair	Little Bear Creek at Bear Line Road	16	37	34

n/d = no data

Table 4. Number of *E. coli* samples collected and sampling station locations

Subwatershed	Site	*E. coli*		
		No. of Samples 2001-2005	No. of Samples 2006-2010	No. of Samples 2011-2015
Sydenham Headwaters	East Sydenham River at Hickory Drive	23	38	40
Upper Sydenham River	East Sydenham River at Shiloh Line	23	37	40
Brown Creek	Brown Creek at Rokeby Line	n/d	n/d	20
Middle East Sydenham	East Sydenham River at Lambton Line	23	37	39
Lower East Sydenham	Main Sydenham River at McNaughton Ave	23	38	40
Bear Creek Headwaters	Bear Creek at Marthaville Road	23	38	40
Lower Bear Creek	Bear Creek at Bickford Line	23	38	40
Black Creek	Black Creek at Marthaville Road	23	38	39
Lower North Sydenham	North Sydenham River at Lambton Line	n/d	n/d	20
Lambton Shores Tributaries	Shashawanda at Rawlings Road	n/d	n/d	20
Plympton Shoreline Tributaries	Hickory Creek at Elmsley Road	n/d	n/d	19
Cow and Perch Creeks	Cow Creek at Lakeshore Road	n/d	n/d	39
St. Clair River Tributaries	Clay Creek at White Line near C&O railroad	n/d	n/d	39
Lake St. Clair	Little Bear Creek at Bear Line Road	n/d	n/d	41

n/d = no data

Table 5. Number of benthic invertebrate samples collected and sampling station locations

Subwatershed	Site	Benthic Invertebrates		
		No. of samples 2001-2005	No. of samples 2006-2010	No. of samples 2011-2015
Sydenham Headwaters	East Sydenham River at Coldstream Road	5	8	10
Upper Sydenham River	East Sydenham River at Sexton Road	5	5*	10
Brown Creek	Brown Creek at Rokeby Line	5	8	10
Middle East Sydenham	East Sydenham River east of Mawlam Road	3	8	10
Lower East Sydenham	East Sydenham River at Dawn Mills Road	5	7	10
Bear Creek Headwaters	Bear Creek at Kingscourt Road	4	7	10
Lower Bear Creek	Bear Creek at Telfer Road	4	7	10
Black Creek	Black Creek at Mandaumin Road	2	8	10
Lower North Sydenham	West Otter Creek Drain at Charlemont Line	4	7	9
Lambton Shores Tributaries	Shashawanda at Kinnaird Road	n/d	6	10
Plympton Shoreline Tributaries	Hickory Creek at Forest Road	5	6	8
Cow and Perch Creeks	Cow Creek at Mandaumin Road	4	6	10
St. Clair River Tributaries	Clay Creek at White Line near Hwy 40	3	6	9
Lake St. Clair	Rankin Creek at Bear Line Road	5	6	10

n/d = no data
**Riffle sample for 2010 not included*

Table 6. Surface water quality indicator results and grades for all subwatersheds

Subwatershed	Total Phosphorus (mg/L)			Bacteria (*E. coli* CFU/100mL)			Benthic Score (FBI)			Overall Grade		
	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015
Sydenham Headwaters	0.06 C	0.06 C	0.08 D	297 C	210 C	324 D	5.91 D	5.40 C	5.71 C	C	C	D
Upper Sydenham River	0.09 D	0.08 D	0.11 D	155 C	223 C	308 D	5.90 D	6.01 D	5.31 C	D	D	D
Brown Creek	0.09 D	0.14 D	0.24 F	n/d	n/d	192 C	5.65 C	5.41 C	5.44 C	C	C	D
Middle East Sydenham	0.08 D	0.08 D	0.12 D	99 B	162 C	234 C	5.76 D	5.55 C	4.88 B	C	C	C
Lower East Sydenham	0.06 C	0.08 D	0.09 D	86 B	50 B	80 B	5.48 C	5.53 C	5.45 C	C	C	C
Bear Creek Headwaters	0.22 F	0.22 F	0.20 F	263 C	192 C	279 C	5.79 D	5.71 C	5.57 C	D	D	D
Lower Bear Creek	0.23 F	0.19 F	0.17 D	216 C	220 C	342 D	5.62 C	5.75 C	5.81 D	D	D	D
Black Creek	0.21 F	0.14 D	0.16 D	219 C	146 C	304 D	6.23 D	5.83 D	6.19 D	D	D	D
Lower North Sydenham	0.15 D	0.13 D	0.12 D	n/d	n/d	23 A	6.62 F	6.30 D	5.95 D	D	D	C
Lambton Shores Tributaries	n/d	0.10 D	0.15 D	n/d	n/d	148 C	5.78 D	5.63 C	5.28 C	D	C	C
Plympton Shoreline Tributaries	n/d	0.07 D	0.17 D	n/d	n/d	146 C	n/d	5.85 D	5.85 D	n/d	D	D
Cow and Perch Creeks	0.15 D	0.16 D	0.16 D	n/d	n/d	409 D	5.77 D	6.00 D	5.96 D	D	D	D
St. Clair River Tributaries	0.18 D	0.15 D	0.26 F	n/d	n/d	129 C	6.92 F	5.68 C	5.74 C	D	C	D
Lake St. Clair Tributaries	0.08 D	0.09 D	0.10 D	n/d	n/d	39 B	6.90 F	7.01 F	7.06 F	D	D	D
St. Clair Region Average	**0.13 D**	**0.12 D**	**0.15 D**	**191 C**	**172 C**	**211 C**	**6.03 D**	**5.83 D**	**5.73 C**	**D**	**D**	**D**

n/d = no data
Sources (2011-2015): Ontario Ministry of the Environment Provincial Water Quality Monitoring Network, Middlesex Health Unit, and SCRCA

Table 7. Subwatersheds sorted by 2011-2015 surface water quality grades (point scores in brackets)

A (> 4.4)	B (3.5 – 4.4)	C (2.5 – 3.4)	D (1.5 – 2.4)	F (< 1.5)
		Middle East Sydenham (3.0)	**St. Clair Region Average (2.4)**	
		Lower East Sydenham (3.0)	Sydenham Headwaters (2.3)	
		Lower North Sydenham (3.0)	Upper Sydenham River (2.3)	
		Lambton Shores Tributaries (2.7)	Brown Creek (2.3)	
			Bear Creek Headwaters (2.3)	
			Plympton Shoreline Tributaries (2.3)	
			St. Clair River Tributaries (2.3)	
			Lake St. Clair Tributaries (2.3)	
			Lower Bear Creek (2.0)	
			Black Creek (2.0)	
			Cow and Perch Creeks (2.0)	

Table 8. Groundwater quality indicators scoring and grading system

Nitrite + Nitrate (mg/L)	Chloride (mg/L)	Overall Groundwater Quality	
		Point Score	Grade
0.0 – 2.5	1.0 – 62.5	5	A
2.6 – 5.0	62.6 – 125.0	4	B
5.1 – 7.5	125.1 – 187.5	3	C
7.6 – 10.0	187.6 – 250.0	2	D
> 10.0	> 250.0	1	F

Source: Conservation Ontario, 2017

Table 9. Groundwater quality indicator results and grades

Well Name (WELL ID)	Closest Intersection	Nitrite + Nitrate				Chloride			
		75th Percentile (mg/L)	No. of Samples	Point Score	Grade	75th Percentile (mg/L)	No. of Samples	Point Score	Grade
Coldstream CA (W0000431-1)	Coldstream Road and Quaker Lane	0.05	7	5	A	32	10	5	A
Clark Wright CA (W0000436-1)	Glen Oak Road and Walkers Drive	0.05	7	5	A	16	10	5	A
Kerwood (W0000459-1)	Kerwood Road and Adele Street	0.05	7	5	A	178	10	3	C
A.W. Campbell CA (W0000435-1)	Peak of Mosa Road and Shiloh Line	0.05	7	5	A	4	10	5	A
Bothwell (W0000461-1)	Downie Road and Fansher Road	0.05	6	5	A	167	9	3	C
Warwick CA (W0000460-1)	Warwick Village Road and London Line	0.05	7	5	A	451	9	1	F
Tiernay (W0000109-2)	Robinson Road and Edy's Mills Line	0.15	6	5	A	300	10	1	F
Guthrie Park (W0000106-2)	St. Clair Parkway and Curran Avenue	0.07	6	5	A	456	10	1	F

Note: The boundaries of surface watersheds and ground watersheds are not the same; nearby well water quality may vary from that of the monitoring wells

Source: SCRCA; Ontario Ministry of the Environment Provincial Groundwater Monitoring Network (2006-2015)

Table 10. Forest condition indicators scoring and grading system

% Forest Cover	% Forest Interior	% Forested Riparian Buffer	Point Score	Grade	Overall Forest Condition	
					Final Points	Final Grade
> 35.0	> 11.5	> 57.5	5	A	> 4.4	A
25.1 – 35.0	8.6 – 11.5	42.6 – 57.5	4	B	3.5 – 4.4	B
15.1 – 25.0	5.6 – 8.5	27.6 – 42.5	3	C	2.5 – 3.4	C
5.0 – 15.0	2.5 – 5.5	12.5 – 27.5	2	D	1.5 – 2.4	D
< 5.0	< 2.5	< 12.5	1	F	< 1.5	F

Source: Conservation Ontario, 2017

Table 11. Forest condition indicator results and grades for all subwatersheds

Subwatershed	% Forest Cover			% Forest Interior			% Forested Riparian Buffer			Overall Grade		
	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015	2001-2005	2006-2010	2011-2015
Sydenham Headwaters	13.9 D	14.3 D	14.4 D	1.3 F	1.6 F	1.6 F	n/d	37.8 C	41.6 C	D	D	D
Upper Sydenham River	15.5 C	16.0 C	16.1 C	1.5 F	2.4 F	2.4 F	n/d	30.9 C	34.4 C	D	D	D
Brown Creek	12.2 D	12.6 D	12.5 D	1.9 F	2.2 F	2.2 F	n/d	25.4 D	28.7 C	D	D	D
Middle East Sydenham	14.5 D	14.7 D	14.6 D	2.3 F	2.7 D	2.6 D	n/d	26.1 D	26.0 D	D	D	D
Lower East Sydenham	5.9 D	5.4 D	5.1 D	0.4 F	0.4 F	0.4 F	n/d	12.3 F	12.9 D	D	F	D
Bear Creek Headwaters	11.8 D	11.7 D	11.5 D	1.7 F	1.8 F	1.8 F	n/d	23.6 D	23.2 D	D	D	D
Lower Bear Creek	14.7 D	14.5 D	14.3 D	2.4 F	2.7 D	2.6 D	n/d	30.4 C	30.8 C	D	D	D
Black Creek	13.0 D	13.5 D	13.4 D	2.1 F	2.3 F	2.3 F	n/d	22.4 D	22.9 D	D	D	D
Lower North Sydenham	9.4 D	9.8 D	9.6 D	1.1 F	1.4 F	1.3 F	n/d	14.1 D	14.0 D	D	D	D
Lambton Shores Tributaries	17.8 C	17.3 C	17.4 C	4.3 D	4.1 D	3.8 D	n/d	32.4 C	32.8 C	C	C	C
Plympton Shoreline Tributaries	10.9 D	10.8 D	10.8 D	1.6 F	1.6 F	1.6 F	n/d	22.5 D	22.9 D	D	D	D
Cow and Perch Creeks	8.9 D	8.0 D	8.0 D	0.9 F	1.1 F	1.0 F	n/d	12.3 F	12.3 F	D	F	F
St. Clair River Tributaries	14.9 D	14.3 D	14.1 D	3.7 D	3.9 D	3.7 D	n/d	18.8 D	18.4 D	D	D	D
Lake St. Clair Tributaries	5.8 D	5.4 D	5.4 D	1.7 F	1.8 F	1.8 F	n/d	3.0 F	3.3 F	D	F	F
St. Clair Region Average	**12.1 D**	**12.5 D**	**12.0 D**	**1.9 F**	**2.1 F**	**2.1 F**	**n/d**	**22.3 D**	**23.1 D**	**D**	**D**	**D**
St. Clair Region Total	**11.5 D**	**11.4 D**	**11.3 D**	**1.8 F**	**2.0 F**	**2.0 F**	**n/d**	**21.2 D**	**21.7 D**	**D**	**D**	**D**

n/d = no data
Note: methodology changed for all three forest condition indicators between 2001-2005 and 2006-2010 but has remained the same since

Table 12. Subwatersheds sorted by 2011-2015 forest condition grades (point scores in brackets)

A (> 4.4)	B (3.5 – 4.4)	C (2.5 – 3.4)	D (1.5 – 2.4)	F (< 1.5)
		Lambton Shores Tributaries (2.7)	Upper Sydenham River (2.3)	Cow and Perch Creeks (1.3)
			Lower Bear Creek (2.3)	Lake St. Clair Tributaries (1.3)
			Sydenham Headwaters (2.0)	
			Brown Creek (2.0)	
			Middle East Sydenham (2.0)	
			St. Clair River Tributaries (2.0)	
			St. Clair Region Average (1.9)	
			Lower East Sydenham (1.7)	
			Bear Creek Headwaters (1.7)	
			Black Creek (1.7)	
			Lower North Sydenham (1.7)	
			Plympton Shoreline Tributaries (1.7)	
			St. Clair Region Total (1.7)	

Table 13: Number of woodlots in each subwatershed by size category

Subwatershed	Number of Woodlots				Total No.	Total Woodlot Area (ha)				Total Area (ha)	Percentage of Woodlot Area				Size of Largest Woodlot (ha)
	<5 ha	5-10 ha	10-30 ha	>30 ha		<5 ha	5-10 ha	10-30 ha	>30 ha		<5 ha	5-10 ha	10-30 ha	>30 ha	
Sydenham Headwaters	228	64	58	26	376	403	471	890	1,455	3,219	13	15	28	45	128
Upper Sydenham River	210	57	51	31	349	392	389	904	2,007	3,692	11	11	24	54	143
Brown Creek	87	22	22	18	149	165	157	409	1,217	1,948	8	8	21	62	156
Middle East Sydenham	340	135	113	72	660	677	979	1,972	4,258	7,886	9	12	25	54	138
Lower East Sydenham	211	60	50	9	330	459	432	757	393	2,041	22	21	37	19	60
Bear Creek Headwaters	163	62	69	43	337	328	457	1,119	2,465	4,369	8	10	26	56	135
Lower Bear Creek	163	38	42	37	280	320	271	743	2,283	3,617	9	7	21	63	171
Black Creek	189	64	70	40	363	399	434	1,168	2,360	4,361	9	10	27	54	155
Lower North Sydenham	137	41	51	20	249	312	311	857	934	2,414	13	13	36	39	79
Lambton Shores Tributaries	89	22	37	11	159	171	164	597	1,276	2,208	8	7	27	58	244
Plympton Shoreline Tributaries	125	44	46	25	240	259	323	767	1,220	2,569	10	13	30	47	95
Cow and Perch Creeks	167	38	49	12	266	318	275	877	656	2,126	15	13	41	31	135
St. Clair River Tributaries	167	46	49	33	295	346	319	848	2,183	3,696	9	9	23	59	261
Lake St. Clair Tributaries	156	26	19	17	218	311	189	338	1,801	2,639	12	7	13	68	353
St. Clair Region Total	**2,432**	**719**	**726**	**394**	**4,271**	**4,860**	**5,171**	**12,246**	**24,508**	**46,785**	**10**	**11**	**26**	**52**	**353***
Average	**174**	**51**	**52**	**28**	**305**	**347**	**369**	**875**	**1,751**	**3,342**	**11**	**11**	**27**	**51**	**161**

**The largest woodlot in the St. Clair Region is located in the Lake St. Clair Tributaries*

Table 14. Wetland cover grading system

% Wetland Cover	Grade
> 11.5	A
8.6 – 11.5	B
5.6 – 8.5	C
2.5 – 5.5	D
< 2.5	F

Source: Conservation Ontario, 2017

Table 15. Wetland cover grades for all subwatersheds

Subwatershed	Total Subwatershed Area (ha)	Potential SCRCA Wetlands		MNRF Wetlands		Wetland Total		Final Grade
		Area (ha)	% Area of Watershed	Area (ha)	% Area of Watershed	Area (ha)	% Area of Watershed	
Sydenham Headwaters	22,391	43	0.2	969	4.3	1,012	4.5	D
Upper Sydenham River	22,917	95	0.4	504	2.2	599	2.6	D
Brown Creek	15,525	20	0.1	48	0.3	68	0.4	F
Middle East Sydenham	53,843	96	0.2	555	1.0	651	1.2	F
Lower East Sydenham	39,670	4	0.0	0	0.0	4	0.0	F
Bear Creek Headwaters	37,869	53	0.1	97	0.3	150	0.4	F
Lower Bear Creek	25,251	12	0.0	187	0.7	199	0.8	F
Black Creek	32,425	19	0.1	68	0.2	87	0.3	F
Lower North Sydenham	25,255	0	0.0	79	0.3	79	0.3	F
Lambton Shores Tributaries	12,665	0	0.0	362	2.9	362	2.9	D
Plympton Shoreline Tributaries	23,863	0	0.0	72	0.3	72	0.3	F
Cow and Perch Creeks	26,628	1	0.0	59	0.2	60	0.2	F
St. Clair River Tributaries	26,237	0	0.0	382	1.5	382	1.5	F
Lake St. Clair Tributaries	48,409	0	0.0	732	1.5	732	1.5	F
St. Clair Region Total	**412,948**	**343**	**0.1**	**4,114**	**1.0**	**4,457**	**1.1**	**F**

Potential SCRCA Wetlands = Areas identified using three GIS-based indicators of wetland potential and desk-top examination of 2010 aerial orthophotography

MNRF Wetlands = Areas evaluated under the Ontario Wetland Evaluation System (OWES) and approved by the Ministry of Natural Resources and Forestry (June 2017); No First Nations Land has been evaluated under OWES.

Note: Wetland cover calculations do not include First Nations land

Table 16. Trees and shrubs planted by the SCRCA from 2011 to 2015

Subwatershed	No. of Projects	No. of Trees and Shrubs Planted
Sydenham Headwaters	16	37,860
Upper Sydenham River	11	14,380
Brown Creek	6	8,020
Middle East Sydenham	16	30,930
Lower East Sydenham	5	8,980
Bear Creek Headwaters	6	4,340
Lower Bear Creek	8	17,590
Black Creek	2	2,590
Lower North Sydenham	14	29,615
Lambton Shores Tributaries	0	0
Plympton Shoreline Tributaries	7	30,020
Cow and Perch Creeks	7	8,070
St. Clair River Tributaries	10	76,545
Lake St. Clair Tributaries	7	5,885
St. Clair Region Total	**115**	**274,825**

Notes: Includes trees planted on private lands and corporate lands by SCRCA staff under the Conservation Services program.

Does not include trees planted by SCRCA under the Memorial Forest program on municipal, SCRCA and other public properties.

Includes projects completed by SCRCA staff in partnership with Rural Lambton Stewardship Network.

Table 17. Memorial Forest and Conservation Area tree plantings from 1988 to 2015

Subwatershed	No. of Projects	No. of Trees Planted
Sydenham Headwaters	15	44,377
Upper Sydenham River	5	6,390
Brown Creek	0	0
Middle East Sydenham	9	11,485
Lower East Sydenham	4	88
Bear Creek Headwaters	9	18,093
Lower Bear Creek	4	10,806
Black Creek	0	0
Lower North Sydenham	11	120,709
Lambton Shores Tributaries	0	0
Plympton Shoreline Tributaries	13	3,054
Cow and Perch Creeks	5	59,952
St. Clair River Tributaries	12	310
Lake St. Clair Tributaries	0	0
St. Clair Region Total	**87**	**275,264**

Note: Memorial Forest program supports tree plantings on public lands, owned by local municipalities, counties or the SCRCA

Table 18. Subwatersheds within each municipality and First Nation

Municipality/ First Nation	Subwatershed(s) within each Municipality/First Nation	Area (km^2)	% Area
Adelaide Metcalfe	Upper Sydenham River	111	49
	Middle East Sydenham	51	23
	Brown Creek	33	15
	Sydenham Headwaters	29	13
	Bear Creek Headwaters	1	<1
Brooke-Alvinston	Middle East Sydenham	130	42
	Brown Creek	69	22
	Bear Creek Headwaters	67	21
	Black Creek	30	9
	Upper Sydenham River	17	5
Chatham-Kent	Lake St. Clair Tributaries	338	52
	Lower East Sydenham	245	38
	Lower North Sydenham	49	8
	Middle East Sydenham	10	1
	St. Clair River Tributaries	5	1
Dawn-Euphemia	Middle East Sydenham	181	40
	Lower East Sydenham	150	33
	Black Creek	73	16
	Lower North Sydenham	45	10
Enniskillen	Black Creek	162	48
	Bear Creek Headwaters	89	26
	Lower Bear Creek	81	24
	Cow and Perch Creeks	7	2
Lambton Shores (not including Kettle and Stony Point First Nation)	Lambton Shores Tributaries	110	97
	Plympton Shoreline Tributaries	3	3
Middlesex Centre	Sydenham Headwaters	115	100
Newbury	Middle East Sydenham	2	100
Oil Springs	Black Creek	8	100
Petrolia	Bear Creek Headwaters	10	77
	Lower Bear Creek	3	23
Point Edward	St. Clair River Tributaries	3	100

Table 18. Subwatersheds within each municipality and First Nation (continued)

Municipality/ First Nation	Subwatershed(s) within each Municipality/First Nation	Area (km^2)	% Area
Plympton-Wyoming	Plympton Shoreline Tributaries	181	56
	Cow and Perch Creeks	86	26
	Bear Creek Headwaters	47	14
	Lower Bear Creek	10	3
	Lambton Shores Tributaries	2	<1
Sarnia (not including Aamjiwnaang First Nation)	Cow and Perch Creeks	141	84
	St. Clair River Tributaries	27	16
Southwest Middlesex	Middle East Sydenham	165	94
	Upper Sydenham River	10	6
St. Clair	St. Clair River Tributaries	216	35
	Lower North Sydenham	159	26
	Lower Bear Creek	159	26
	Black Creek	51	8
	Cow and Perch Creeks	33	5
	Lower East Sydenham	2	<1
Strathroy-Caradoc	Upper Sydenham River	92	54
	Sydenham Headwaters	79	46
Warwick	Bear Creek Headwaters	166	59
	Plympton Shoreline Tributaries	54	19
	Brown Creek	54	19
	Lambton Shores Tributaries	6	2
Aamjiwnaang First Nation	St. Clair River Tributaries	12	94
	Cow and Perch Creeks	1	6
Kettle and Stony Point First Nation	Lambton Shores Tributaries	9	100
Walpole Island First Nation	Lake St. Clair Tributaries	147	100

Table 19. Municipalities and First Nations within each subwatershed

Subwatershed	Total Area (km^2)	Municipalities/ First Nations within each Subwatershed	Area (km^2)	% Area
Sydenham Headwaters	223.9	Middlesex Centre	115.2	51
		Strathroy-Caradoc	79.3	35
		Adelaide-Metcalfe	29.4	13
Upper Sydenham River	229.2	Adelaide-Metcalfe	110.6	48
		Strathroy-Caradoc	92.2	40
		Brooke-Alvinston	16.5	7
		Southwest Middlesex	9.9	4
Brown Creek	155.2	Brooke-Alvinston	69.0	44
		Warwick	53.6	35
		Adelaide-Metcalfe	32.6	21
Middle East Sydenham	538.4	Dawn-Euphemia	180.9	34
		Southwest Middlesex	164.9	31
		Brooke-Alvinston	129.8	24
		Adelaide-Metcalfe	51.2	10
		Chatham-Kent	9.5	2
		Newbury	2.1	<1
Lower East Sydenham	396.8	Chatham-Kent	244.5	62
		Dawn-Euphemia	149.9	38
		St. Clair	2.3	1
Bear Creek Headwaters	378.7	Warwick	165.6	44
		Enniskillen	89.1	24
		Brooke-Alvinston	67.0	18
		Plympton	46.8	12
		Petrolia	9.6	3
		Adelaide-Metcalfe	0.6	<1
Lower Bear Creek	252.5	St. Clair	158.6	63
		Enniskillen	81.0	32
		Plympton-Wyoming	10.1	4
		Petrolia	2.8	1

Table 19. Municipalities and First Nations within each subwatershed (continued)

Subwatershed	Total Area (km^2)	Municipalities/ First Nations within each Subwatershed	Area (km^2)	% Area
Black Creek	324.2	Enniskillen	162.4	50
		Dawn-Euphemia	72.7	22
		St. Clair	51.2	16
		Brooke-Alvinston	29.6	9
		Oil Springs	8.3	3
Lower North Sydenham	252.7	St. Clair	159.3	63
		Chatham-Kent	48.8	19
		Dawn-Euphemia	44.6	18
Lambton Shores Tributaries	126.7	Lambton Shores	110.0	87
		Kettle and Stony Point FN	8.9	7
		Warwick	6.3	5
		Plympton-Wyoming	1.5	<1
Plympton Shoreline Tributaries	238.6	Plympton-Wyoming	181.0	76
		Warwick	54.4	23
		Lambton Shores	3.2	1
Cow and Perch Creeks	266.3	Sarnia	140.9	53
		Plympton-Wyoming	85.5	32
		St. Clair	32.6	12
		Enniskillen	6.5	2
		Aamjiwnaang First Nation	0.8	<1
St. Clair River Tributaries	261.2	St. Clair	214.6	82
		Sarnia	26.8	10
		Aamjiwnaang First Nation	11.6	4
		Chatham-Kent	4.9	2
		Point Edward	3.3	1
Lake St. Clair Tributaries	483.2	Chatham-Kent	337.3	70
		Walpole Island First Nation	145.9	30

Table 20. Land use by subwatershed

Subwatershed	% Agricultural	% Forest *	% Urban/Industrial	% Other/ Not Mapped
Sydenham Headwaters	81	11	7	0.3
Upper Sydenham River	84	14	0.8	0.6
Brown Creek	87	13	0.4	0.1
Middle East Sydenham	85	14	0.6	0.4
Lower East Sydenham	91	6	2	0.9
Bear Creek Headwaters	85	11	3	0.2
Lower Bear Creek	85	12	3	0.8
Black Creek	84	13	2	0.4
Lower North Sydenham	88	11	1	0.5
Lambton Shores Tributaries	77	19	3	0.8
Plympton Shoreline Tributaries	86	11	2	0.8
Cow and Perch Creeks	79	6	14	1
St. Clair River Tributaries	68	9	23	0.4
Lake St. Clair Tributaries	66	1	1	32
St. Clair Region Average	**82**	**11**	**4**	**3**

Note: This table provides a broad overview of land use within the subwatersheds

**Updated forest area analysis, using 2015 aerial photography, is within "Table 11. Forest condition indicator results and grades for all subwatersheds"*

Source: GIS derived from "Agriculture Resource Inventory," Ontario Ministry of Agriculture and Food, 1983

Table 21. Soil types in each subwatershed by percent area

Subwatershed	% Bottom Land and Beach	% Loam	% Sand Loams	% Silt and Clay	% Silt and Clay Loams	% Organic	% Not Mapped	% Fine Sand	% Water
Sydenham Headwaters	11.2	14.7	20.4	40.8	8.9	0.1	3.3	0.6	
Upper Sydenham River	8.1	9.7	42.4	37.3		0.2	0.2	2.1	
Brown Creek	4.6	4.1	1.7	64.3	25.1		0.2		
Middle East Sydenham	5.2	3.4	34.5	53.5	2.9		0.5		
Lower East Sydenham	3.5	7.0	18.1	63.2	5.6		1.8	0.3	0.7
Bear Creek Headwaters	4.1	4.9	1.9	83.9	5.3				
Lower Bear Creek	3.6	0.2	1.1	94.5	0.6				
Black Creek	3.4	0.2		95.9	0.5				
Lower North Sydenham	1.7	2.7	1.0	93.0	0.5		0.8		0.4
Lambton Shores Tributaries	3.1	5.6	2.1	79.8	9.5				
Plympton Shoreline Tributaries	3.3	3.2	3.5	90.0					
Cow and Perch Creeks	0.9	1.0	3.3	90.6	2.7	0.9	0.6		
St. Clair River Tributaries	0.8	7.4	3.2	79.8	5.0		3.8		
Lake St. Clair Tributaries		5.5	35.8	30.9	7.1	16.5	3.8	0.2	0.2

Water = open waterbodies within subwatersheds

Not Mapped = mainly urban/built-up areas

Note: Figures represent the percentage of the subwatershed area in each soil type

Source: Derived using GIS and soil maps from the Ontario Ministry of Agriculture and Food, Soils Ontario Version 1.0

Table 22. Physiography of each subwatershed by percent area

Subwatershed	% Spillways	% Till Moraines	% Clay Plains	% Sand Plains	% Till Plains Undrumlinized	% Beaches and Shorecliffs	% Bevelled Till Plains	% Peat and Muck
Sydenham Headwaters	11.2	14.7	20.4	40.8	8.9	0.1	3.3	0.6
Upper Sydenham River	8.1	9.7	42.4	37.3		0.2	0.2	2.1
Brown Creek	4.6	4.1	1.7	64.3	25.1		0.2	
Middle East Sydenham	5.2	3.4	34.5	53.5	2.9		0.5	
Lower East Sydenham	3.5	7.0	18.1	63.2	5.6		1.8	0.3
Bear Creek Headwaters	4.1	4.9	1.9	83.9	5.3			
Lower Bear Creek	3.6	0.2	1.1	94.5	0.6			
Black Creek	3.4	0.2		95.9	0.5			
Lower North Sydenham	1.7	2.7	1.0	93.0	0.5		0.8	
Lambton Shores Tributaries	3.1	5.6	2.1	79.8	9.5			
Plympton Shoreline Tributaries	3.3	3.2	3.5	90.0				
Cow and Perch Creeks	0.9	1.0	3.3	90.6	2.7	0.9	0.6	
St. Clair River Tributaries	0.8	7.4	3.2	79.8	5.0		3.8	
Lake St. Clair Tributaries		5.5	35.8	30.9	7.1	16.5	3.8	0.2

Note: Figures represent the percentage of the subwatershed area in each physiographic unit

Source: GIS derived from Chapman, L.J. & D.F. Putnam, 1973

Table 23. Average annual air temperature from 2011 to 2015

Relevant Subwatershed(s)	Station Name	Average Annual Air Temperature (°C)								
		2011	2012	2013	2014	2015	Mean 2002-2005	Mean 2006-2010	Mean 2011-2015	Mean 2002-2015
Sydenham Headwaters, Upper Sydenham River, Brown Creek, Middle East Sydenham	Strathroy	8.56	9.98	7.96	6.62	8.05	8.40	8.78	8.23	8.48
Bear Creek Headwaters, Lower Bear Creek, Black Creek	Petrolia	9.08	10.41	8.48	7.35	8.29	8.94	8.93	8.72	8.86
Lower East Sydenham, Lower North Sydenham, Lake St. Clair Tributaries	Wallaceburg	10.93	12.22	10.44	9.42	10.34	9.87	10.57	10.67	10.40
Lambton Shoreline Tributaries, Plympton Shores Tributaries, Cow and Perch Creeks, St. Clair River Tributaries	Sarnia	8.95	10.37	8.35	7.14	8.61	8.41	8.96	8.68	8.70
Average		**9.38**	**10.75**	**8.81**	**7.63**	**8.82**				

Station name = relevant meteorological station for each subwatershed

Table 24. Annual precipitation from 2011 to 2015

Relevant Subwatershed(s)	Station Name	Annual Precipitation (mm)								
		2011	2012	2013	2014	2015	Mean 2002-2005	Mean 2006-2010	Mean 2011-2015	Mean 2002-2015
Sydenham Headwaters, Upper Sydenham River, Brown Creek, Middle East Sydenham	Strathroy	1,165	663	1,032	876	776	835	983	902	912
Bear Creek Headwaters, Lower Bear Creek, Black Creek	Petrolia	1,118	833	989	693	625	860	972	852	897
Lower East Sydenham, Lower North Sydenham, Lake St. Clair Tributaries	Wallaceburg	1,226	657	841	807	682	842	924	843	871
Lambton Shoreline Tributaries, Plympton Shores Tributaries, Cow and Perch Creeks, St. Clair River Tributaries	Sarnia	986	733	812	687	614	822	849	766	812
Average		**1,124**	**722**	**919**	**766**	**674**				

Station name = relevant meteorological station for each subwatershed

Table 25. Mean annual streamflow from 2011 to 2015

Relevant Subwatershed(s)	Station Name (Station ID)	Mean Annual Streamflow (m^3/s)								
		2011	2012	2013	2014	2015	Mean 2003-2005	Mean 2006-2010	Mean 2011-2015	Mean 2003-2015
Sydenham Headwaters, Upper Sydenham River	Strathroy (02GG005)	2.09	1.92	2.05	1.99	1.94	1.80	2.32	2.00	2.08
Middle East Sydenham	Alvinston (02GG002)	10.93	10.66	10.84	10.84	10.71	6.81	8.47	10.79	8.98
Middle East Sydenham	Florence (02GG003)	3.97	3.40	3.74	3.71	3.48	10.89	13.64	3.66	9.17
Lower East Sydenham	Dresden (02GG007)	11.17	10.92	8.96	19.19	11.92	14.93	17.92	12.43	15.12
Bear Creek Headwaters, Lower Bear Creek	Petrolia (02GG006)	4.34	4.07	4.25	4.27	4.17	2.42	3.20	4.22	3.41
Lower Bear Creek	Brigden (02GG009)	4.76	3.84	4.08	4.32	3.92	4.96	6.47	4.18	5.24
Black Creek	Black Creek (02GG013)	6.79	6.42	6.52	6.63	6.31	n/a	2.81	6.53	4.67
Cow and Perch Creeks	Perch Creek (02FF012)	3.04	2.79	3.17	3.14	2.89	0.61	0.95	3.01	1.66
Average		**5.89**	**5.50**	**5.45**	**6.76**	**5.67**				

Station Name= relevant stream gauge station for each subwatershed

Note: There is no streamflow data available for the following subwatersheds – Brown Creek, Lower North Sydenham, Lambton Shores Tributaries, Plympton Shoreline Tributaries, St. Clair River Tributaries, Lake St. Clair Tributaries

Table 26. Major watercourses and drains by subwatershed

Subwatershed	Major Watercourses
Sydenham Headwaters	East Sydenham River (in part), Taylor Drain, Calvin Creek, Gold Creek, Bell Drain, Trout Creek, Stokman Creek, Cable Drain
Upper Sydenham River	East Sydenham River (in part), Campbell Creek, Spring Creek, Brigham-Watts Drain, O'Neil Drain, Dortmans Creek, White Drain, Lipset Drain
Brown Creek	Brown Creek, Hardy Creek, Hair Creek, Edgar Drain No.1, Cameron Drain, Kersey Drain
Middle East Sydenham	East Sydenham River (in part), Morrogh Creek, Haggerty Creek Drain, Fansher Creek, Hugh McLaughlin Drain, McCracken Drain, Peter Mitchell Drain, Cherry Drain
Lower East Sydenham	East Sydenham River (in part), Butler Drain, Dankey Creek Drain, Crowell Creek, Little Bear Creek, Drummond Creek, Long Creek, Molly Creek
Bear Creek Headwaters	Bear Creek (in part), Gilliland Geerts Drain, Leach Drain, Higgins Drain, Durham Creek, Graham Drain, Moffatt Drain, Moore Drain
Lower Bear Creek	Bear Creek (in part), Stonehouse Drain, Stewart Drain, Nobel Wooley Drain, Johnson Drain, Burton Creek, Nichol Creek, Jarvis Drain
Black Creek	Black Creek, Fox Creek, McMurphy Drain, Simpson Drain, Groves Drain, Plum Creek, Currie Creek Drain, Booth Creek Drain
Lower North Sydenham	North Sydenham River, Heyland Drain, Gooden Creek, Indian Creek, Running Creek, Otter Creek Drain, East Otter Creek Drain, West Otter Creek Drain
Lambton Shores Tributaries	Duffus Creek, Shashawandah Creek, James Creek, Woods Creek, Walden Drain, Haney Drain
Plympton Shoreline Tributaries	Hickory Creek, Douglas Drain, Highland Creek, Aberarder Creek, Bonnie Doon Creek, Errol Creek, Kernohan O'Donnell Drain, McPherson Drain
Cow and Perch Creeks	Cow Creek, Pulse Creek Drain, Waddell Creek, Perch Creek, Wawanosh Drain, Armstrong Drain, Park Drain
St. Clair River Tributaries	Talfourd Creek, Marshy Creek, Baby Creek, Bowens Creek, Clay Creek, Marsh Creek, Grape Run Drain
Lake St. Clair Tributaries	Maxwell Creek, Little Bear Creek Drain, Rankin Creek Drain, Big Creek Drain, Purdie Creek Drain

Table 27. Flow and temperature regime of watercourses in each subwatershed

Subwatershed	Flow Regime							Temperature Regime				
	Total Length of Watercourses (km)	Permanent (km)	Intermittent (km)	Unknown (km)	% Permanent	% Intermittent	% Unknown	Total Open Watercourses (km)	Cold (km)	Warm (km)	% Cold	% Warm
Sydenham Headwaters	342	157	40	145	46	12	42	197	17	180	8	92
Upper Sydenham River	417	171	60	186	41	14	45	231	8	224	3	97
Brown Creek	329	95	48	186	29	15	56	143	0	143	0	100
Middle East Sydenham	973	357	277	340	37	28	35	633	0	633	0	100
Lower East Sydenham	594	274	236	84	46	40	14	510	0	510	0	100
Bear Creek Headwaters	685	244	193	248	36	28	36	437	0	437	0	100
Lower Bear Creek	333	173	97	63	52	29	19	270	0	270	0	100
Black Creek	580	205	233	143	35	40	25	437	0	437	0	100
Lower North Sydenham	275	125	116	34	45	42	12	241	0	241	0	100
Lambton Shoreline Tributaries	156	64	79	13	41	51	9	143	2	141	1	99
Plympton Shores Tributaries	330	151	77	103	46	23	31	227	0	227	0	100
Cow and Perch Creeks	369	158	74	137	43	20	37	232	2	230	1	99
St. Clair River Tributaries	276	83	102	91	30	37	33	185	0	185	0	100
Lake St. Clair Tributaries	521	234	198	89	45	38	17	432	0	432	0	100
St. Clair Region Total	**6,179**	**2,487**	**1,831**	**1,862**	**40**	**30**	**30**	**4,317**	**28**	**4,289**	**1**	**99**
Average	**441**	**178**	**131**	**133**	**41**	**30**	**29**	**308**	**2**	**306**	**1**	**99**

Unknown= Municipal drains that are buried or unknown classification
Open = Classified watercourses that are not buried
Cold = Cold or cool watercourse based on limited temperature sampling
Warm = Warm watercourse based on fish communities
Sources: Ministry of Natural Resources NRVIS for SCRCA; SCRCA Drain Classification database

Table 28. Length of watercourses in each subwatershed by type (natural, municipal drain or unclassified)

Subwatershed	Total Length of Watercourses (km)	Natural Watercourse (km)	Municipal Drain (km)	Unclassified (km)	% Natural Watercourse	% Municipal Drain	% Unclassified Watercourse
Sydenham Headwaters	248	74	117	57	30	47	23
Upper Sydenham River	352	75	153	124	21	43	35
Brown Creek	209	49	88	72	23	42	34
Middle East Sydenham	923	105	525	293	11	57	32
Lower East Sydenham	588	108	402	78	18	68	13
Bear Creek Headwaters	540	114	329	97	21	61	18
Lower Bear Creek	327	103	166	58	31	51	18
Black Creek	553	90	342	121	16	62	22
Lower North Sydenham	277	37	206	34	13	74	12
Lambton Shores Tributaries*	153	31	122	0	20	80	0
Plympton Shoreline Tributaries	283	56	169	58	20	60	20
Cow and Perch Creeks	353	36	195	122	10	55	35
St. Clair River Tributaries	277	36	151	90	13	55	32
Lake St. Clair Tributaries	521	0	437	84	0	84	16
St. Clair Region Total	**5,604**	**914**	**3,402**	**1,288**	**16**	**61**	**23**

Total Length of Watercourses = Total length of inland, surface watercourses; Great Lakes connecting channels and watercourses on Walpole Island First Nation lands are not included.

Natural Watercourse = Watercourse not identified as a Municipal Drain (Classified as N during OMAFRA Drain classification project 2004)

Municipal Drain = Watercourses identified as a Municipal Drain (classified as A, B, C, D, E, F during OMAFRA Drain classification project 2004)

Unclassified = Watercourses with an Unknown Drain Class (classified as U during OMAFRA Drain Classification project 2004)

**All watercourses in Lambton Shores were classified by Ausable Bayfield Conservation Authority as Open (Type A, B, C, D, E, or F) or Buried (Type T), whether they were a Natural Watercourse or a Municipal Drain; queries were based on Channel Type (Natural, Channelized or Unknown).*

Source: SCRCA Municipal Drain Classification, 2004; except for Lambton Shores, where watercourses were assessed by Ausable Bayfield Conservation Authority.

Table 29. Agricultural tile drainage by subwatershed

Subwatershed	Total Area (km^2)	Unknown Drainage (km^2)	Randomly Tiled (km^2)	Systematically Tiled (km^2)	% Unknown Drainage	% Randomly Tiled	% Systematically Tiled
Sydenham Headwaters	224	160	23	41	71	10	18
Upper Sydenham River	229	139	35	55	61	15	24
Brown Creek	155	49	32	74	32	21	48
Middle East Sydenham	540	224	99	217	41	18	40
Lower East Sydenham	398	83	77	238	21	19	60
Bear Creek Headwaters	379	114	44	221	30	12	58
Lower Bear Creek	253	78	75	100	31	30	40
Black Creek	325	98	20	207	30	6	64
Lower North Sydenham	253	57	20	176	23	8	70
Lambton Shores Tributaries	127	54	14	59	43	11	46
Plympton Shoreline Tributaries	240	74	31	135	31	13	56
Cow and Perch Creeks	267	100	36	131	37	13	49
St. Clair River Tributaries	263	132	45	86	50	17	33
Lake St. Clair Tributaries	484	180	30	274	37	6	57
St. Clair Region Total	**4,137**	**1,542**	**581**	**2,014**	**37**	**14**	**49**
Average	**296**	**110**	**42**	**144**	**38**	**14**	**47**

Unknown Drainage = Land without agricultural tiles

Source: Based on "Tile Drainage Area," Ontario Ministry of Agriculture, Food and Rural Affairs, 2015

Table 30. Dams and barriers to fish movement

Subwatershed	Total No. of Dams or Barriers	No. of Private Dams and Barriers	No. of Public Dams and Barriers	Names of Public Dams and Barriers
Sydenham Headwaters	10	7	3	Cuddy Woods Dam, Coldstream CA Dam, Strathroy CA Dam
Upper Sydenham River	6	5	1	Wright CA Dam
Brown Creek	4	4	0	
Middle East Sydenham	3	1	2	Campbell CA Dams
Lower East Sydenham	2	1	1	VanderVeeken Dam
Bear Creek Headwaters	5	3	2	Petrolia CA Dam, Warwick CA Dam
Lower Bear Creek	7	3	4	Henderson CA Weir 1, Weir 2 and Weir 3, Marthaville HMA Dam
Black Creek	0	0	0	
Lower North Sydenham	2	1	1	McKeough CA Dam
Lambton Shores Tributaries	2	2	0	
Plympton Shoreline Tributaries	4	3	1	Dodge CA Dam
Cow and Perch Creeks	0	0	0	
St. Clair River Tributaries	1	0	1	McKeough CA Drop Structure
Lake St. Clair Tributaries	5	1	4	Bay Lodge Dam, Hind Relief Dam, Rankin Creek Dam
St. Clair Region Total	**51**	**31**	**20**	

Source: SCRCA Dam and Barrier Inventory, 2007

Table 31. Sewage Treatment Plant facilities

Subwatershed	Wastewater Treatment Plants or Lagoons	Receiving Watershed within SCRCA	Plant Discharging outside SCRCA	Updates During Reporting Time Window	Receiving Watercourse
Sydenham Headwaters	Ilderton WWTP		Ilderton WWTP		Oxbow Creek, a tributary of Thames River
	Strathroy WWTP	Sydenham Headwaters			East Sydenham River
Upper Sydenham River					
Brown Creek	Kerwood Facility	Brown Creek			
Middle East Sydenham	Alvinston WWTP	Middle East Sydenham			East Sydenham River
	Newbury WWTP	Middle East Sydenham			Dolby Drain
Lower East Sydenham	Dresden WWTP	Lower East Sydenham			East Sydenham River
	Wallaceburg WWTP	Lower East Sydenham			East Sydenham River
Bear Creek Headwaters	Watford Lagoons	Bear Creek Headwaters		Upgrade – 2014	Moffatt Drain, a tributary of Bear Creek
	Petrolia WWTP	Lower Bear Creek			Bear Creek
Lower Bear Creek	Wyoming WWTP	Lower Bear Creek			Bear Creek
	Brigden Lagoons	Lower Bear Creek			One annual seasonal outfall to Bear Creek

Table 31. Sewage treatment plant facilities (continued)

Subwatershed	Wastewater Treatment Plants or Lagoons	Receiving Watershed within SCRCA	Plant Discharging outside SCRCA	Updates During Reporting Time Window	Receiving Watercourse
Black Creek	Oil City Lagoons	Black Creek			Seasonal outfall to Fox Creek Drain, a tributary of Black Creek
	Oil Springs Lagoons	Black Creek			Seasonal outfall to Black Creek
Lower North Sydenham					
Lambton Shores Tributaries					
Plympton Shoreline Tributaries	Plympton-Lakeshore WWTP		Plympton-Lakeshore WWTP		Lake Huron
	Forest Lagoons	Plympton Shores Tributaries			Hickory Creek
Cow and Perch Creeks	Brights Grove Lagoons	Cow and Perch Creeks			
St. Clair River Tributaries	Point Edward WWTP		Point Edward WWTP		St. Clair River
	Sarnia WWTP		Sarnia WWTP		St. Clair River
	Sombra Lagoons	St. Clair River Tributaries			Seasonal outfall spring and fall to Meyers Drain
	Courtright WWTP		Courtright WWTP		St. Clair River
	Port Lambton Lagoons	St. Clair River Tributaries			Marshy Creek Drain
Lake St. Clair Tributaries	Mitchell's Bay Lagoons	Lake St. Clair Tributaries			Rankin Creek Drain

WWTP = Wastewater Treatment Plant

Table 32. Significant natural areas within each subwatershed

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Sydenham Headwaters	Sydenham River Wetlands (SC 8)	Gold Creek Wetland	Coldstream Woodlot		Telfer Woodlot	
	Komoka/South Strathroy Creek Wetlands (SC 9)	Sinker Drain Wetland (SC 53)	Vanneck Woods		Ivan Woodlot	
	South Ilderton Heronry Wetlands and Woodlot (SC 12)	Hyde Park Wetland (SC 55)	Ivan Woods			
	Telfer Woods and Wetland	Harford Wetland (AB 9)	Caradoc North Woods			
	Duncrief Wetland	Telfer Woodlot (SC 11)				
		Lamont Drive Wetland				
Upper Sydenham River	Longwoods Woods and Wetland Complex (SC 6)	Melwood Wetland	Brooke Township Sydenham Woods		Kerwood Woods	
	Sydenham River Wetlands (SC 8)	Scotchmere Drive Wetlands				
	Kerwood Swamp	Napier Swamp (SC 16)				
	Komoka/South Strathroy Creek Wetlands (SC 9)					
Brown Creek	Walnut Heronry Woods	Hardy Creek Swamp (SC 14)	Walnut Hickory Woods		Brown Creek Woods	
	Brown Creek Woods and Wetland		Kerwood Bluff		Walnut Woods	

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Middle East Sydenham	Skunks Misery (LT22) (in part)	West Newbury Wetland (SC 1)	Sydenham River Corridor Carolinian Canada Site	Skunk's Misery	Oakdale Woods	
	Bobcat Swamp Wetland Complex (SC 2)	McPhail Woodland and Wetland	Shetland Heronry			
	McCready Woods and Wetland (SC 22)		Shetland Kentucky Coffee-tree Grove Carolinian Canada Site			
	Grape Fern Woods and Wetland		Knapdale Woods			
	Melbourne Marsh (SC 3)		Newbury Woods			
	Euphemia #3 (Cairo Wetland)		Cairo Woods			
			County Line Woods			
			Cottonwood Swamp			
			Fansher Creek Natural Area			
			Shield Woods			
			A. W. Campbell Conservation Area			
			Gawne Management Area			
			Sinclair Management Area			
			Euphemia Woodlot			
			Dawn-Euphemia Forest			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Lower East Sydenham	Lower East Sydenham			Deyo's or Dare's Woods		Thamesville Moor
				Langbank Woods		Oakdale Woods
				Huff's Corners Woods		
				Rutherford Woods		
Bear Creek Headwaters	Warwick Conservation Area Wetlands	Bear Creek Source Woods and Wetland	Little Bear Creek Natural Area		Brown Creek Woods	
		Bridgeview (Petrolia) Conservation Area Wetland (SC 37)	Highway 402 Woods		Bear Creek South of Wyoming	
		West Warwick Woods (SC 54)	Bear Creek Woodlot #1		Walnut Woods	

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Lower Bear Creek	Moore Wildlife Management Area (Bear Creek Woods #4) and Wetland	Bear Creek Woods #3 and Wetland	Waubuno Woods	Bear Creek Floodplain	Clay Creek Woodland	
	Burton Drain Woods #3 and Wetland	Brigden Crown Game Reserve Wetland	Nichol Creek Woods			
	Bickford Oak Woods Wetland Complex (SC 50)	Lambton Landfill Wetlands	Bear Creek Woodlot #5			
		Henderson Conservation Area (Bear Creek Woods #2) and Wetlands (SC 34)	Burton Drain Woods #2			
Black Creek	Walnut Heronry Woods	Plum Creek Woods and Wetland	Bickford Line Woods	Plum Creek	Black Creek	
		Black Creek Woods #1 (Fox Creek Woods) and Wetland	Plum Creek	Bear Creek Floodplain	Walnut Woods	
			Black Creek Natural Area #2			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Lower North Sydenham	Snye River Marshes (SC 17)		Wallaceburg Woods		Duthill Woodlot	
	Chicken Island Wetland (SC 19)		Rutherford Woods			
	Reid Conservation Area (Duthill Woods #2) and Wetlands	McKeough C.A. and Grant's Wetland	Terminus Woods			
	Bickford Oak Woods Wetland Complex (SC 50)		Combine Woods			
	Bray's Swamp (SC 27)		Wilkesport Woods			
			McKeough Conservation Area (Duthill Woods #1) and Floodway			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Lambton Shores Tributaries	South Kettle Point Lakeshore Marshes (SC 49)		Cedar Point	Former Ipperwash Provincial Park	Gustin Grove Marsh/ Shashawandah Creek	Former Ipperwash Provincial Park
	Ipperwash Inner Dunal Complex (SC 48)		Ipperwash Natural Areas	Kettle Point		Kettle Point
	Cedar Point, Dolmage & Rawlings Rd Wetland Complex (SC 56)		Shashawandah Creek/Lakeshore Marsh complex	Port Franks Wetlands and Forested Dunes		
			Jericho Creek/Mud Creek Woods			
			Port Franks Natural Areas			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Plympton Shoreline Tributaries	Cedar Point, Dolmage & Rawlings Rd Wetland Complex (SC 56)	Uttoxeter Swamp (SC 41)	Aberarder Creek Woods			
		Spicebush Swamp (SC 43)	Esli Dodge Conservation Area			
		Plympton/West Warwick Woods and Wetland (SC 54)	Uttoxeter Swamp			
		West Warwick Woods (SC 54)	McEwen Conservation Area			
			Highland Creek Conservation Area			
			Reeces Corners Gravel Pits			
			Camlachie Woods			
			Blue Point Woods			
			Egremont Road Woods			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Cow and Perch Creeks	Wawanosh Conservation Area Wetlands (SC 46)	Perch Creek (Sarnia Landfill) Wetland (SC 40)	402 Woods			
			Dennis Rupert Prairie			
			Brights Grove Lagoons			
			Reeces Corners Gravel Pits			
			Camlachie Woods			
			Jackson Drive Woods			
			Deptford Pink Woods			
			Saredeca Woods			
			Logans Pond			
			Mandaumin Nature Reserve			
			Blackwell Prairie/ Howard Watson Nature Trail			
			Suncor Natureway			
			Perch Creek Wildlife Management Area and Wetland			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
St. Clair River Tributaries	Stag Island Natural Area and Wetland (SC 52)	McKeough C.A. and Grant's Wetland	Aamjiwnaang First Nation	Walpole Island	Duthill Woodlot	
	Marshy Creek Marsh (SC 35)	Upper Clay Creek Wetland Complex (SC 52)	Sassafras Woods		Clay Creek Woodland	
	Bickford Oak Woods Wetland Complex (SC 50)	Bickford Oak Woods Wetland Complex (SC 50)	Sombra Sycamore Woods			
			Upland Plover Woods			
			Spice Bush Woods			
			Fertilizer Plant Woods			
			Bickford Oak Woods (Clay Creek Woods)			
			Indian Pipe Woods			
			Payne Woods			
			Hydro Plant Woods			
			Dow Wetlands			

Table 32. Significant natural areas within each subwatershed (continued)

Subwatershed	Provincially Significant Wetland	Locally Significant Wetland	Significant Natural Area/ Environmentally Significant Area*	Provincial Life Science ANSI	Regional Life Science ANSI	Provincial Earth Science ANSI
Lake St. Clair Tributaries	Chenal Ecarte Marshes (SC 18)		Walpole Island First Nation	Walpole Island	Chenal Ecarte Prairie	
	Deyo's Woodlot		Chenal Ecarte Prairie	Lake St. Clair Marshes		
	St. Clair Marsh Complex					
	Snye River Marshes (SC 17)					

ANSI = Area of Natural and Scientific Interest
Note: Wording varies by county

Table 33. Known and potential bird Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Acadian Flycatcher	END	END	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Bank Swallow	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Barn Swallow	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Black Tern	SC	NAR														X	1
Bobolink	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Cerulean Warbler	THR	END					X	X	X		X			X	X		6
Chimney Swift	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Eastern Meadowlark	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Eastern Whip-poor-will	THR	THR										X					1
Forster's Tern*	DD	DD										X					1
Hooded Warbler	NAR	NAR				X						X					2
King Rail	END	END	X	X												X	3
Least Bittern	THR	THR	X	X	X	X	X	X	X	X	X	X	X	X		X	13
Loggerhead Shrike	END	END											X				1
Northern Bobwhite	END	END							X					X			2
Peregrine Falcon	SC	NAR													X		1
Prothonotary Warbler	END	END		X	X	X	X	X	X	X	X		X	X	X	X	12
Red-headed Woodpecker	SC	THR				X											1
Yellow-breasted Chat	END	END	X		X	X	X	X	X	X	X	X	X	X	X		12
Total No. Species			**9**	**9**	**9**	**11**	**10**	**10**	**11**	**9**	**10**	**11**	**10**	**11**	**10**	**10**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

**Forster's Tern has an SRANK of S2B (SRANK = Provincial rank based on the Committee On the Status of Species At Risk in Ontario (COSSARO); S2B = Imperiled/Very Rare Breeding Population)*

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 34. Known and potential mammal Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
American Badger (Southwestern Ontario population)	END	END						X		X	X	X	X			X	6
Eastern Small-footed Myotis	END	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Little Brown Myotis	END	END	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Northern Myotis	END	END	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Total No. Species			**3**	**3**	**3**	**3**	**3**	**4**	**3**	**4**	**4**	**4**	**4**	**3**	**3**	**4**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 35. Known and potential reptile Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Blanding's Turtle	THR	END			X		X	X	X	X	X		X		X		8
Butler's Gartersnake	END	END					X	X		X	X		X	X	X		7
Eastern Foxsnake (Carolinian population)	END	END			X		X	X	X		X		X		X	X	8
Eastern Hog-nosed Snake	THR	THR	X				X			X	X						4
Eastern Milksnake	NAR	SC										X					1
Eastern Ribbonsnake	SC	SC										X					1
Gray Ratsnake (Carolinian population)	END	END				X											1
Northern Map Turtle	SC	SC			X											X	2
Queensnake	END	END	X		X			X				X	X				5
Snapping Turtle	SC	SC	X	X		X	X					X			X	X	7
Spiny Softshell	END	END	X	X	X	X	X	X	X	X	X	X		X		X	12
Total No. Species			**4**	**2**	**5**	**3**	**7**	**6**	**4**	**5**	**5**	**6**	**4**	**3**	**5**	**5**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 36. Known and potential fish Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Blackstripe Topminnow	SC	SC					X	X		X	X						4
Brindled Madtom	NAR	NAR				X	X	X								X	4
Channel Darter	THR	0							X	X	X			X	X	X	6
Eastern Sand Darter	END	THR				X	X	X		X	X						5
Ghost Shiner	NAR	NAR														X	1
Grass Pickerel	SC	SC													X	X	2
Lake Chubsucker	THR	END										X				X	2
Lake Sturgeon (Great Lakes - Upper St. Lawrence River population)	THR	THR													X	X	2
Northern Brook Lamprey	SC	SC													X		1
Northern Madtom	END	END														X	1
Pugnose Minnow	THR	THR									X					X	2
Pugnose Shiner	THR	THR										X				X	2
Silver Chub	THR	END														X	1
Silver Shiner	THR	THR	X														1
Spotted Sucker	SC	SC				X	X	X	X		X				X	X	7
Total No. Species			**1**	**1**	**0**	**4**	**4**	**7**	**5**	**6**	**6**	**3**	**1**	**3**	**6**	**11**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 37. Known and potential mussel Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Eastern Pondmussel	END	SC		X	X	X		X		X						X	6
Fawnsfoot	END	END				X	X			X	X						4
Kidneyshell	END	END		X			X	X		X	X					X	6
Mapleleaf Mussel	THR	SC				X	X		X	X	X	X		X			7
Northern Riffleshell	END	END		X	X	X		X		X	X						6
Rainbow Mussel	SC	SC				X											1
Rayed Bean	END	END		X	X	X	X	X		X	X					X	8
Round Hickorynut	END	END	X	X		X	X	X		X	X					X	8
Round Pigtoe	END	END		X	X	X	X	X		X	X	X	X			X	10
Salamander Mussel	END	END		X	X	X	X	X		X	X	X	X				9
Snuffbox	END	END		X	X	X	X	X		X	X	X					8
Threehorn Wartyback	THR	THR					X										1
Wavy-rayed Lampmussel	THR	SC		X	X	X	X	X		X	X			X		X	9
Total No. Species			**1**	**9**	**7**	**11**	**10**	**9**	**1**	**11**	**10**	**4**	**2**	**2**	**0**	**6**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 38. Known and potential insect Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Mottled Duskywing	END	END										X					1
Northern Barrens Tiger Beetle	END	END										X					1
Rusty-patched Bumble Bee	END	END										X		X			2
Total No. Species			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**1**	**0**	**0**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk;

SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 39. Known and potential plant Species at Risk occurrences by subwatershed

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
American Bluehearts	END	END										X					1
American Chestnut	END	END	X	X	X			X	X	X	X	X	X	X	X	X	12
Blue Ash	THR	THR	X		X	X	X	X	X	X	X		X	X	X		11
Broad Beech Fern	SC	SC										X					1
Butternut	END	END	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Climbing Prairie Rose	SC	SC									X				X	X	3
Common Hop-tree	SC	SC							X	X	X			X	X	X	6
Crooked-stem Aster	SC	SC	X														1
Dense Blazing-star	THR	THR					X			X		X			X	X	5
Drooping Trillium	END	END	X			X											2
Dwarf Hackberry	THR	THR										X					1
Eastern False Rue-anemone	THR	THR	X									X					2
Eastern Flowering Dogwood	END	END	X	X	X	X	X	X		X	X	X	X	X		X	12
Eastern Prairie Fringed Orchid	END	END					X									X	2
False Hop Sedge	END	END	X	X				X	X	X	X			X	X		8
Gattinger's False Foxglove	END	END														X	1
Green Dragon	SC	SC	X	X	X				X			X					5
Heart-leaved Plantain	END	END										X					1
Kentucky Coffee-tree	THR	THR		X	X			X	X	X	X			X	X	X	9

Table 39. Known and potential plant Species at Risk occurrences by subwatershed (continued)

Common Name	SARO	COSEWIC	Sydenham Headwaters	Upper Sydenham River	Brown Creek	Middle East Sydenham	Lower East Sydenham	Bear Creek Headwaters	Lower Bear Creek	Black Creek	Lower North Sydenham	Lambton Shores Tributaries	Plympton Shoreline Tributaries	Cow and Perch Creeks	St. Clair River Tributaries	Lake St. Clair Tributaries	No. Subwatersheds Occur
Large Whorled Pogonia	END	END		X		X											2
Pink Milkwort	END	END														X	1
Pitcher's Thistle	THR	SC										X					1
Purple Twayblade	THR	THR				X	X			X	X					X	5
Riddell's Goldenrod	SC	SC		X		X								X		X	4
Shumard Oak	SC	SC									X	X	X				3
Skinner's False Foxglove	END	END														X	1
Small White Lady's-slipper	END	THR					X										1
Spoon-leaved Moss	END	THR							X	X	X			X	X		5
Stiff-leaved Showy Goldenrod	END	END													X		1
Swamp Rose-mallow	SC	SC									X				X	X	3
White Prairie Gentian	END	END													X	X	2
Willow-leaved Aster	THR	THR	X	X				X	X	X						X	6
Wood-poppy	END	END	X														1
Total No. Species			**12**	**10**	**8**	**8**	**9**	**9**	**11**	**12**	**14**	**13**	**7**	**11**	**14**	**17**	

EXP = Extirpated; END = Endangered; DD = Data Deficient; NA = Not Assessed; NAR = Not At Risk; SC = Special Concern; THR = Threatened

SARO = Species At Risk of Ontario, designated by the Ontario Ministry of Natural Resources (OMNRF) in accordance with the provincial Endangered Species Act (ESA)

COSEWIC = Committee on the Status of Endangered Wildlife in Canada (independent group of experts)

Source: MNRF Natural Heritage Information Centre (NHIC) data; SCRCA records; 1995 to 2015 occurrences

Table 40. Fish species occurrences by subwatershed

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Alewife (NN)					X				X	X		X	X		5
American Brook Lamprey	X												X		2
Banded Killifish					X				X			X		X	4
Bigmouth Buffalo				X	X		X	X	X						5
Black Bullhead	X	X	X	X	X	X	X	X	X		X	X	X	X	13
Black Crappie	X	X		X	X	X	X	X	X	X			X	X	11
Blackchin Shiner	X				X								X	X	4
Blacknose Dace		X		X		X				X				X	5
Blacknose Shiner								X						X	2
Blackside Darter	X	X	X	X	X	X	X	X	X	X	X		X	X	13
Black Redhorse					X										1
Blackstripe Topminnow	X	X		X	X	X	X	X	X				X	X	10
Bluegill	X	X		X	X	X	X	X	X			X	X	X	11
Bluntnose Minnow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Bowfin	X				X				X				X	X	5
Brassy Minnow		X		X	X	X		X				X			6
Brindled Madtom		X		X	X	X								X	5
Brook Silverside	X			X	X		X	X		X			X	X	8
Brook Stickleback	X	X		X	X	X	X			X	X	X	X		10
Brown Trout	X												X		2
Brook Lamprey	X												X		2
Brown Bullhead	X		X	X	X	X	X	X				X	X	X	10
Burbot												X			1
Central Mudminnow	X	X		X	X	X	X	X	X	X	X	X	X	X	13

Table 40. Fish species occurrences by subwatershed (continued)

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Central Stoneroller	X								X	X			X	X	5
Channel Catfish	X			X	X		X	X	X				X	X	8
Channel Darter									X					X	2
Chinook Salmon	X											X	X		3
Coho Salmon														X	1
Common Carp (NN)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Common Shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Creek Chub	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Eastern Sand Darter		X		X	X				X						4
Emerald Shiner	X			X	X	X	X	X	X	X	X	X	X	X	12
Fantail Darter		X		X	X	X								X	5
Fathead Minnow	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Finescale Dace			X												1
Freshwater Drum	X			X	X		X	X	X				X	X	8
Ghost Shiner	X	X		X	X		X	X	X				X	X	9
Gizzard Shad	X	X		X	X	X	X	X	X	X	X	X	X	X	13
Golden Redhorse	X	X	X	X	X	X	X	X	X				X	X	11
Goldfish (NN)	X			X	X	X		X				X	X	X	8
Golden Shiner	X						X	X		X			X	X	6
Grass Carp												X	X		2
Grass Pickerel					X									X	2
Greater Redhorse					X	X							X		3
Green Sunfish	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Greenside Darter		X	X	X	X	X	X	X						X	8

Table 40. Fish species occurrences by subwatershed (continued)

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Hornyhead Chub	X			X	X	X							X	X	6
Hydrid Sunfish	X												X		2
Iowa Darter													X	X	2
Johnny Darter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Lake Chubsucker														X	1
Lake Herring	X												X		2
Lake Sturgeon															0
Lake Whitefish												X			1
Largemouth Bass	X	X		X	X	X	X	X	X	X			X	X	11
Least Darter		X	X	X	X	X				X	X	X		X	9
Logperch	X	X	X	X	X	X	X	X	X	X	X		X	X	13
Longear Sunfish		X	X	X	X	X	X	X						X	8
Longnose Gar	X			X	X	X	X	X	X	X			X	X	10
Longnose Dace											X				1
Longnose Sucker						X									1
Mimic Shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Mudpuppy						X									1
Mottled Sculpin	X	X			X								X	X	5
Mooneye	X			X	X				X				X		5
Muskellunge					X						X	X			3
Northern Hog Sucker		X		X	X	X			X				X		6
Northern Madtom				X	X										2
Northern Pike	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Northern Sunfish		X	X	X	X	X		X	X					X	8

Table 40. Fish species occurrences by subwatershed (continued)

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Northern Redbelly Dace	X	X		X	X	X				X	X	X	X	X	10
Northern Pearl Dace		X				X				X					3
Ninespine Stickleback	X												X		2
Pugnose Minnow					X		X		X					X	4
Pugnose Shiner	X												X	X	3
Pumpkinseed	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Quillback		X		X	X		X	X	X		X			X	8
Rainbow Darter	X			X	X	X				X	X	X	X	X	9
Rainbow Smelt	X									X		X	X	X	5
Rainbow Trout (NN)	X	X		X						X	X	X	X		7
Redfin Shiner	X	X	X	X	X	X	X	X	X		X	X	X	X	13
River Chub		X		X	X										3
River Redhorse		X													1
River Darter					X		X		X						3
Rock Bass	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Rosyface Shiner	X	X		X	X	X							X		6
Round Goby (NN)	X				X				X	X	X	X	X	X	8
Sand Shiner	X			X		X			X		X		X	X	7
Sea Lamprey															0
Shorthead Redhorse	X	X		X	X	X	X	X	X				X	X	10
Silver Bass															0
Silver Lamprey	X												X		2
Silver Redhorse		X		X	X	X	X	X						X	7
Smallmouth Bass	X			X	X	X			X	X	X	X	X	X	10

Table 40. Fish species occurrences by subwatershed (continued)

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Spotfin Shiner	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Spottail Shiner	X	X		X	X	X	X	X	X	X	X	X	X	X	13
Spotted Gar					X										1
Spotted Sucker				X	X	X	X	X	X				X	X	8
Stonecat	X	X	X	X	X	X	X	X	X				X	X	11
Striped Shiner	X	X		X	X			X				X	X	X	8
Tadpole Madtom	X			X	X	X	X	X	X				X	X	9
Threespine Stickleback	X												X	X	3
Trout-Perch	X	X		X	X		X		X	X			X	X	9
Tubenose Goby (NN)	X								X				X	X	4
Walleye	X			X	X		X		X				X	X	7
White Bass				X	X			X	X			X			5
White Crappie	X	X	X		X	X	X	X	X			X	X	X	11
White Perch	X			X	X	X	X		X				X	X	8
White Sucker	X	X	X	X	X	X	X	X	X	X	X	X	X	X	14
Yellow Bullhead	X		X	X	X	X	X	X	X				X	X	10
Yellow Perch	X	X		X	X	X	X	X	X			X	X	X	11
Total No. Species	**70**	**52**	**27**	**68**	**79**	**58**	**51**	**51**	**58**	**37**	**32**	**42**	**76**	**76**	

NN = Non-native species

Notes: There are a total of 110 fish species present in the St. Clair Region – 104 of which are native and 6 of which are non-native (NN: Alewife, Common Carp, Goldfish, Rainbow Trout, Round Goby, Tubenose Goby).

Based on sampling records from: SCRCA; Mark Poos, Department of Fisheries and Oceans; Ministry of Natural Resources and Forestry; Royal Ontario Museum.

Table 41. Mussel species occurrences by subwatershed

COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK*	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Black Sandshell		X		X	X										3
Creek Heelsplitter						X									1
Creeper		X				X				X					3
Cylindrical Papershell										X	X				2
Deertoe		X		X	X	X	X	X	X						7
Eastern Pondmussel														X	1
Eastern Floater													X		1
Elktoe		X		X	X		X								4
Fatmucket		X		X		X	X	X	X					X	7
Fawnsfoot					X		X								2
Flutedshell		X		X	X		X	X							5
Fragile Papershell		X		X	X	X	X	X	X				X		8
Giant Floater	X	X		X	X	X	X	X	X	X	X	X	X		12
Kidneyshell		X		X											2
Lilliput								X	X						2
Mapleleaf		X		X	X	X	X	X				X	X		8
Mucket		X		X	X	X									4
Northern Riffleshell				X	X										2
Paper Pondshell							X		X			X	X		4
Pimpleback				X	X										2
Pink Heelsplitter					X	X		X				X	X		5
Plain Pocketbook		X		X		X									3
Purple Wartyback		X		X	X										3
Rainbow Mussel						X								X	2

Table 41. Mussel species occurrences by subwatershed (continued)

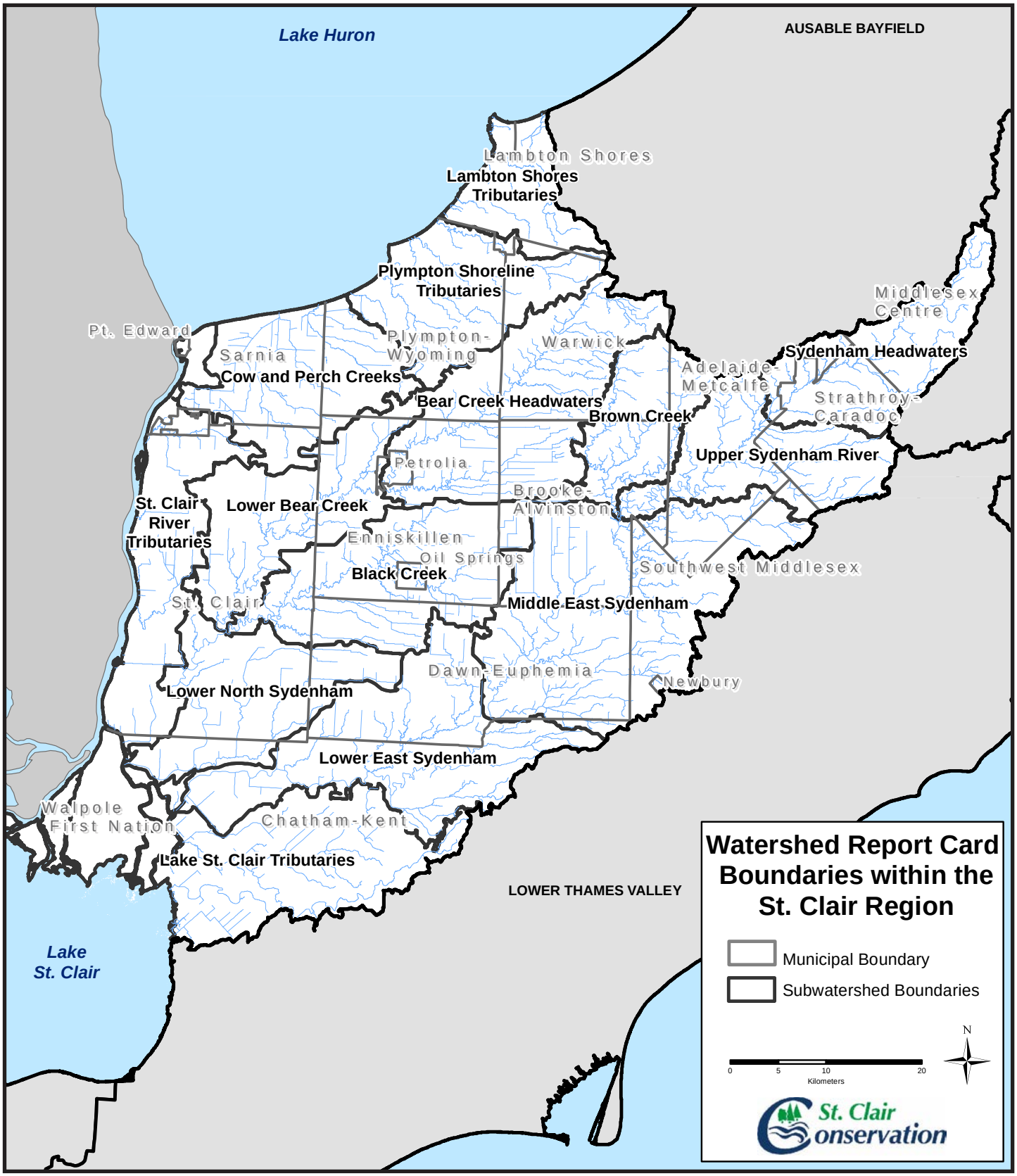
COMMON NAME	SYDENHAM HEADWATERS	UPPER SYDENHAM RIVER	BROWN CREEK*	MIDDLE EAST SYDENHAM	LOWER EAST SYDENHAM	BEAR CREEK HEADWATERS	LOWER BEAR CREEK	BLACK CREEK	LOWER NORTH SYDENHAM	LAMBTON SHORES TRIBUTARIES	PLYMPTON SHORELINE TRIBUTARIES	COW AND PERCH CREEKS	ST. CLAIR RIVER TRIBUTARIES	LAKE ST. CLAIR TRIBUTARIES	NO. SUBWATERSHEDS OCCUR
Rayed Bean				X	X										2
Round Hickorynut		X			X										2
Round Pigtoe		X		X		X	X								4
Salamander/ Mudpuppy Mussel				X	X	X									3
Snuffbox				X	X										2
Spike		X		X		X	X		X						5
Threehorn Wartyback															0
Threeridge		X		X	X	X	X	X						X	7
Wabash Pigtoe		X		X		X								X	4
White Heelsplitter	X	X		X	X	X	X	X			X	X			9
Total No. Species	**2**	**19**	*****	**22**	**19**	**17**	**13**	**10**	**7**	**3**	**3**	**5**	**6**	**5**	

**Lack of mussel records due to lack of sampling effort.*

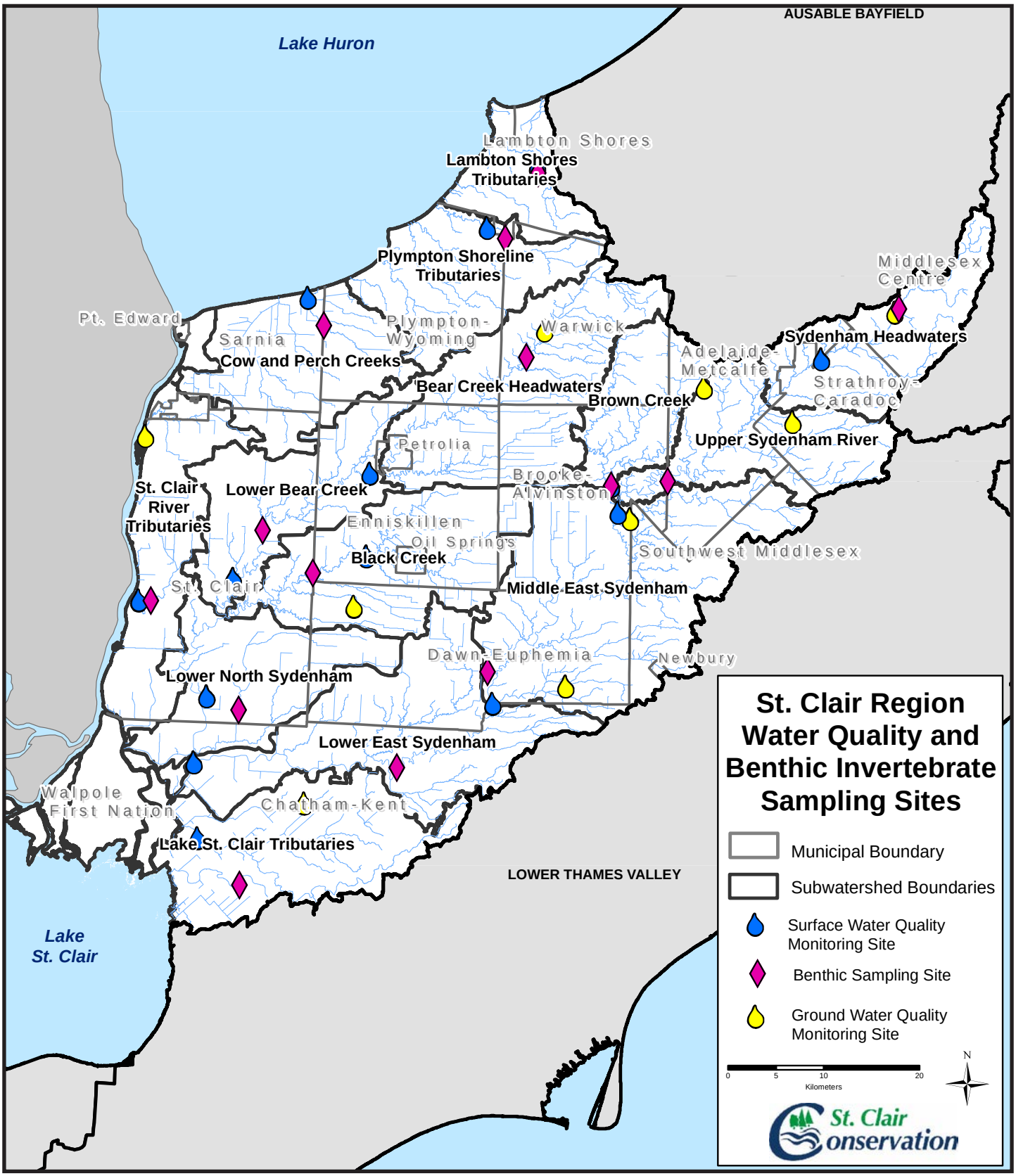
Note: Total of 33 native species recorded live in subwatersheds

Based on sampling records from: SCRCA; Department of Fisheries and Oceans; Royal Ontario Museum; Ecosearch Inc.

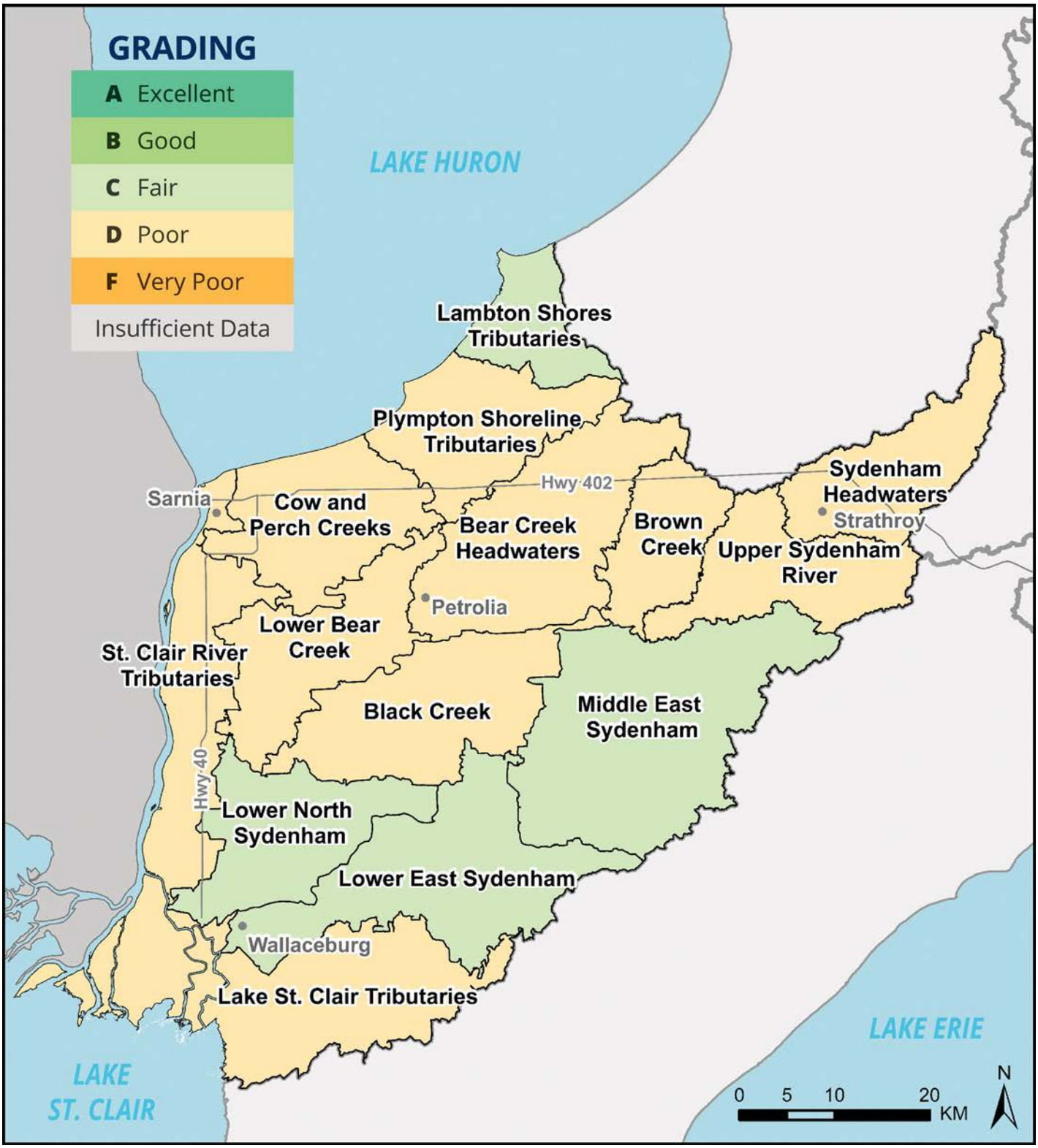
Map 1. Boundaries of the 14 subwatersheds within the St. Clair Region



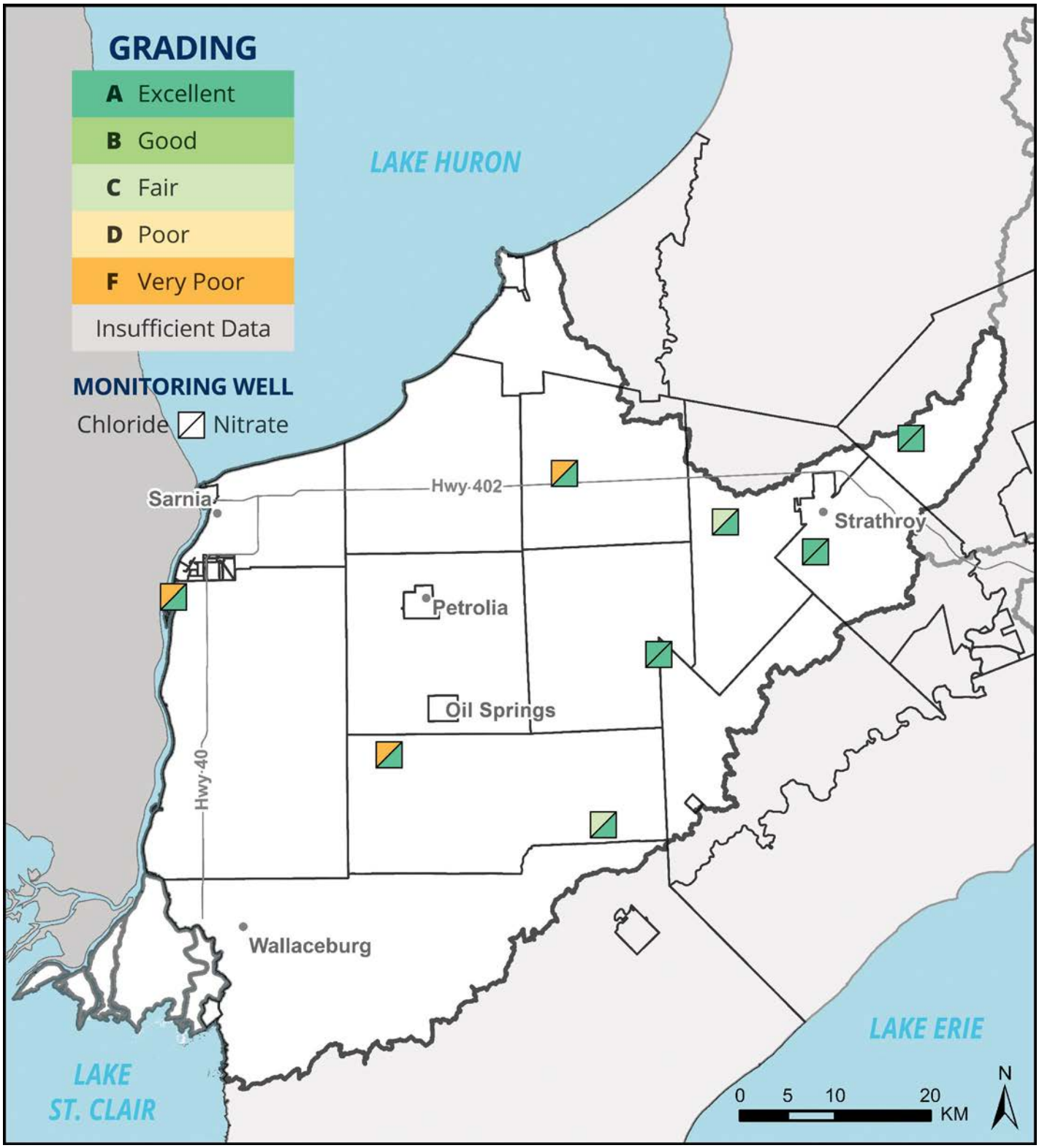
Map 2. Locations of water quality and benthic sampling sites in the St. Clair Region



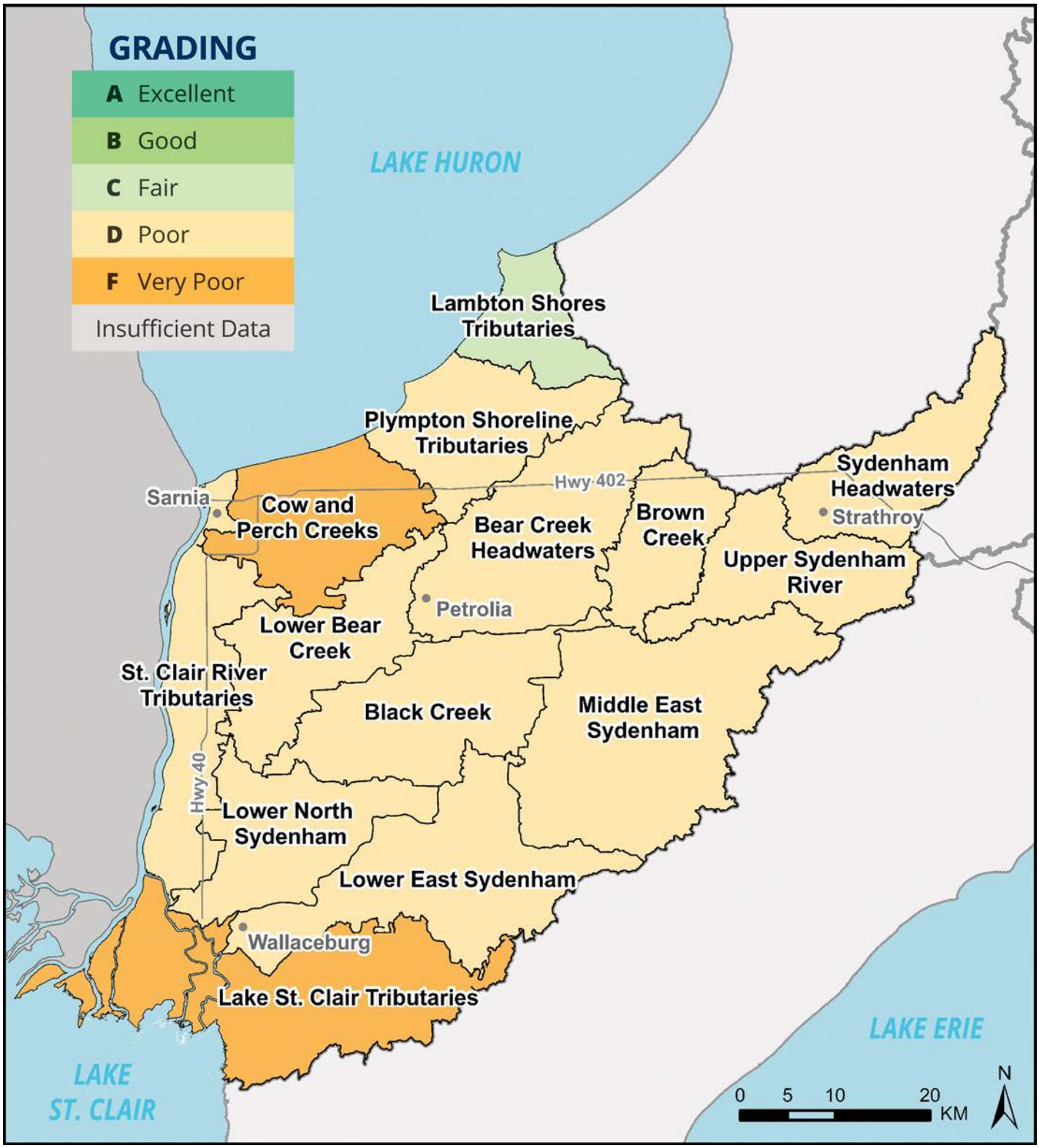
Map 3. Overall surface water quality grades by subwatershed



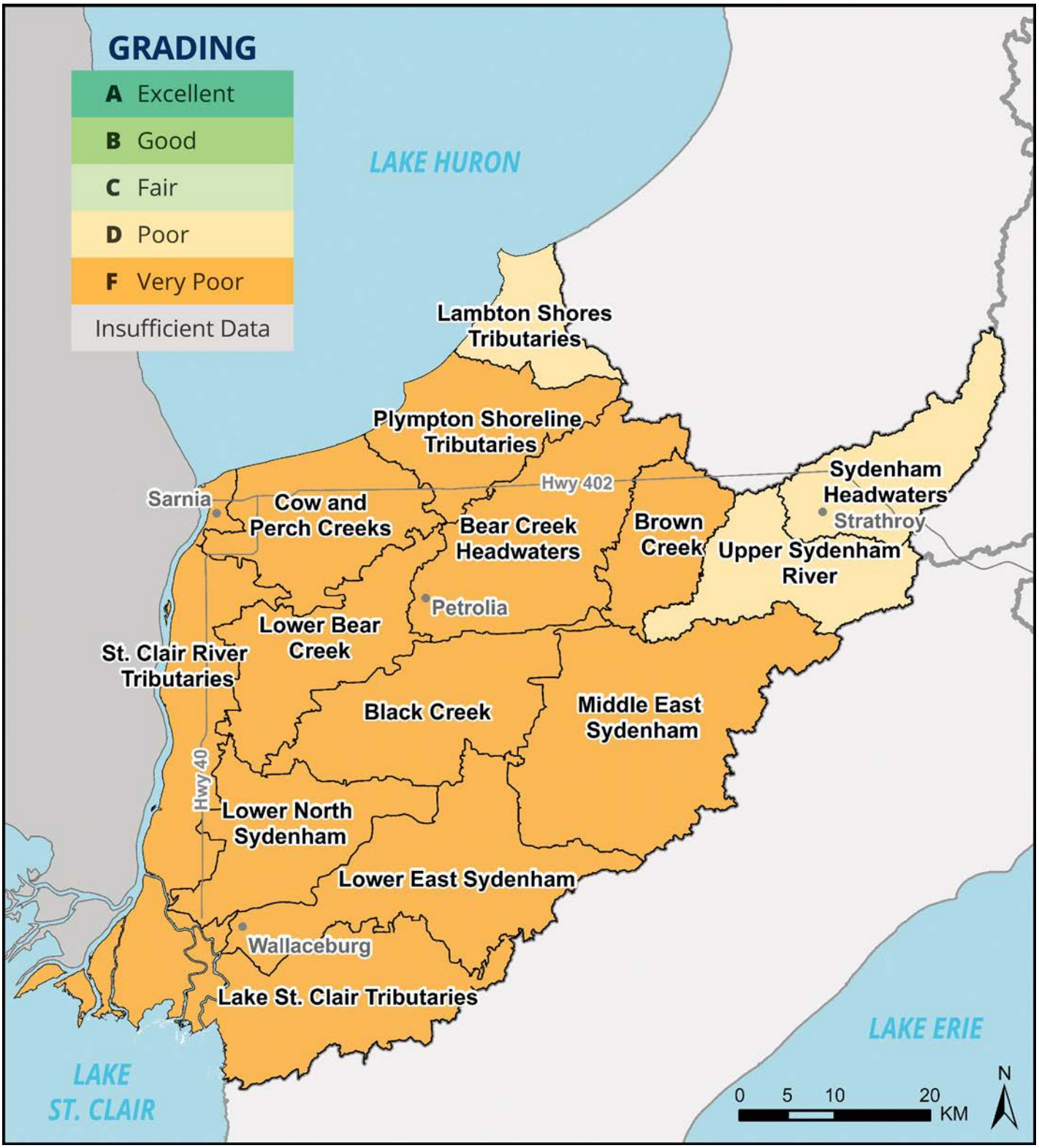
Map 4. Groundwater quality monitoring well sites and grades



Map 5. Overall forest condition grades by subwatershed



Map 6. Wetland cover grades by subwatershed



**Wetland cover calculations do not include First Nations land*

Section 3: Summary Report Cards

A. St. Clair Region Summary Watershed Report Card

B. Subwatershed Report Cards

1. Sydenham Headwaters
2. Upper Sydenham River
3. Brown Creek
4. Middle East Sydenham
5. Lower East Sydenham
6. Bear Creek Headwaters
7. Lower Bear Creek
8. Black Creek
9. Lower North Sydenham
10. Lambton Shores Tributaries
11. Plympton Shoreline Tributaries
12. Cow and Perch Creeks
13. St. Clair River Tributaries
14. Lake St. Clair Tributaries

APPENDIX C: MOOSE Plan, May 25 2021

MICHIGAN-ONTARIO OZONE SOURCE EXPERIMENT (MOOSE)

Science Plan

May 25, 2021

EXECUTIVE SUMMARY

Southeast Michigan (SEMI) is currently designated as in Marginal Nonattainment of the U.S. federal ozone standard and is likely to be bumped up to Moderate Nonattainment based on monitoring data for the years 2018, 2019, and 2020. Many locations in southern Ontario also frequently exceed the Canadian ambient air quality standard for ozone. The Michigan Department of Environment, Great Lakes, and Energy (EGLE) seeks an attainment strategy for the SEMI ozone nonattainment area that remains open to all viable options as appropriate, including a U.S. Clean Air Act (CAA) Section179B(b) international transport petition and demonstration, an exceptional event demonstration, or an ozone attainment plan and attainment demonstration. There is also interest from the Ontario Ministry of Environment, Conservation and Parks (MECP), Environment and Climate Change Canada (ECCC), and the U.S. Environmental Protection Agency (EPA) to better understand what contributes to elevated ozone levels in the Border region. To ensure a viable ozone attainment strategy, both in the short and long term, regulatory and scientific agencies, including EGLE, MECP, the U.S. EPA, ECCC, and other partners, have decided to conduct field studies in 2021 and 2022 to be known as the Michigan-Ontario Ozone Source Experiment (MOOSE).

MOOSE will consist of three sub-experiments with the following objectives:

Great Lakes Meteorology and Ozone Recirculation (GLAMOR)

- To understand and simulate complex 3D flows associated with lake breeze circulations;
- To understand and simulate the urban heat island (UHI) and its interaction with the lake breeze;
- To understand and simulate the impact of lake breezes and the UHI on ozone and ozone precursor transport;
- To understand and track the influence of urban emissions and land-lake breezes on urban oxidative capacity through nitrous acid (HONO) and related reactive nitrogen species.
- To determine the conceptual picture (mesoscale meteorological patterns and photochemical production locations) for ozone exceedances in the Border region;
- To select representative ozone episodes for each identified mesoscale pattern, which can then be used as model base case periods for future ozone attainment demonstrations; and
- To conduct modeling and data analyses in support of an ozone attainment demonstration or, if warranted, a CAA 179B(b) petition or ozone exceptional event demonstration.

Chemical Source Signatures (CHESS)

- To characterize the ozone precursor signatures at key monitoring stations in the Border region where design values are highest during ozone exceedances in a normal year;
- To characterize emission plumes from point sources, area sources, and major industrial sectors in the Border region and their impacts on ozone design values on both sides of the U.S.-Canada border;
- To develop emission source fingerprints for the most important industrial facilities and source sectors in the Border region;
- To characterize the horizontal variations (including upwind, interior, and downwind concentrations) of NOx and VOC in SEMI;
- To perform receptor modeling, source apportionment, and ozone culpability analyses to improve emission inventories and inform potential control strategies; and
- To perform air quality model simulations of potential emission control strategies.

Methane Releases from Landfills and Gas Lines (MERLIN)

- To determine the natural gas leakage rate of pipeline or other infrastructure in SEMI;
- To quantify methane, formaldehyde, and other emissions from landfills in the Border region; and
- To determine the contributions of large methane sources to ozone exceedances in the Border region, thereby informing potential control strategies.

1. BACKGROUND

1.1 Air Quality Issues in Michigan, USA

1.1.1 Southeast Michigan Ozone Attainment Status

The U.S. National Ambient Air Quality Standard (NAAQS) for ozone is set at 70 parts per billion (ppb) by volume averaged over 8 hours. Attainment of the ozone NAAQS is based on a design value computed for each monitoring station in a regulatory monitoring network. The design value is defined as the three-year average of the yearly fourth highest daily maximum 8-hour average ozone concentration measured at a monitoring site. A design value exceeding 70 ppb at any monitoring site in a metropolitan area normally results in that area's being designated by the U.S. Environmental Protection Agency (EPA) as an ozone nonattainment area. The Southeast Michigan (SEMI) ozone nonattainment area consists of the seven counties of St. Clair, Macomb, Oakland, Livingston, Wayne, Washtenaw, and Monroe.

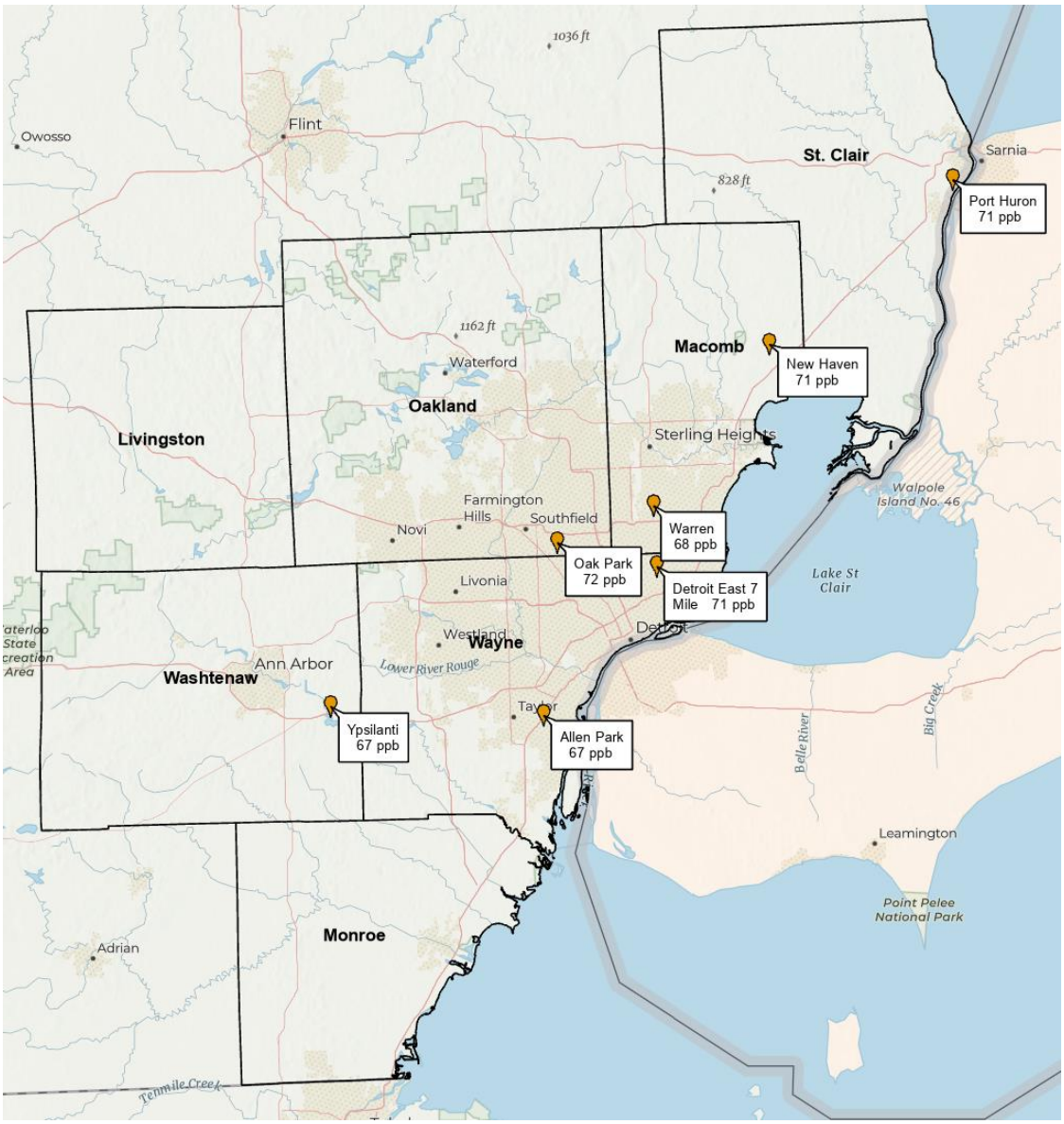


Figure 1. Monitoring sites and 2018-2020 ozone design values in SEMI nonattainment counties.

SEMI is currently designated as a Marginal Nonattainment area, the lowest nonattainment category, based on design values computed for the years 2015, 2016, and 2017. The next highest nonattainment category is Moderate Nonattainment, which imposes stricter requirements, including mandatory vehicle inspection and maintenance, higher industrial emission offsets (1.15-to-1), imposition of Reasonably Available Control Technology (RACT), and 15% Reasonable Further Progress (RFP) reductions in precursor emissions. A nonattainment area that fails to attain the ozone standard by the relevant deadline is normally "bumped up" to the next nonattainment category.

The attainment deadline for the SEMI region is August 3, 2021 based on design values computed for the years 2018, 2019, and 2020. Monitored ozone values for these three years (see Figure 1) indicate that SEMI will be bumped up to Moderate Nonattainment status, most likely around February 2022. This would require the State of Michigan to submit a State Implementation Plan (SIP) to the EPA that includes an ozone attainment plan and attainment demonstration, in which a computer model simulates the impact of control strategies intended to bring design values below 70 ppb.

1.1.2 Options for a Section 179B(b) Petition and Exceptional Event Demonstration

The SEMI non-attainment area is immediately across the Detroit River, Lake St. Clair, and the St. Clair River from two industrialized cities in Canada, namely Windsor and Sarnia. Ozone exceedances in SEMI normally occur with southwesterly winds, based on trajectory analyses performed by technical staff of the Lake Michigan Air Directors Consortium (LADCO). However, these same analyses indicate that SEMI ozone exceedances can sometimes occur during periods of easterly wind, when Canadian sources are likely to contribute to SEMI ozone design values. Regulatory relief from several of the nonattainment provisions of the U.S. Clean Air Act (CAA) may be obtained by filing a CAA Section 179B(b) petition that demonstrates attainment of the NAAQS "but for emissions emanating from outside the United States." While this does not demonstrate actual attainment, it would allow SEMI to avoid the consequences of a pending or future bump-up if the petition is approved by the EPA.

In addition to International Transport petitions under CAA 179B(b), flagging monitoring data that have been impacted by exceptional events is also an option. A successful exceptional event demonstration can sufficiently lower ozone design values, and on that basis demonstrate attainment. An example of an exceptional event is a wildfire. For a wildfire exceptional event demonstration to be successful, the plume must be shown to impact the state on policy-relevant, high ozone days. The Department of Environment, Great Lakes, and Energy (EGLE) is currently pursuing wildfire exceptional event demonstrations for Michigan's western nonattainment areas bordering Lake Michigan based on data from 2018-2020. After an initial analysis of relevant data, EGLE has not decided to pursue such a demonstration for the SEMI region for the same three-year period, while remaining open to the possibility in future years.

1.2 Air Quality Issues in Ontario, Canada

Air quality impacts all Canadians and affects many aspects of society, including human health, the natural environment, buildings and infrastructure, crop production, and the economy. Federal, provincial, and territorial governments in Canada share responsibility for air quality management. Under the Canadian Council of Ministers of the Environment (CCME), federal, provincial, and territorial governments work collaboratively to improve air quality by implementing the Air Quality Management System (AQMS)[1].

Ambient air quality in Canada is assessed in part by comparing measurements to the Canadian Ambient Air Quality Standards (CAAQS), which are health- and environmental-based air quality objectives to further protect human health and the environment and to provide the drivers for air quality improvement across the country. Currently, more than 25% of Canadians live in areas that exceed at least one of the 2020 CAAQS.

[1] Although Québec supports the general objectives of AQMS, it will not implement the System since it includes federal industrial emission requirements that duplicate Québec's Regulation. However, Québec is collaborating with jurisdictions on developing other elements of the system, notably air zones and airsheds.

Overall, air quality in Ontario has improved over time as both ambient concentrations of common air pollutants and emissions to air have decreased over the last 10 years. Ozone and fine particulate matter, the main components of smog, remain as pollutants of concern. Some areas of Ontario continue to experience elevated levels of some pollutants due to local sources (e.g., industry, transportation), increasing background levels, and transboundary air pollution. Many locations in southern Ontario continue to exceed the ozone CAAQS. As more stringent ozone CAAQS come into force in 2020 (62 ppb) and 2025 (60 ppb), it may become even more difficult to achieve the standards. (Note that that the statistical form of the CAAQS for ozone is identical to that of the U.S. ozone NAAQS.)

Smog-related air pollutants are generated both locally and regionally, and, with winds, can travel hundreds of kilometers, affecting areas far from the source of pollution. Long-range transport and transboundary flow of air pollutants play a significant role in Ontario's air quality. Typically, during the summer, elevated levels of these pollutants are associated with distinct weather patterns (e.g., slow-moving high-pressure systems originating from south of the lower Great Lakes) that result in the long-range transport of these pollutants into Ontario from neighboring U.S. industrial and urbanized states during south to southwesterly flow conditions. Transboundary sources from around the globe (global background) are also significant contributors to Ontario's ozone levels.

Ontario's framework for managing local and regional air quality issues has been developing for over 40 years. The framework has evolved from regulating industrial emissions from individual stacks, to protecting local air quality, and ultimately to addressing pollutants that have a regional impact, such as smog and acid rain. More recently, the Ontario Ministry of Environment, Conservation and Parks (MECP) has been looking at how to manage air issues that result from multiple sources of air pollution in a specific area, as well as how to deal with emissions that come from sources outside Ontario's boundaries.

Under AQMS the federal government has the responsibility to lead the actions and negotiations to address the transboundary flow of air pollutants originating from other countries with the involvement of affected provinces and territories. Canada has also been working closely with the United States under international agreements such as the Canada-U.S. Air Quality Agreement for many years. This collaborative project with Michigan, Ontario, the U.S. EPA, and other partners will further collective efforts to improve understanding of air quality in our common cross-border airshed.

1.3 The Need for New Observational Data

To control air pollution and avoid transboundary impacts in both Ontario and Michigan, an ozone strategy based on rigorous science is needed to support technical analyses and to pursue any of the available regulatory options. Although the regulatory systems in Canada and the U.S. are different, new observational data for the Border region, as a whole, will contribute to informing the responsible agencies as to which pollutants, sources, and sectors have the most important influence on air quality, and allow them to develop the most appropriate risk management actions. There are several scientific and technical issues that make this difficult to accomplish without additional research-grade measurement data.

1.3.1 Influence of the Lake Breeze and Urban Heat Island

Proximity to the Great Lakes poses difficulties in understanding how pollution is transported from land areas around the Great Lakes to the Border region. A fundamental need is to account for complex lake breeze effects. The previous 2017 Lake Michigan Ozone Study (LMOS) examined this issue in the context of the western Great Lakes region. A major conclusion of the LMOS was that very high resolution is required in a meteorological model (i.e., ~1 km horizontal grid cells) to be able to properly simulate lake breeze fronts and their effects on the transport of ozone and its precursors across Lake Michigan (LADCO, 2019). Likewise, the older 2007 Canadian Border Air Quality-Meteorology Study (BAQS-MET) demonstrated the importance of correctly simulating complex 3D air flows in modeling ozone over the eastern Great Lakes, as surrounding land areas may contribute up to ~30 ppb to regional background ozone (Makar et al., 2010; see Figures 2-4). The most recently available ozone model for SEMI only has 4 km horizontal resolution and is thus incapable of properly simulating lake breeze transport.

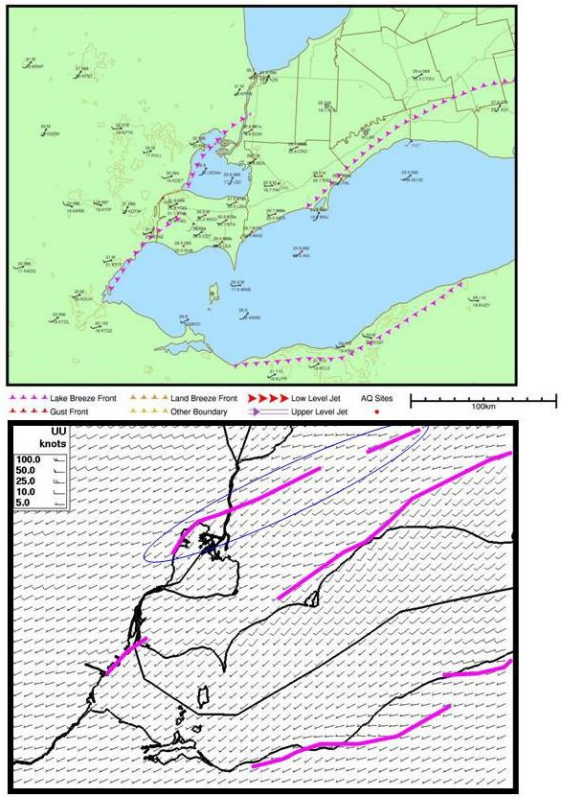


Figure 2. July 8, 2007, 1:00 p.m. local time. **(a)** meso-analysis lake-breeze front locations; **(b)** lake-breeze front locations inferred from convergence pattern of 2.5-km resolution model winds. (After Makar et al., 2010)

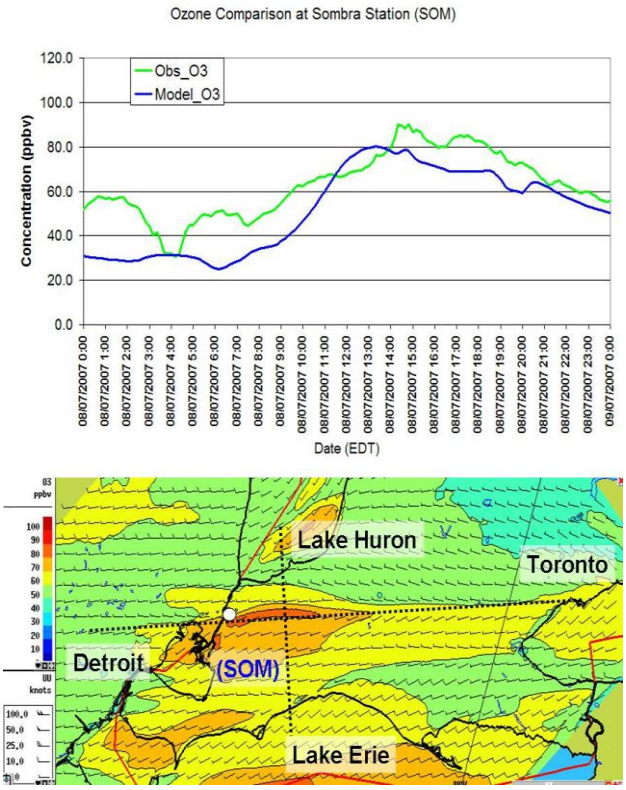


Figure 3. (a) Model-predicted ozone versus observations, July 8, 2007, Sombra (SOM) station. **(b)** Model-predicted ozone and winds at surface, 1:00 p.m. local time. (After Makar et al., 2010)

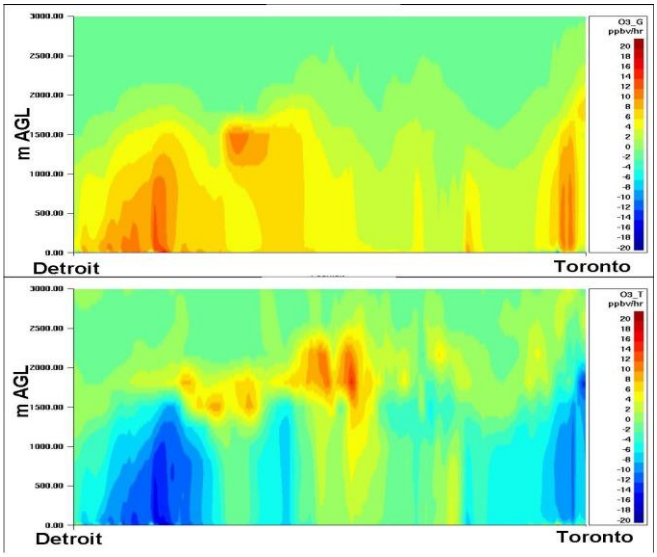


Figure 4. Model-predicted ozone mass tracking fields for July 8, 2007, 1:00 p.m. local time, Detroit to Toronto cross-section. **(a)** Gas-phase photochemical production, and loss; **(b)** total transport rate of change. (After Makar et al., 2010)

Another complicating factor in simulating ozone exceedances is the Urban Heat Island (UHI). The UHI influences meteorological parameters of importance to ozone photochemistry and transport, including surface air temperature, boundary layer height, and vertical mixing efficiency. In addition, the UHI can interact with the lake breeze, possibly intensifying some of its features due to increased updrafts associated with warmer surface temperatures.

The UHI was a prominent feature studied during the BAQS-MET campaign (Brook et al, 2013), and the 2015 Pan American Games in Toronto (Stroud et al., 2020), which have resulted in much higher resolution treatments of this phenomenon in Canadian meteorological and air quality models. These models now have horizontal resolutions as fine as 1 km. Stroud et al. (2020) discovered that a transition regime in ozone formation chemistry occurs in the updraft region of lake-breeze fronts. A chemical analysis along the trajectory of the lake-breeze circulation showed that in Toronto the most efficient ozone production occurs in the updraft region of the lake breeze front where the NOx emissions are diluted.

A key need for ozone modeling in the Border region is more detailed meteorological measurements and higher resolution wind models to characterize 3D flow associated with lake breezes, and to account for the most important UHI influences on local and regional atmospheric chemistry and transport.

1.3.2 Chemical Fingerprints of Emission Sources

Recent weekday-weekend analyses funded by the Southeast Michigan Council of Governments (SEMCOG) indicate that the SEMI region is neither clearly VOC-limited nor NOx-limited, but somewhere in between. A Photochemical Assessment Monitoring Station (PAMS), including an automated gas chromatograph (auto-GC) with flame ionization detection (FID) that measures speciated, hourly ambient concentrations of VOCs, has only recently been established at the East 7 Mile site in Detroit. As of this writing, it has yet to provide data to determine what emission sources to control to bring the SEMI region into ozone attainment. Chemical fingerprints identifying the dominant sources that contribute to ozone exceedances in the Border region would be very helpful in designing effective ozone control strategies.

Because of cleaner cars and other successful controls, urban VOC emissions have changed in recent years to favor oxygenated VOCs and other species associated with commercial and industrial Volatile Chemical Products (VCPs). VCPs may now make up more than half the mass and reactivity of urban VOC emissions (McDonald et al., 2018). While official VOC inventories are in the process of being adjusted in acknowledgement of this development (Seltzer et al., 2021), there is an ongoing need for new information and field measurements to constrain VOC emissions used as inputs to air quality models.

Among the most important oxygenated VOCs outside of VCPs is primary formaldehyde produced by incomplete combustion, as opposed to secondary formaldehyde produced by VOC reactions in air. Formaldehyde differs from most VOCs because it is can efficiently generate an initial pool of atmospheric radicals that fuel ozone production. Unfortunately, formaldehyde emission inventories are unreliable, and measurements are needed to correct these inventories and avoid a deficit of ozone production in air quality models (see Figure 3a), including those used in attainment demonstrations (Olaguer et al., 2014).

Successful apportionment of emission sources may depend on clearly understanding concentration gradients of ozone precursors. An integrated strategy to characterize spatial gradients of NOx and VOC has been successfully employed in other field studies, notably the 2017 Lake Michigan Ozone Study in the Chicago-Zion-Sheboygan area, and the 2018 Long Island Sound Ozone Study (LISTOS). These studies included airborne mapping measurements, such as from the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) instrument (Nowlan et al., 2016), in-situ vertical profiles of NO_2 and O_3, and ground-based column measurements of NO_2 and HCHO from Pandora spectrometers. GeoTASO and a sister instrument called the GEO-CAPE Airborne Simulator (GCAS) were developed as test beds for geostationary satellite instruments like NASA's Tropospheric Emissions: Monitoring of Pollution, TEMPO, instrument (Zoogman et al., 2017). GCAS/GeoTASO and Pandora were developed as validation instruments for OMI and TROPOMI measurements (Herman et al., 2009; Judd et al., 2020), and have been shown to provide valuable high time and spatial resolution measurements of NO_2 and HCHO columns. As in previous campaigns, remote sensing measurements can provide unique

perspectives on above-ground pollutant concentrations, regional transport, and diurnal variation, as well as the ability to learn how future measurements from TEMPO can aid in air quality analysis in the region.

Results of the MOOSE study will provide regional air planners with a better and more current understanding of ozone formation sensitivity to VOC and NOx emissions in the Border region. Comparison to other urban areas where land/water interactions play a role in pollution transformation and transport (e.g., Lake Michigan, Chesapeake Bay, Long Island Sound) may help identify common or unique features among these regions that could be important in analyzing future satellite measurements. The nitrogen dioxide and formaldehyde measurements and high-resolution meteorological and chemical modeling will provide valuable information for developing more refined retrieval algorithms for TEMPO and companion missions. The Border region provides a robust test case for satellite observations due to its complex emissions profile (temporally and spatially) and the higher land/sea spatial resolution challenge within the relatively narrow and complex land/lake interface.

1.3.3 The Role of Methane Emissions

Methane is the second most important anthropogenic greenhouse gas after carbon dioxide, but it is also a global tropospheric ozone precursor. Because of its long atmospheric lifetime (~9 years), it has been thought of as too unreactive to be a significant local ozone precursor. However, methane emissions from natural gas distribution and end use may be 2-3 times larger than predicted by existing inventory methodologies and industry reports (McKain et al., 2015). Moreover, urban areas with corrosion-prone distribution lines may leak twenty-five times more methane than cities with more modern pipeline materials (von Fischer et al., 2017). Phillips et al. (2013) identified 3356 methane leaks in Boston with concentrations exceeding up to 15 times the global background level (1.8 ppm). Internal modeling experiments by the EPA Office of Research and Development showed that elevated methane levels in urban areas may increase local ozone levels by a few parts per billion (Dr. Rohit Mathur, personal communication), which is the typical width of ozone control strategies.

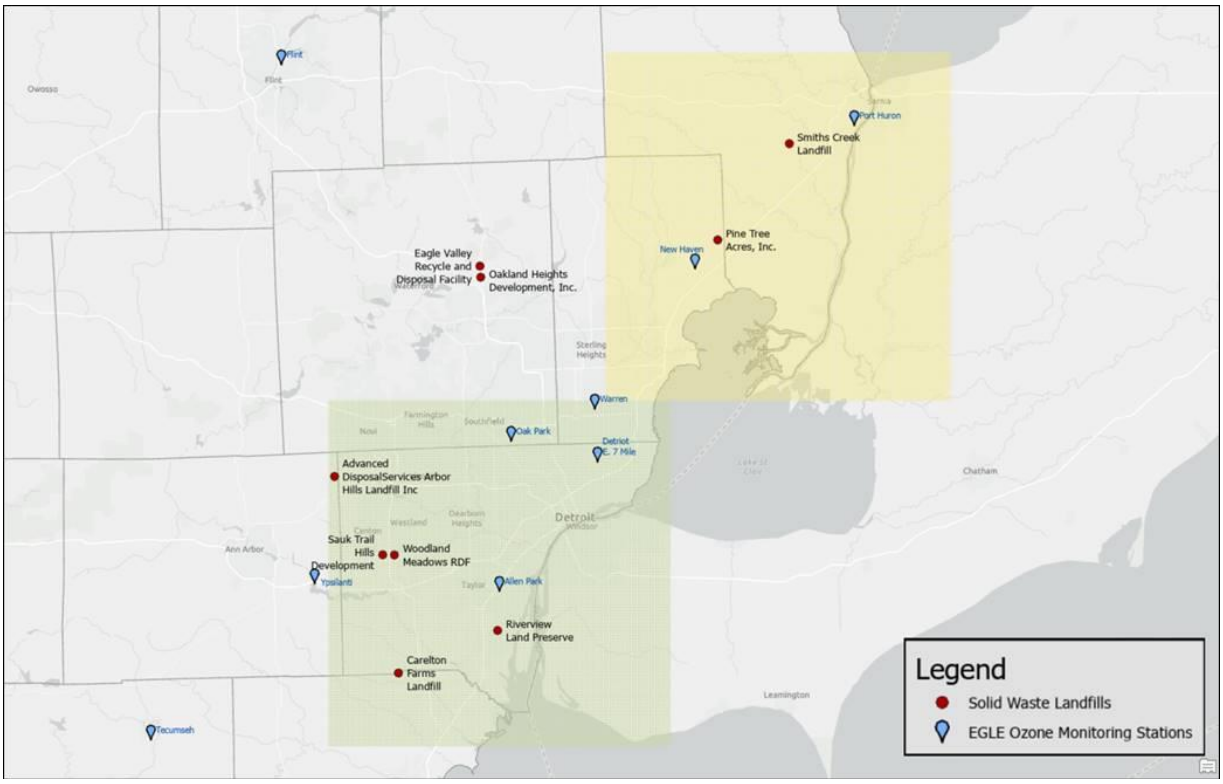


Figure 5. Locations of solid waste landfills and EGLE ozone monitoring stations in SEMI relative to proposed microscale modeling grids.

Another major source of methane is landfills. The California Methane Survey (Duren et al., 2019) deployed airborne visible and infrared imaging spectrometry to measure methane point sources (i.e., emissions from infrastructure elements or localized surface features) at 30 landfills and two composting facilities. These 32 sources collectively contributed about 43% to total point source emissions of methane in California, indicating the presence of super-emitters among the surveyed facilities. In the Great Lakes region, mobile infrared cavity ring-down spectrometry measurements by the EPA in 2016 and 2019 revealed ambient methane concentrations approximately 20 to 40 times the current global background level just outside one of the largest landfills in Michigan.

Besides methane, landfills are also a significant source of primary formaldehyde, mainly from landfill gas combustion in flares and in stationary engines at gas-to-energy conversion facilities. The combination of large emissions of methane and formaldehyde, along with combustion emissions of nitrogen oxides (NOx) and VOCs other than formaldehyde (both in landfill gas and in products of incomplete combustion), may make landfills significant contributors to ozone. In SEMI, landfills are typically to the south and/or west (i.e., often upwind) of the key monitoring stations in the region (see Figure 5).

A key need for an ozone attainment demonstration is the quantification of the natural gas leakage rate in the Border region and of methane emissions from local landfills.

2. FIELD STUDY OVERVIEW

2.1 Organization

To ensure a viable ozone attainment strategy, both in the short and long term, regulatory and scientific agencies, including EGLE, MECP, the U.S. EPA, ECCC, and other partners, have decided to conduct field studies in 2021 and 2022 to be known as the Michigan-Ontario Ozone Source Experiment (MOOSE). Table 1 shows the main field study technical contacts for the various participating agencies.

Table 1. *Participating agencies and technical contacts*

Institution	Technical Contact	Position
Michigan Department of Environment, Great Lakes, and Energy (EGLE)	Dr. Eduardo (Jay) Olaguer Principal Investigator	Assistant Director, Air Quality Division
Environment and Climate Change Canada (ECCC) Environmental Protection Branch	Andrew Snider	Head, Project Management, Air Emissions Priorities Division
Environment and Climate Change Canada (ECCC) Science and Technology Branch	Dr. Craig Stroud Dr. Felix R. Vogel Dr. Zen Mariani Katherine Hayden Dr. Kevin Strawbridge	Research Scientist, Air Quality Research Division Research Scientist Climate Research Division Research Scientist Meteorological Research Division Atmospheric Chemist, Air Quality Research Division Research Scientist, Air Quality Research Division
Environment and Climate Change Canada (ECCC) Meteorological Service of Canada	Jacinthe Racine	Manager, Canadian Meteorological Centre Operations Division
Ontario Ministry of Environment, Conservation, and Parks (MECP)	Dr. Yushan Su Dr. Rob Healy Kelly Miki Yvonne Hall	Senior Scientific Advisor, Air Monitoring and Modelling Section Senior Scientist, Air Monitoring and Modelling Section Manager (Acting) Local Air Quality Permits Supervisor, Air Modelling and Emissions Unit
Lake Michigan Air Directors Consortium (LADCO)	Zachary Adelman	Executive Director

U.S. Environmental Protection Agency (EPA) Region 5	Dr. Jennifer Liljegren Marta Fuoco	Physical Scientist Physical Scientist
U.S. Environmental Protection Agency (EPA) Office of Research & Development Center for Environmental Measurement & Modeling	Dr. Rohit Mathur Dr. Lukas Valin	Senior Scientist Research Scientist
U.S. Environmental Protection Agency (EPA) Office of Air Quality Planning & Standards	Dr. Kirk Baker	Physical Scientist
U.S. Forest Service (USFS), Northern Research Station	Dr. Joseph Charney	Research Meteorologist
National Aeronautical and Space Agency (NASA) Langley Research Center NASA Goddard Space Flight Center	Dr. Laura Judd Dr. John Sullivan	Associate Program Manager, Health and Air Quality Applied Sciences Project Scientist, NASA Tropospheric Ozone Lidar Network
Aerodyne Research, Inc. (ARI)	Dr. Tara Yacovitch	Principal Scientist
University of Michigan (UM)	Dr. Stuart Batterman	Professor, School of Public Health
Brown University Institute at Brown for Environment & Society	Dr. Jiajue Chai Dr. Meredith Hastings	Assistant Professor (Research) Professor, Department of Earth, Environment and Planetary Science
Wayne State University (WSU)	Dr. Yaoxian Huang	Assistant Professor Department of Civil and Environmental Engineering
State University of New York College of Environmental Science and Forestry (SUNY-ESF)	Dr. Huiting Mao	Professor, Associate Chair, Department of Chemistry
Colorado State University (CSU)	Dr. Joseph von Fischer	Professor, Department of Biology
Environmental Defense Fund (EDF)	Mary Gade	Advisor
Michigan Department of Technology, Management, and Budget (DTMB)	Shelley Jeltema	GIS Contractor

2.2 Period of Performance

Given the long timelines associated with ozone designations and emission control implementation, it is important to consider multiple years of data in understanding elevated ozone in the Border region, while minimizing the influence of non-conducive meteorology or other unusual circumstances such as the COVID19 pandemic. A concerted effort will be made to have as many of the project components and instruments operating simultaneously, to provide a robust description of elevated ozone conditions and precursor contributions. However, a multi-year effort provides flexibility for deployment of instruments that may not be available during certain periods, and also provides a longer time arc for understanding the impact of the unusual change in emissions activity related to the COVID19 pandemic.

MOOSE will have two phases: Phase I in 2021 and Phase II in 2022. Phase I will take place for six weeks in May and June of 2021. Phase II will occur during the summer of 2022. The measurement periods are intended to coincide with the most serious ozone exceedances. Historical data (see Table 2) indicate that late May, to early August are favorable times for ozone exceedances in the Border region. Available meteorological forecasts closer to the summer of 2022, as well as logistical considerations, will help to solidify the choice of study period for Phase II.

Table 2. *Time periods corresponding to ozone and temperature metrics at the Detroit East 7 Mile site*

Metric	**2016**	**2017**	**2018**	**2019**
Ozone 8hr 70+ppb	4/10 – 8/10	6/10 – 9/25	5/25 – 8/4	6/27 – 7/10
Ozone 1-hr. max	5/24	7/6	7/13	7/1
	6/10	7/19	8/4	7/10
	6/19	7/18	6/29	6/27
	4/18	8/1	5/25	7/15
	5/25	8/10	5/28	6/28
Max. 1-hour temp	*7/22*	*6/12*	*5/28*	*6/27*
	7/23	*6/11*	*6/17*	*6/29*
	8/10		*6/18*	*5/25*
	8/12		*5/5*	*6/26*
	6/11			*6/27*

2.3 MOOSE Sub-Experiments

Three main sub-experiments will occur during MOOSE, based on data needs identified in Section 1.2. The activities outlined below will proceed in 2021, while planning for a second phase of work in 2022 will be informed by lessons learned from 2021 activities, identified gaps and the availability of instrumentation that could not be deployed in 2021.

2.3.1 Great Lakes Meteorology and Ozone Recirculation (GLAMOR)

Performing Institutions: ECCC, MECP, EGLE, USFS, LADCO, WSU, SUNY-ESF, Brown University

Objectives:

- To understand and simulate complex 3D flows associated with lake breeze circulations;
- To understand and simulate the urban heat island (UHI) and its interaction with the lake breeze;
- To understand and simulate the impact of lake breezes and the UHI on ozone and ozone precursor transport;

- To understand and track the influence of urban emissions and land-lake breezes on urban oxidative capacity through nitrous acid (HONO) and related reactive nitrogen species.
- To determine the conceptual picture (mesoscale meteorological patterns and photochemical production locations) for ozone exceedances in the Border region;
- To select representative ozone episodes for each identified mesoscale pattern, which can then be used as model base case periods for future ozone attainment demonstrations; and
- To conduct modeling and data analyses in support of an ozone attainment demonstration or, if warranted, a CAA 179B(b) petition or ozone exceptional event demonstration.

Summary:
MECP will conduct enhanced monitoring at its Windsor West air monitoring station in Windsor, Ontario. MECP will deploy a meteorological sensor at 10 m above ground level to measure wind speed, wind direction, and temperature. Fast response measurements for NO, NO_2, SO_2, CO, O_3, black carbon, and PM2.5 will be performed. MECP will also deploy a PAMS GC instrument for hourly VOC monitoring and an Xact 625 instrument for hourly monitoring of trace elements. ECCC will co-locate a ceilometer to measure the height of the atmospheric boundary layer. Integrated 24-hour DNPH cartridge measurements of carbonyl species and 24-hour canister measurements of VOCs will also be conducted once every six days. A positive matrix factorization of all the hourly data at Windsor West will be performed to extract factors that can be interpreted along with meteorological back trajectories to provide insight into VOC source apportionment during the ozone exceedance periods. These receptor-based estimates can be compared with emission inventory-based estimates from numerical models, as discussed in Section 3.3.

Due to COVID19 restrictions, the deployment of additional instruments by ECCC at the ministry's Windsor West air monitoring station has been postponed to Phase II of MOOSE in 2022. These instruments include:

- either a SODAR or wind lidar to measure the vertical profile of wind in the boundary layer;
- an ozone lidar to measure the corresponding vertical profile of ozone;
- ozonesondes and a Vaisala system; and
- a Pandora instrument to measure column densities (and planar fluxes when paired with wind measurements) of ozone, nitrogen dioxide, and formaldehyde.

Measurements at the MECP's Windsor West air monitoring station will be complemented by additional meteorological and chemical measurements at the Detroit East 7 Mile PAMS station operated by EGLE. In addition to wind, temperature, and relative humidity measurements, EGLE will also operate a ceilometer to measure atmospheric boundary layer height and an auto-GC for VOC measurements. The East 7 Mile site also has instruments to measure NO_2 and O_3 concentrations.

An additional GLAMOR site will be operated by the USFS at the EGLE Port Huron monitoring station or other appropriate location in SEMI. Instruments will include a ceilometer and SODAR to perform continuous measurements of boundary layer height and wind profile.

Brown University, WSU, and SUNY-ESF will collaborate in performing field measurements of concentration and isotopic composition of NO_x ($\delta^{15}N$)**,** HONO ($\delta^{15}N$, $\delta^{18}O$ and $\Delta^{17}O$)**,** NO_2 ($\delta^{15}N$, $\delta^{18}O$ and $\Delta^{17}O$)**,** HNO_3 ($\delta^{15}N$, $\delta^{18}O$ and $\Delta^{17}O$) and NO_3^-(p) ($\delta^{15}N$, $\delta^{18}O$ and $\Delta^{17}O$). These measurements will: 1) constrain emissions, secondary production pathways, and sinks of HONO; 2) identify oxidation pathways of NO, NO_2, HONO, HNO_3 and NO_3^-(p), and 3) quantify relative abundance of oxidants (O_3 vs RO_2). The field data will be used to develop an up-to-date and comprehensive chemical mechanism for reactive nitrogen species using a 0-D box model, and to add isotopic components to the EPA's National Emissions Inventory (NEI) concerning NO_2 and HONO. The new mechanism will then be applied to a 3-D chemical transport model (CMAQ), together with the improved EPA NEI, to quantify the role of HONO in urban to regional O_3 and secondary aerosol budgets.

After each phase of MOOSE, high-resolution meteorological simulations of the appropriate episodes will be performed using the Weather Research and Forecasting (WRF) and Global Environmental Multiscale

(GEM) models, with the aim of characterizing the dynamics of lake breezes, taking into account the influence of the local urban heat island. These meteorological simulations will then be used to drive air quality model simulations of the most interesting ozone episodes (see Section 3). Meteorological and air quality simulations will either be constrained (via 4D data assimilation) by or evaluated against the appropriate measurements at GLAMOR sites and other EGLE or MECP monitoring stations. The land surface scheme in the GEM model will be constrained with data from the Canadian Land Data Assimilation Surface (CALDAS) system, including lake water temperatures measured from buoys.

2.3.2 Chemical Source Signatures (CHESS)

Performing Institutions: ARI, UM, EGLE, ECCC, MECP, NASA

Objectives:

- To characterize the ozone precursor signatures at key monitoring stations in the Border region where design values are highest during ozone exceedances in a normal year;
- To characterize emission plumes from point sources, area sources, and major industrial sectors in the Border region and their impacts on ozone design values on both sides of the U.S.-Canada border;
- To develop emission source fingerprints for the most important industrial facilities and source sectors in the Border region;
- To characterize the horizontal variations (including upwind, interior, and downwind concentrations) of NOx and VOC in SEMI;
- To perform receptor modeling, source apportionment, and ozone culpability analyses to improve emission inventories and inform potential control strategies; and
- To perform air quality model simulations of potential emission control strategies.

Table 3. *Chemical Instrument Manifest showing key instruments on board the mobile laboratories operated by ARI (AML) and UM (MPAL).*

Measurement	LOD	Rate	Instrument	Platform
Select VOCs	30-300 ppt	1 s	Vocus proton transfer – time of flight mass spectrometer (Vocus PTR-ToF)	AML
Select VOCs	1-20 ppt	10 min	Gas chromatograph – electron impact – time of flight mass spectrometer (GC-EI-ToF)	AML
Methane (CH_4), ethane, formaldehyde (HCHO), carbon monoxide (CO)	30 ppt - 3 ppb	1 s	Tunable infrared laser direct absorption spectrometer (TILDAS, multiple instruments)	AML
Carbon dioxide (CO_2), CO, CH_4, H_2O, H_2S	1 ppb	1 s	Cavity ring-down spectrometers (Picarro G2401, Picarro G2204)	MPAL
Nitric oxide (NO) and Nitrogen dioxide (NO_2)	0.3-1 ppb	1 s	Thermo 42i Chemiluminescence detector and Cavity Enhanced Phase Shift spectrometer; alternatively, TILDAS EcoPhysics CLD 700 AL	AML PAL
CO_2	1.5 ppb	1 s	Licor 6262 non-dispersive infrared (NDIR) spectrometer	AML
Ozone (O_3)	3 ppb	2 s	2BTech Ozone Monitor API 400A	AML MPAL
Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Pb, Al, Si, S, K, Ca	~1-10 ng/m^3	30 min	PM_{10} inlet, X-ray fluorescence, and β attenuation (Horiba PX375)	MPAL

Summary:
During CHESS, two mobile labs, operated by ARI and UM respectively, will be deployed in SEMI to measure a variety of chemical species (see Table 3). The mobile labs will measure source and air mass chemical fingerprints at various locations, guided by real-time meteorological and air quality forecasts provided by ECCC. Both mobile labs will be equipped with meteorological instruments, as well as a

Global Positioning System (GPS) to mark the precise locations of chemical and meteorological measurements.

The Aerodyne Mobile Laboratory (AML) will deploy a variety of advanced real-time sensors, including a Vocus Proton Transfer Reaction, Time-of-Flight, Mass Spectrometer for the measurement of a large suite of VOCs at high temporal (time response of 1 s) and mass resolution and very low limits of detection (<1 part per trillion). UM will deploy the Michigan Pollution Assessment Laboratory (MPAL) to measure sulfur dioxide (SO_2), carbon monoxide (CO), carbon dioxide (CO_2), methane (CH_4), hydrogen sulfide (H_2S), nitrogen oxides (NOx, NO, NO_2), ozone (O_3), size-specific particulate matter (PM), black and brown carbon, and trace metals.

In Southern Ontario during Phase I, MECP will also deploy a mobile laboratory equipped with a GPS and real-time instrumentation, including a Proton Transfer Reaction Time-of-Flight Mass Spectrometer for the measurement of VOCs (time response of 1 s) and limits of detection <1 part per billion. The MECP mobile laboratory also features instrumentation for the measurement of ozone, sulphur dioxide, nitrogen oxides, aromatic VOCs (BTEX), and particulate matter at 5 s temporal resolution, as well as meteorological parameters. This platform will be used to measure air pollutant concentrations and chemical fingerprints immediately downwind of industrial sources in Sarnia and Windsor. It will also provide larger-scale spatial gradients of VOCs and ozone along the Ontario-Michigan border guided by ECCC meteorological forecasts. Data will be collected with 3 objectives: 1) to characterize the release of VOCs from point sources, 2) measure transboundary flow of pollution and 3) to map out the ozone spatial distribution for periods when 1-hr ozone exceedances are predicted in the study region.

To further understanding of the emissions and transport of key ozone precursors, as well as their spatial gradients, NASA will operate a Langley Research Center Gulfstream III (G-III) aircraft equipped with two instruments: the GeoCAPE Airborne Simulator (GCAS; Nowlan et al., 2016; Judd et al., 2020) and the Cloud Physics Lidar (CPL; McGill et al., 2002). GCAS is a UV-visible spectrometer that can measure below aircraft columns of NO_2 and formaldehyde at 350 x 350 m and 1 x 1 km spatial resolution, respectively, on the G-III. CPL is a backscatter lidar with three wavelengths that can provide profiles of clouds, aerosols, and smoke above and within the planetary boundary layer. During Phase I of MOOSE, NASA will perform at least 24 hours of instrumented flights over 3 days in June 2021 to reveal influence of emissions and meteorology on the structure of pollution plumes through repeated sampling over a region spanning from Monroe, Michigan to Sarnia, Ontario. This sampling strategy aims to simulate geostationary UV/VIS air quality mapping like those expected from NASA Tropospheric Emissions: Monitoring of Pollution Mission (TEMPO: https://tempo.si.edu).

After the field study, participants will collaborate in performing high-resolution receptor and inverse modeling to determine the contributions of various sources to ozone exceedances observed during MOOSE, as described in greater detail in Section 3.

2.3.3 Methane Releases from Landfills and Gas Lines (MERLIN)

Performing Institutions: UM, ARI, EGLE, EPA, ECCC, CSU, EDF

Objectives:

- To determine the natural gas leakage rate of pipeline or other infrastructure in SEMI;
- To quantify methane, formaldehyde, and other emissions from landfills in the Border region; and
- To determine the contributions of large methane sources to ozone exceedances in the Border region, thereby informing potential control strategies.

Summary:
MERLIN will occur during Phase I of MOOSE. UM, EPA, and CSU will each deploy GPS-equipped mobile laboratories with a Picarro cavity ring-down analyzer for methane and (in the case of EPA) formaldehyde, as well as supplementary instruments for measurement of combustion trace gases (in the UM and EPA mobile labs) and meteorological parameters. In addition, EGLE will deploy drone-mounted meteorological and chemical sensors to quantify emissions of methane, formaldehyde, and other ozone precursors from

selected landfills in SEMI. The ARI mobile lab may also be deployed during MERLIN to investigate emissions from natural gas pipelines and landfills, as well as the spatial, temporal, and chemical structure of any accompanying ozone plumes.

EPA Region 5 has developed a Geospatial Monitoring of Air Pollution (GMAP) platform with EPA's Office of Research and Development (ORD). GMAP implements an advanced technology that utilizes fast response instruments and a precise GPS that maps air pollution patterns around sources. This system uses a mobile platform to measure hydrogen sulfide (H_2S), methane (CH_4), benzene (C_6H_6), toluene (C_7H_8), ethylbenzene (C_8H_{10}), m-o-p xylene(C_8H_{10}), and ozone (O_3), along with meteorological parameters (wind speed, wind direction). By integrating these parameters with a concurrently collected geospatial tag from an incorporated GPS, the platform can be used to obtain highly sensitive ambient measurements to quantify air pollution concentrations, identify sources, and evaluate geospatial impact.

ECCC is hoping to conduct mobile methane surveys, as well as a landfill campaign, in southwest Ontario later in the summer or early fall of 2021. There are also plans to deploy the EM27/SUN solar tracking FTIRs for direct sun greenhouse gas measurements on a landfill. All these plans depend on COVID19 restrictions.

After the experiment, project partners will collaborate in performing data analysis and inverse modeling to quantify emissions of methane and any accompanying combustion tracers (in the case of landfills), as well their contributions to observed ozone exceedances.

3. MODELING, DATA ANALYSIS, AND INFORMATION MANAGEMENT

3.1 Information Management

EGLE is in the process of setting up a data management platform for MOOSE based on Geographical Information System (GIS) software (ESRI ArcGIS Pro). The platform will enable various layers of information, including those pertaining to EGLE monitoring stations and MOOSE field study sites, industrial facilities in the SEMI area, and emissions inventories, to be (at least in some cases) interactively displayed over the Web and analyzed in systematic fashion. LADCO and EGLE are also collaborating in the set-up of an emissions management platform for MOOSE based on the U.S. EPA's Emissions Modeling Framework (EMF).

An example of a GIS layer that EGLE is currently building consists of underground pipeline segment shapefiles that will be useful in interpreting methane measurements made during the MERLIN sub-experiment in 2021. Access to proprietary and confidential business information will be limited on a strict need-to-know basis, and according to the appropriate guidelines and agreements between EGLE and concerned parties.

EGLE will also explore the possibility of providing a real time data broadcast capability during MOOSE, at least for the MERLIN sub-experiment. For example, UM mobile lab measurements may be made visible to field study participants over the Internet every few seconds so that the MPAL can serve as a "scout" to direct other mobile labs to high value measurement targets, and to perform coordinated upwind-downwind studies.

For long-term archival of MOOSE data, NASA will maintain a data repository, with submitted files subject to the ICARTT formatting convention. This file format had its origin in the International Consortium for Atmospheric Research on Transport and Transformation (ICARTT) field study in 2004, and has since been extensively used in other experimental campaigns. The ICARTT format is a text-based, self-describing, and relatively simple-to-use file structure composed of two sections: a header section (metadata) and a data section. The header section has the instructions for extracting data from the file and the critical information describing the data (e.g., data source, contact information, brief description of measurement technique, measurement uncertainties, and data revision comments) so that a user would have sufficient information to either make direct use of the data or contact the measurement PI to get further clarification on certain issues. The data section can accommodate different types of data, with an emphasis on standard time-series types of data, which is typical for in-situ chemical measurements. ICARTT is designed to fulfill the data management needs for all phases of a field study, i.e., field deployment, post deployment data processing and analysis, and publications.

3.2 Data Analysis

EGLE will collaborate with field study partners in deploying data analytics to process and understand MOOSE field measurements. For example, EGLE is working with CSU to deploy a Python-coded analysis tool for estimating natural gas pipeline leak volumes from real-time measurements of ambient methane concentrations. EGLE is also currently working with UM to develop consistent quality assurance procedures for mobile measurements during MOOSE, and to perform hot-spot analyses of mobile lab data for methane using various mathematical techniques.

ESRI ArcGIS Pro has native data and statistical analysis tools. It also allows integration of Python and R scripts along with other applications to provide a workflow process that is well documented, consistent, and easy to use. Standard data formats will be employed whenever possible. A data dictionary will document data fields, calculation variables, and constants used in scripts and workflow processes. Instrument specifications assumed in measurement data analyses will also be documented.

Among the key data analysis efforts that will take place in the aftermath of MOOSE is receptor modeling by EGLE and other MOOSE participants. For example, Chemical Mass Balance (CMB) and Positive Matrix Factorization (PMF) will be used to interpret chemical fingerprint data derived from the CHESS

sub-experiment. This will be enhanced by forward and inverse air quality modeling described below. The analysis and interpretation of measurements by factor and with high resolution air mass back trajectories will identify sources and the precursor VOC mixtures involved in the ozone production. For example, ranking VOCs by their OH-reactivity for the unique factors will be performed and compared to air quality model results for the same identified sources in model output.

Fast response VOC data can also be analyzed in terms of their diurnal pattern. Emissions, mixing, transport, and ozone photochemistry play different roles at different times of the day. In the early morning, stable surface conditions and rush-hour traffic emissions play a key role. At mid-morning, downward vertical mixing of regionally representative air occurs. In late morning and afternoon, photochemistry, mixing, and transport play a dominant role. Evaluating the model at these different times can help to understand what processes are responsible for biases.

3.3 Modeling and Forecasting

MOOSE presents an opportunity to explore meteorological and air quality modeling on finer scales than is the custom in SIP ozone attainment demonstrations. The necessity of this is conveyed by Figure 6, which shows tropospheric vertical columns of nitrogen dioxide at 250 m horizontal resolution in Chicago as measured by NASA's airborne GeoTASO UV/visible spectrometer in June, 2017 (Judd et al., 2019). Note the very fine horizontal filaments of NO_2 captured by the GeoTASO instrument. *[GeoTASO and GCAS have nearly identical capabilities for mapping NO_2 and HCHO.]* Datasets collected over the MOOSE domain from GCAS can help evaluate models at resolutions spanning from less than a kilometer up to the size of the domain sampled.

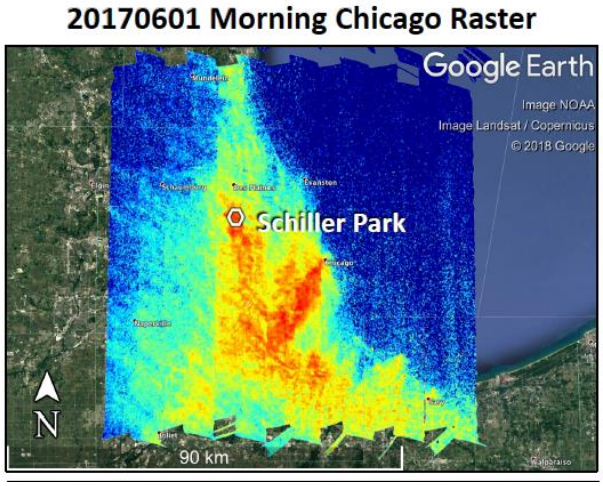


Figure 6. GeoTASO high resolution NO_2 Tropospheric Vertical Column (TropVC) measurements in Chicago as performed by NASA in June 2017 (Judd et al., 2019)

Olaguer (2012a,b) used a 3D Eulerian microscale chemical transport model at 200 m horizontal resolution to demonstrate that very fine ozone plumes may result from VOC and NOx emitted by upstream and downstream petrochemical facilities, especially when accompanied by emissions of primary formaldehyde. Figure 7 shows fine-scale ozone and formaldehyde plumes from a large olefin flare event in the Houston Ship Channel as simulated by Olaguer (2012b). Olaguer (2013) and Olaguer et al. (2013) used an adjoint version of the model of Olaguer (2012a,b) to infer significant emissions of chemically reactive formaldehyde from petrochemical facilities based on research-grade field measurements.

Various models will be used by field study partners to analyze information during and after the MOOSE campaign. During the MOOSE intensive, ECCC will conduct high-resolution, real-time meteorological and air quality forecasts using the GEM-MACH model to guide the placement of the ARI mobile laboratory

during the CHESS sub-experiment. This may be complemented by WRF meteorological forecasts by the USFS at 500 m horizontal resolution. LADCO will deploy the WRF meteorological and CAMx regional air quality models at 1.3 km horizontal resolution in the innermost grid to perform simulations of key wind and ozone episodes identified during MOOSE.

CAMx regional simulations will be complemented by even finer scale forward and inverse modeling by EGLE using a microscale chemical transport model at 200-400 m horizontal resolution with an intra-urban chemical mechanism valid for ambient NO concentrations above ~0.25 ppb. This mechanism will be more condensed and computationally efficient than a regional atmospheric chemical mechanism such as CB06, but more detailed than the daytime, very near source mechanism originally developed by Olaguer (2012a,b; 2013). The intra-urban mechanism will include night-time chemical reactions involving nitrate radical. It will also include heterogeneous secondary formation of nitrous acid (HONO), an important HOx radical precursor, based on the parameterization of Sarwar et al. (2008) as modified by Fu et al. (2019). An accompanying semi-analytical chemical solver, with an explicitly derived chemical Jacobian matrix, will facilitate 4D variational data assimilation and inverse modeling based on the adjoint method.

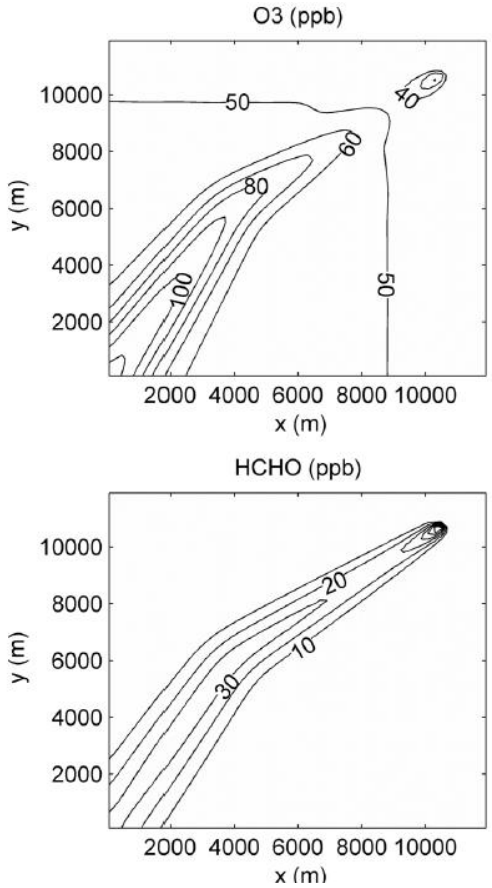


Figure 7. Concentration isopleths of ozone (upper figure) and formaldehyde (lower figure) generated by a large olefin flare event, as simulated by Olaguer (2012b).

The microscale air quality model will make use of building-sensitive wind fields from the Quick Industrial Complex (QUIC) model developed by Los Alamos National Laboratory, using Open Street Maps urban morphology data as input, or in select cases, more recent lidar-derived building data for key industrial facilities. Microscale modeling of ozone in the atmospheric boundary layer will be conducted using two 60 km × 60 km limited area fine mesh domains (see Figure 5). One microscale domain will cover the Detroit

metropolitan area in the southern part of the SEMI region (including Windsor), while the other will cover the northern SEMI region including Port Huron (along with Sarnia).

The Global Environmental Multi-scale (GEM) numerical model is ECCC's operational meteorological forecasting model with a national domain and 2.5-km grid spacing (Milbrandt et al., 2016). The GEM-MACH model is a chemical transport model composed of dynamics, physics and atmospheric chemistry modules run on-line within the GEM model (Stroud et al., 2020). For this study, GEM-MACH will be run in nested mode, comprised of an outer national domain at 10-km grid-spacing, intermediate domain of 2.5-km grid spacing, and high-resolution domain of 1-km spacing encompassing the cities of Toledo, Windsor, Detroit, and Sarnia. In a recent development, the 2.5-km GEM model can now be used to create a meteorological analysis to initialize the higher resolution GEM-MACH cycles. The surface scheme in GEM-MACH is based on an advanced soil moisture and land surface temperature data assimilation system. Hourly lake water temperature is also assimilated into a lake model analysis. An urban canopy scheme, called the Town Energy Balance (TEB), is used to simulate the urban heat island effect (Ren et al., 2020). The impact of new, remotely sensed information on urban roughness will be compared to existing data for the Border region. Sensitivity studies with more resolved urban roughness information can assess the importance of uncertainties in the urban surface structure on urban meteorology.

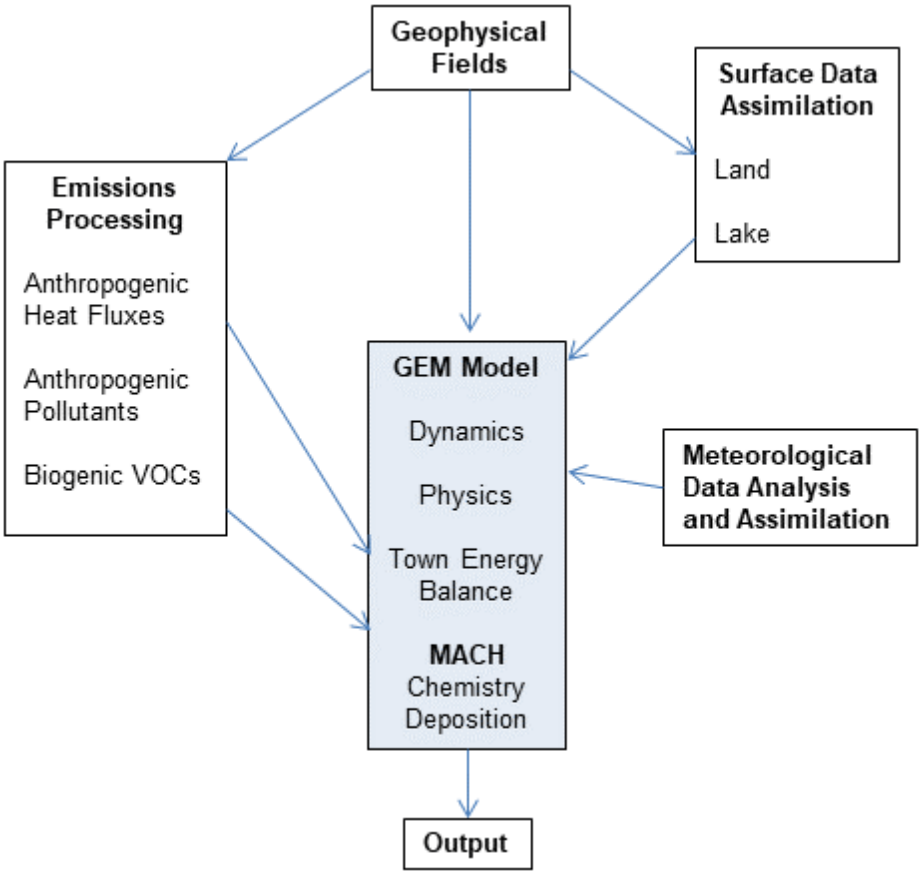


Figure 8. Schematic of processes in the GEM-MACH model.

Table 4. *High-Resolution GEM-MACH model configuration and settings used for this study.*

Numerical Model Option	Option Description
Grid Spacing	2.5-km × 2.5-km
Meteorology Data Assimilation	Ensemble variational (EnVAR) method
Cloud Microphysics	Milbrandt and Yau two-moment bulk
Longwave Radiation	Li-Barker correlated-k distribution
Boundary Layer Scheme	TKE with statistical representation of sub-grid clouds (MoisTKE)
Cloud Convection	Kain-Fritch scheme, important for summertime convection
Land Surface Scheme	ISBA and Town Energy Balance
Surface Data Assimilation	CALDAS with ensemble Kalman filtering, hourly for temperature and moisture assimilation; 2-km NEMO model for lake with 10-km analysis
Gas-Phase Chemistry	ADOM-II mechanism
Gas-to-Particle Equilibrium	HETV (Heterogeneous Chemistry Vectorized)
Gaseous Deposition	Resistance model using Henry's Law and Oxidation Potential
Photolysis Rates	Look-up table and modulation based on cloud fraction
Physics Time Step	120 s
Chemistry Time Step	240 s

Figure 8 shows a schematic of the dynamics, physics, and chemistry processes represented in GEM-MACH-TEB. GEM-MACH-TEB includes a comprehensive chemistry process package that represents gas-phase chemistry, aqueous-phase chemistry, and particle microphysics (nucleation, condensation, coagulation, settling and deposition). Table 4 lists the key model settings for chemistry and physics.

For GEM-MACH simulations, the Canadian National Pollutant Release Inventory (NPRI) will be considered for point-source emissions, and the Canadian Air Pollutant Emission Inventory (APEI) will be used for area-source emissions. For the U.S., pollutant emissions will be obtained from the U.S. EPA National Emissions Inventory, with mobile emissions based on the MOVES traffic model.

The GEM-MACH study will analyze ozone exceedance periods in 2018 at the Windsor West site. The model will be validated with available air quality data in the Border region. A conceptual picture for ozone exceedance events will be created. Case study periods will be selected for future ozone attainment demonstration experiments. The sensitivity of the modelled 8-hr ozone maximum for the case study periods will be determined through a series of incremental emission perturbation simulations. The sensitivity of modelled ozone maxima to incremental NOx emission reduction for a Border region domain will be determined. This will provide insight to the ozone production chemical regime (NOx, VOC, or transitional). Incremental NOx emission reductions by source sector can provide information on NOx source apportionment in the Border domain. Similar sensitivity runs can be performed by VOC source sector with particular interest in the non-combustion sector as a whole (paints, glues, VCPs), as collectively it is larger than combustion sector in cities and it has the largest uncertainty (MacDonald et al., 2018). These incremental emission reduction simulations can be used to derive source apportionment by emission sector for select locations, and can be compared with receptor-modelling, such as PMF. Based on these sensitivity simulations and feasibility analyses, a series of emission reduction scenarios will be developed and applied to the case study periods to assess attainment.

The GEM model will be run at 250-m grid spacing for the Border region during the MOOSE study period to generate detailed wind fields and turbulence characteristics. These high-resolution model outputs can be used to constrain local-scale dispersion models. MECP uses these dispersion models for inverse-emission modelling of point sources using mobile laboratory measurements (see section 2.3.2). Emissions derived from both EGLE and MECP via inverse modeling will benefit both ECCC and EPA in their modeling and source apportionment assessments.

The team from Brown University, WSU, and SUNY-ESF will develop a state-of-the-art isotope-driven 0-D photochemical box model and a chemical transport model, constrained by MOOSE reactive nitrogen concentration and isotope field measurements, to improve our understanding of the chemical mechanisms of ozone formation. The isotope-enabled NEI will be implemented in CMAQ to quantify the impacts of the updated chemical mechanisms on urban to regional ozone air quality and secondary aerosol budgets.

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