Carruthers Creek Watershed Plan

Terrestrial Impact Assessment

Technical Report

Prepared for the Region of Durham

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Acronyms

CCVA	Climate Change Vulnerability Assessment
CCWP	Carruthers Creek Watershed Plan
CLOCA	Central Lake Ontario Conservation Authority
ELC	Ecological Land Classification
FBWB	Feature-based Water Balance
GI	Green Infrastructure
IPCC	Intergovernmental Panel on Climate Change
LAM	Landscape Analysis Model
LID	Low Impact Development
LIO	Land Information Ontario
MNR	Ministry of Natural Resources
MNRF	Ministry of Natural Resources and Forestry
MOEE	Ministry of Environment and Energy
NHS	Natural Heritage System
OCC	Ontario Climate Consortium
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
OP	Official Plan
ROP	Restoration Opportunity Planning
RWMP	Regional Watershed Monitoring Program
SARO	Species at Risk in Ontario
TIA	Terrestrial Impact Assessment
TNHS	Terrestrial Natural Heritage System
TNHSS	Terrestrial Natural Heritage System Strategy
TRCA	Toronto and Region Conservation Authority
UHI	Urban Heat Island
VF	Vulnerability Factors

Foreword

The Region of Durham recognizes watershed plans as an effective tool to inform the management of Durham's water resources, natural heritage, and natural hazards, such as flooding. In 2015, the Region retained the Toronto and Region Conservation Authority (TRCA) to update the watershed plan for Carruthers Creek.

This four-year study will build upon the goals, objectives, and management recommendations established in the 2003 *Watershed Plan for Duffins Creek and Carruthers Creek.*

The following report is one of a series of scenario analysis technical reports that follow the watershed characterization studies (completed in 2017). Information contained in these technical reports will examine potential impacts of future growth and land use changes in combination with other influences such as climate change. Additionally, these technical reports provide the knowledge base necessary to develop the plan's management recommendations. Any recommendations contained in the scenario analysis technical reports are consolidated in the Carruthers Creek Watershed Plan's management framework. The Watershed Plan is the final source for goals, objectives, indicators and management recommendations related to Carruthers Creek. Readers are encouraged to refer to the technical reports for more detailed implementation suggestions.

1 Executive summary

The southern Ontario landscape has historically been dominated by forests and wetlands, especially prior to European settlement (Butt et al. 2005). With European settlement in the 18^{th} century, most of the wetlands were drained and forests were cleared for agriculture, which threatened the health of the ecosystem. More recently, increasing urbanization has resulted in conversion of natural cover and agricultural lands to alternate land uses dominated by impermeable built surfaces. These land use changes continue today in the Greater Toronto Area including the Carruthers Creek watershed, which has compromised the health and resilience of the terrestrial ecosystem and limited its capacity to provide function and services important for community well-being.

Urbanization has direct and indirect effects on ecosystem structure, processes, and functions including disruption of biogeochemical cycles, alteration of hydrology, and loss of habitat and biodiversity (Grimm et al. 2008). These functions are often critical to provide ecosystem services that humans benefit from and value for community well-being. For example, the biophysical structures in the landscape, such as trees and water, and the processes happening within them (e.g. primary production and infiltration) enable proper functioning of the ecosystem (e.g. viable species populations and maintaining water flows). These functions produce ecosystem services (e.g. wildlife viewing opportunities and flood protection) that benefit human well-being in various ways (e.g. improving mental health and safer communities). Ecosystem services have numerous monetary and non-monetary values associated with them such as savings in health care and insurance costs (Moudrak et al. 2018) and cultural or spiritual significance. These are important considerations for all aspects of decision-making for resilient ecological and social systems across the watershed.

There have been various policies, plans, programs, strategies, and initiatives put in place with the goal of achieving sustainable and resilient social and ecological systems in Durham Region. The updated Carruthers

Creek Watershed Plan (in progress) (hereafter referred to as updated CCWP) is one of the most recent initiatives that supports the Region in comprehensively advancing its sustainability and resiliency goals. In addition to providing various technical information relevant for watershed planning process, the updated CCWP aligns with the recommendations for watershed planning from the Provincial guidance document, natural heritage planning, and recommendations made in the 2016 Durham Community Climate Adaptation Plan. As such, the technical information provided in the CCWP will also inform Durham Region as it undertakes the provincially mandated municipal comprehensive review (MCR) process.

The updated CCWP is founded on the principles and goals set in the 2003 CCWP including the goal **to protect and enhance terrestrial habitat and species**. This goal highlights the three main objectives for terrestrial system, which has been carried forward from 2003 CCWP to this updated CCWP, in addition to the proposed fourth objective as listed below:

1. Objective 14: Increase natural cover quantity to ensure protection of long-term terrestrial biodiversity
2. Objective 15: Protect natural system quality and function from the influence of surrounding land uses
3. Objective 16: Protect and restore all native terrestrial community types and species
4. Objective 17: Manage and adapt to the climate vulnerabilities of the terrestrial system

This Terrestrial Impact Assessment (TIA) study focuses on assessing the implications of different land use scenarios on the four objectives for the terrestrial system in the Carruthers Creek watershed. A comparison of potential impacts of each scenario would (i) update overall objectives and targets for the watershed, (ii) provide a better understanding of the implications of each land use scenario on each objective, and (iii) identify strategic actions that will assist Durham Region in its objective to achieve greater sustainability and resilience.

The land use scenarios used in the TIA included the current landscape (Current scenario) and three potential future scenarios that represented the land use changes based on implementation of the approved Official Plan (+OP), Official Plan and targeted enhancement to the natural heritage system (+NHS), and additional potential urbanization in the northern portions of the watershed (+Potential Urban). The five key indicators were assessed under each scenario to understand and illustrate the extent of impact on each objective. These indicators include the following (a) natural cover quantity (Objective 14), (b) natural cover quality (Objective 15), (c) landscape connectivity (Objective 15), (d) vegetation communities and fauna (Objective 16), and climate change vulnerabilities (Objective 17).

Overall, the results of the TIA suggest that the CCWP goal of protecting and enhancing terrestrial habitat and species in the Carruthers Creek watershed can be achieved at various levels under the Current and the three future land use scenarios examined in this study. The differences are mostly driven by the varied level of success expected for the four objectives focussed on improving habitat quantity, quality, species and community composition, and addressing climate vulnerabilities.

In terms of the first and second objectives of the CCWP that aim to increase **natural cover quantity and quality**, there is not much difference between the Current and +OP scenarios. However, when compared to the +NHS scenario, there is a substantial positive influence with an increase in natural cover (from 25% to 36%). This is driven by the additional areas delineated for the enhanced NHS, primarily in the north portion of the watershed. The potential increase in quantity also seems to enhance the quality of natural cover as there are more good and excellent patches in the watershed under the enhanced NHS condition. This is attributed to the larger patches with lesser edge effects and a more conducive matrix around these habitat patches under +NHS scenario. However, when compared to the +Potential Urban scenario even though natural cover remained constant as both scenarios use the same enhanced NHS, there was a substantial decrease in habitat quality, which is attributed to the increased negative matrix influence.

A comparison of the habitat connectivity priorities coverage within the NHS under each land use scenario indicates that under the +NHS scenario there is a substantial increase in areal coverage of local and regional habitat connectivity priority areas. This is an important functional ecological gain beyond adding quantity as it facilitates the long-term dispersal movements between habitats that allows wildlife to adapt to negative impacts posed by land use and climate change.

The third objective of **protecting and restoring species and vegetation communities** is challenging for the Carruthers Creek watershed, especially in the urban portions of the watershed. The conversion of open space areas to industrial or residential land uses (from the Current to +OP scenarios) could lead to the loss of habitat for at least six species currently using these areas including bobolink. An urban matrix often has more negative consequences for wildlife using natural cover patches compared to an agricultural matrix because of various direct and indirect effects such as noise and predator presence. Enhancement to the NHS under the +NHS scenario can buffer some of these impacts and should be considered strongly for these areas. Many fauna species inhabit the forest patches within the rural portion of the Carruthers Creek watershed, most of which are likely not directly impacted under the +OP scenario, since only minimal changes are proposed. However, a small portion of the land that may change from open space to industrial may have increased matrix influences that may affect the surrounding habitat patches. Maintenance of agricultural lands under the +NHS scenario in the north will continue to provide habitat for numerous species such as those dependent on open and/or agricultural landscapes. Restoring some of the agricultural areas to forested natural cover under the +NHS scenario will change the species communities from grassland-associated species to more forest-associated species. Under the +Potential Urban scenario, if agricultural lands are converted into built surfaces then it will cause a direct loss of habitat for numerous species mentioned earlier that currently use these areas. While the addition of natural cover through the enhanced NHS provides benefits, negative matrix influences associated with urban areas may negate some of the gains achieved from the enhanced NHS.

Lastly, the fourth objective of incorporating climate change vulnerabilities in natural systems planning is accomplished through the NHS, especially for those areas where vulnerabilities are driven by natural features such as climate sensitive vegetation, habitat patch quality, and wetlands. Under all land use scenarios, a substantial portion of the high vulnerability areas defined by these vulnerability indicators are within the NHS, but highest under +NHS scenario. However, the vulnerable areas driven by indicators that are general landscape parameters such as ground temperature and soil drainage are very limited in the NHS. These results illustrate that the NHS is beneficial for protecting the existing natural features such as vulnerable vegetation community patches, lower quality habitat patches, and vulnerable wetlands. However, to reduce the vulnerability outside the natural features in the urban matrix, the NHS has a smaller influence. The potential solution to this requires management and implementation of climate adaptation measures outside of the traditionally defined NHS, which may include less built up areas and implementing more green infrastructure (e.g. urban canopy, green roofs, and other LID tools).

The TIA results indicate that to achieve the terrestrial goals and objectives the key recommendations that need to be followed through are listed below. These broad recommendations are supplemented by illustrations of the specific actions across the entire watershed (in the conclusion section) to facilitate achievement of the terrestrial goal and objectives in the Carruthers Creek watershed.

1. Protect and enhance natural cover in collaboration with diverse partners to increase overall quantity and function as well as restore diverse habitat types allowing for the recovery of species of regional concern.
2. Protect and enhance quality of natural cover, which includes actions to improve management of public uses in habitat patches, invasive species management, as well as managing the surrounding areas to minimize and / or mitigate negative urban matrix influence including incorporating different forms of green infrastructure in planning processes and design (e.g. street and backyard trees, green roofs, pollinator gardens) across entire watershed.
3. Account for the cumulative effects of the land use changes on habitat in planning processes even when the amount of habitat is not directly lost.
4. Improve connectivity among habitat patches to allow for wildlife movement and long term gene flow that can help biodiversity adapt to any changes in existing habitat, may it be due to land use or climate change.
5. Implement actions to protect and enhance sensitive species and their habitat, which may require finer level management interventions at site level including creating larger habitat patches with interior habitat, and maintaining agricultural areas in north Carruthers for meadow-dependent species.
6. Focus on building climate resilience of the habitat, communities, and species including high and medium vulnerability natural features and areas in the targeted enhanced natural heritage system to protect further loss of habitat and their functions due to climate change drivers and managing urban matrix to address the high and medium vulnerability areas for ground surface temperatures.
7. Adapt restoration and land management measures in the high and medium vulnerability areas for climate sensitive vegetation such that it accounts for the possibility that climate drivers may pose challenging conditions for these vegetation communities to thrive in the watershed. Relatively new adaptation and management approaches such as assisted migration and facilitating native seed banks should be explored as standard management practice, as appropriate.
8. Develop a list of long-term strategic questions that are important to be answered to assess the state of the terrestrial system and target setting and achievements in the Carruthers Creek watershed in future.
9. Establish a long term monitoring network to allow for the strategic research questions to be answered to help achieve the terrestrial goal and objectives of the CCWP.

2 Introduction

The creation of municipal Official Plans (OPs) under current land use planning policy is an important tool for guiding the location of urban development as the human population expands (Ontario Planning Act 1990). OPs are important for identifying areas of potential development and also have the ability to protect and enhance natural systems and the ecosystem services they provide (Lam and Conway 2018). The ecosystem approach to land use planning requires that the boundaries for planning are based on biophysical boundaries such as watershed boundaries and not necessarily political boundaries (MOEE and MNR 1993, Summers et al. 2013). Planning on a watershed basis was formally introduced in 1946 through the Conservation Authorities Act and continues to be an important tool for identifying natural systems for protection, providing water management recommendations and the overall protection of ecosystem function. Watershed plans are most effective when directly integrated into municipal OPs and can also be used as references for environmental impact assessments, environmental management plans, stormwater management planning and prioritizing environmental issues and funding (Summers et al. 2013).

The 2003 Carruthers Creek Watershed Plan (CCWP) is currently being updated to develop the next generation of CCWP (in progress), which incorporate the most up-to-date information from both science and practice locally and globally. The update process involved the evaluation of existing watershed conditions (2015/2016) during Phase 1 (TRCA 2018). These existing conditions are then used to inform Phase 2 to evaluate land use and land cover changes between historical and current conditions and predicting the implications of future changes using three future land use scenarios on various goals and objectives of the CCWP. This report focuses on the methods and results of the Terrestrial Impact Assessment (TIA), which is one of several impact assessments being conducted during Phase 2 (reported as separate documents).

Land use scenario comparison is a technical exercise that is typically undertaken when developing Toronto and Region Conservation Authority (TRCA) watershed plans to ensure management recommendations are based on the best available science that are grounded on what-if scenarios. The results help to guide the evaluation of proposed management actions and inform municipalities as they embark on the land use and environmental assessment processes. It is important to stress that land use scenarios do not result in decisions about the type and configuration of land uses, but instead it can inform these decisions, which are ultimately the responsibility of municipalities to make. The land use type and configuration, as determined by the municipality at the end of this process, may look very different from those that were applied through the scenario analysis exercise while developing the watershed plan.

This document also provides case studies of past land use impacts in the watershed and suggests measures to mitigate current impacts and prevent exacerbation of these in the future. There are several references within this document to the Urban Forest Assessment technical document (TRCA 2019), which examined tree cover and composition primarily in the urban portion of the watershed including trees within the natural cover as well as in the built portions (e.g. street and backyard trees, parkettes). While the TIA and Urban Forest Assessment analyses used some overlapping data, mainly within the natural areas, they are unique in their purpose and scope, and as such, remain separate technical documents.

2.1 Goal and Objectives

The updated CCWP (in progress) is founded on the principles and goals set in the 2003 CCWP including the goal **to protect and enhance terrestrial habitat and species**. This goal highlights the three main objectives for terrestrial system, which has been carried forward to this updated CCWP, in addition to the fourth objective proposed as listed below:

5. Objective 14: Increase the amount of natural cover to a quantity that will protect long-term terrestrial biodiversity
6. Objective 15: Protect natural system quality and function from the influence of surrounding land uses
7. Objective 16: Protect and restore all native terrestrial community types and species
8. Objective 17: Manage and adapt to the climate vulnerabilities of the terrestrial system

2.2 Purpose of the Terrestrial Impact Assessment

The main purpose of the TIA is to enable the CCWP to achieve its terrestrial goal and objectives by

a. Updating the 2003 CCWP objectives, indicators, and metrics using the most-up-to-date information from science and practice.
b. Assessing the impacts of different land use scenarios on the Carruthers's Creek watershed and provide a better understanding of the implications on each objective, and
c. Providing strategic recommendations for actions on-the-ground that will assist CCWP and Durham Region in meeting its terrestrial ecosystem goals and objectives.

A detailed discussion on data, methods, results, and discussion on the TIA are provided in this report in the subsequent sections.

3 Study area and land use scenarios

3.1 Carruthers Creek Watershed

Carruthers Creek is the easternmost watershed that comprises the jurisdiction of the TRCA. It is one of the jurisdiction's smaller watersheds, encompassing approximately 38km^2 of land area. Carruthers Creek provides a continuous corridor of natural habitat from the Oak Ridges Moraine in the north to the Lake Ontario shoreline in the south (TRCA 2017a). The watershed is noteworthy for its riverine and lacustrine wetlands in its lower reaches, large areas of mixed and deciduous forest especially in the north-central portion of the watershed and extensive areas of meadow and successional habitat across the whole watershed (TRCA 2017a). It is home to several important natural heritage features, numerous fauna species and is an important area for recreation and enjoyment of the natural environment (TRCA 2017a).

3.2 Land use Scenarios

Land use scenario development is often a technical exercise that is undertaken when developing high level strategic plans at large geographic scales such as TRCA's watershed plans. The main intent of this is to ensure management recommendations are based on the best available science that are grounded on what-if scenarios representing the broader context from policy and/or practice. The results help to understand and evaluate the implications of proposed management actions. This informs the municipal land use, environmental assessment, and other planning processes.

It is important to stress that land use scenarios do not determine the ultimate decisions on the type and configuration of land uses, but instead it is meant to inform these decisions, which are ultimately the responsibility of municipalities to make. The specific land use type and configuration at the finer geographic scales may evolve from those that are depicted in the land use scenarios used for the TIA. This will be informed by the insights provided by the TIA as well as the results of the other impact assessments being completed for the additional goals of the CCWP. This will be further refined through the various land use, environmental assessment, and other planning processes that the municipalities will undertake.

In this TIA five landscape scenarios are used to provide a better understanding of the implications of each land use scenario on terrestrial ecosystems and identify strategic on-the-ground actions that will assist Durham Region in ensuring a resilient terrestrial ecosystem as the climate and land uses continue to change. Specifically, five scenarios were used, which included historical and current conditions that were compared with the predicted conditions under three future land use scenarios (Table 1, Figure 1).

Historical conditions characterize the watershed in the 2003 Carruthers Creek Watershed Plan (CCWP). Current conditions represent existing land cover and land use based on data available in 2015, when these scenarios were developed. Scenario 1 (+OP) reflects current conditions with some additional refinement south of the Greenbelt based on OP data. Scenario 2 (+NHS) reflects predicted changes in land cover when the proposed enhanced Natural Heritage System (NHS) is implemented, which includes both existing natural cover and potential areas that could be restored to natural cover. Scenario 3 (+Potential Urban) reflects potential changes in land cover beyond +OP and +NHS scenarios, mostly driven by the potential full growth outside of the proposed enhanced NHS. Further methodological details are provided below and additional technical information in Appendix 1.

3.2.1 Historical 1999 (Historical)

The “Historical” land use scenario reflects the land use prior to the 2003 CCWP, and is intended to depict the historical watershed context and changes in land use and watershed conditions that have occurred since 1999. This scenario informs what the land use change has occurred over the past decade and a half and allows for an understanding of the shifts in land use conditions and implications related to objectives.

3.2.2 Current 2015 (Current)

The “Current” land use scenario assumes maintenance of existing (2015 data) land use conditions and associated land cover characteristics (i.e. areas of imperviousness, vegetation, etc.). Current land uses and NHS were delineated based on a combination of data including orthophoto interpreted natural cover data, land use data, NHS data from municipalities, and Ecological Land Classification (ELC) data. Agricultural lands were additionally updated using maps that were ground verified. Evaluation of this scenario related to watershed objectives provides a benchmark to describe current watershed conditions, and to identify elements to be protected and existing problems to be addressed.

3.2.3 Scenario 1 – Current + OP (+OP)

The “Official Plan” scenario utilizes updated information from local and regional municipalities OPs to supplement the “Current” scenario. Evaluation of this scenario in relation to watershed objectives provides insight into how the watershed conditions will likely change as OPs are implemented and whether there are key priorities for CCWP objectives that emerge for management consideration. The most up-to-date OP data were downloaded from Ajax, Pickering, and Durham, which was refined with on-the-ground information for both land use and land cover categories as well as the currently delineated NHS in the OPs.

3.2.4 Scenario 2 – Current + OP + Enhanced NHS (+NHS)

The “Enhanced Natural Heritage System” (hereafter referred to as enhanced NHS) scenario was built on the current land use and land cover and official plan designated land uses (+OP) scenario including the municipal OP adopted NHSs. The information in the +OP scenario was supplemented with new and updated information from natural heritage planning science and practice locally and globally as well as updated data from ortho-photo interpretation and expert knowledge (as of 2017). This enhanced NHS includes existing natural cover (e.g. forests, wetlands, meadows etc.) as well as additional potential areas for restoration to natural cover that would bolster the natural cover function and services into future. Nevertheless, in the +NHS scenario map there may be minor discrepancies in land use categories due to the reasons associated with the data discrepancies and / or continued changes in land use. These errors are minor for the purposes of the TIA and not expected to influence the inferences at the watershed scale assessment that TIA focuses on. These will be identified in the recommendations and are expected to be corrected through land use and other planning processes as municipalities undertake them.

Evaluation of +NHS scenario in relation to watershed objectives provides insights into how the watershed conditions will likely change as OPs are implemented with explicit consideration to additional protection and management for natural heritage goals and objectives. This will proactively identify additional potential key priorities and provide opportunities for proactive management to move towards a sustainable and resilient future.

This scenario includes OP land use designations including the enhanced NHS. This scenario was developed based on TRCA's Terrestrial Natural Heritage System Strategy (TNHSS) (TRCA 2007). The TNHSS is based on the principle that if there is a robust natural system that can sustain ecosystem functions in terms of habitat and species diversity in the face of climate and land use change, then it will likely ensure the long-term provision of a variety of ecosystem services for human well-being. Thus, it is important to note that this scenario explicitly included additional areas based on the needs and opportunities for enhancing the terrestrial natural system only. It is important to note that one of the unique features of the TNHS is that it is not confined to the watershed or jurisdictional boundary and is a continuum that extends in adjacent watersheds.

Minor refinements were made to the 2007 TNHS to ensure it is based on the most up-to-date information and reflects current land use developments as well as restoration opportunities. Additional areas for natural habitat protection and restoration were identified based on three major priorities and associated data as outlined below. Spatial data, landscape ecology principles, and expert opinion were used in conjunction with the data to identify locations within the watershed that most effectively address these three priorities. Aerial photos and land use data were used to help ensure all proposed additions were practical/feasible.

a. *<u>Priorities for local and regional connectivity for habitat and wildlife movement</u>*
In recent years, habitat connectivity and wildlife movement priorities have been highlighted and addressed through various development planning and environmental planning processes in Durham and elsewhere with support from the partner Conservation Authorities including TRCA, Lake Simcoe Region Conservation Authority (LSRCA), and the Central Lake Ontario Conservation Authority (CLOCA). The new and updated data and information on habitat connectivity (TRCA 2015a) was used to identify the priority areas for local connectivity (important for daily and seasonal movements of wildlife) as well as regional connectivity (important for long-term adaptation movements). The updated information on north-south as well as east-west connections were used to identify additional areas for protection/restoration, where possible, within the watershed as a part of the enhanced NHS.

b. *<u>Priorities for climate change adaptation for highly vulnerable areas</u>*
Climate change adaptation has been at the forefront of priority planning for all levels of government locally and globally. TRCA has recently completed a terrestrial systems climate change vulnerability assessment to identify areas that are predicted to be highly vulnerable to changes in climate (TRCA 2018a). The climate condition that was assumed predicts higher temperatures at all times of the year, changes to seasonal precipitation patterns, more rainstorms and more heat waves. Winter, spring, and fall are predicted to be wetter, while summer will likely be drier on average, but punctuated by heavy storms. Based on this, the terrestrial systems including forest, wetland, and meadow areas were assessed to identify the gradient of vulnerability between watershed areas. The areas of high climate vulnerability were used to enhance the NHS to ensure that these were protected and that resilience was built into the system.

c. *<u>Priorities for enhancing habitat size and configuration for ecosystem quality and diversity</u>*
   The size and configuration of natural features influences habitat quality and the ability to support a diversity of vegetation communities and species. Size and configuration (both existing and potential) in conjunction with TRCA's restoration opportunities database, species inventory data, and the available information on existing and planned land use were used to identify additional areas for the enhanced NHS.

This enhanced NHS is meant to be a first approximation of the recommended target system for the Carruthers Creek watershed in line with the TRCA Living City Policies (TRCA 2014) objectives for NHS. This also considers Provincial guidance on NHS planning (MECP 2018). Further refinement is recommended through the planning process to address other ecosystem services and community objectives. For example, specific needs such as those driven by Species at Risk legislation and other priorities require additional considerations to supplement the proposed enhancements in this scenario. The design of the enhanced NHS is not bound to the original 2003 CCWP watershed targets. Additional existing and potential natural cover has been identified to help meet watershed goals. However, there may be additional areas required for protection that are not easily identified at the watershed scale. The design of the enhanced NHS has attempted to capture the natural features and areas identified for protection based on the natural heritage policies within municipal OPs. Additional areas that need to be protected to address other goals of CCWP are being addressed in separate technical impact assessments and will be integrated in the final draft of the CCWP for final recommendations.

3.2.5 Scenario 3 – Current + OP + Enhanced NHS + Potential Urbanization (+Potential Urban)

The "Potential Urban" scenario was created by adding the build out to the +NHS scenario. This illustrates prospective development post-2031 in the headwaters area outside of the enhanced NHS. In this scenario, there is no change in the existing urban area south of the Greenbelt beyond what is included in the approved OP. Evaluation of this scenario in relation to watershed objectives provides insights into how the watershed conditions will likely change if potential full growth is approved in the watershed and whether there are key priorities that emerge for management consideration.

Table 1. Summary descriptions of historical and benchmark conditions, and future land use scenarios used in the TIA for the Carruthers Creek watershed

Scenario	Description
Historical	Historical land use conditions from 1999 prior to 2003 CCWP.
Current	Existing land use conditions from 2015 based on aerial photo interpretation.
Scenario 1 (+OP)	Refines Current conditions by assuming all lands south of the Greenbelt are now developed as approved up to 2031 in the OPs. Only minor changes from 2015 have resulted as most of the urban area was already developed in 2015.
Scenario 2 (+NHS)	Refines Scenario 1 by adding an enhanced NHS as per the approved OPs and using updated information on terrestrial habitat connectivity, habitat configurations, and climate vulnerabilities.
Scenario 3 (+Potential Urban)	Illustrates prospective development post-2031 in the headwaters area outside of the enhanced NHS identified in Scenario 2. There is no change in the existing urban area south of the Greenbelt.

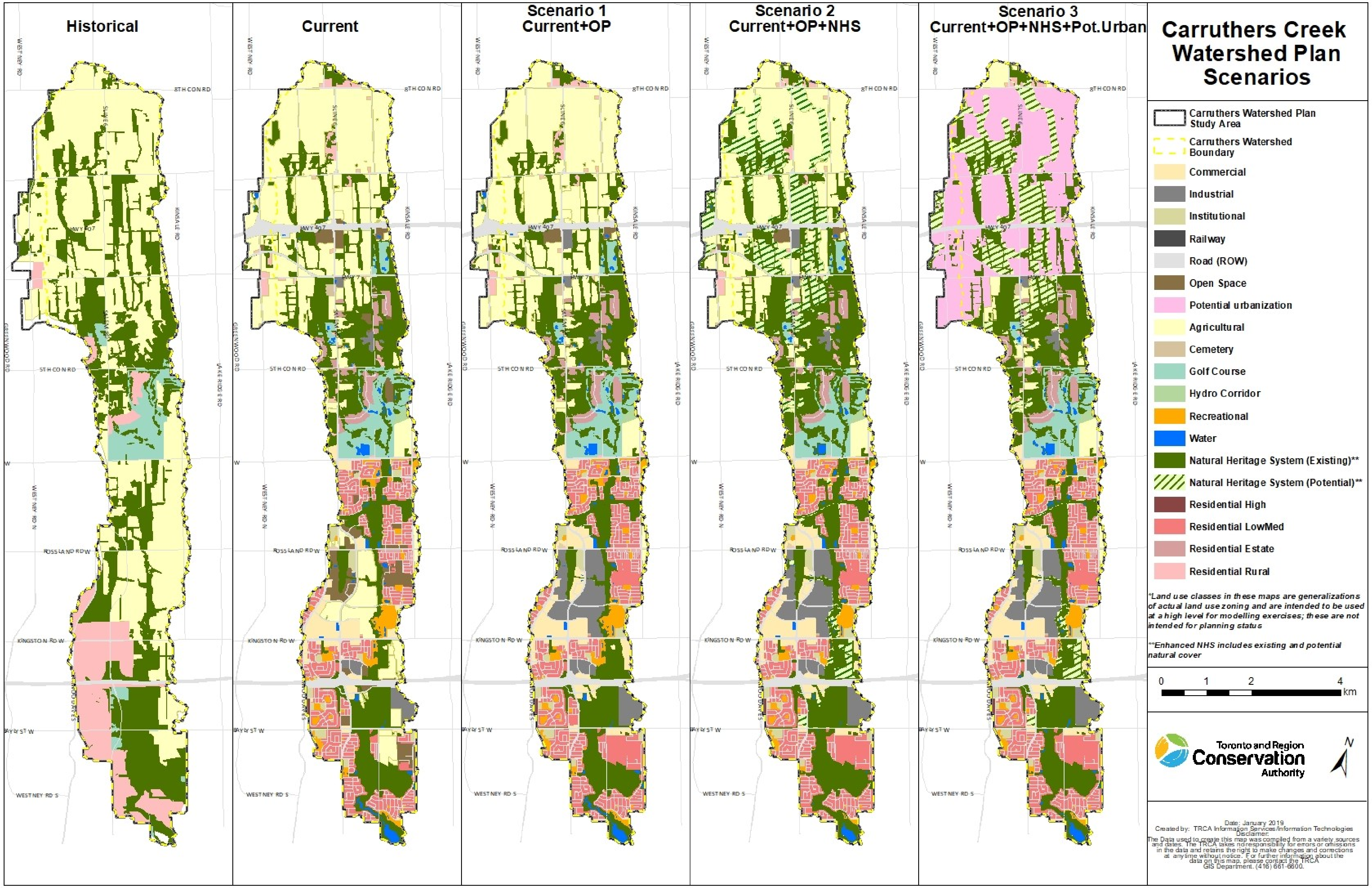


Figure 1. Five land use scenarios for the Carruthers Creek watershed depicting (i) Historical, (ii) Current, (iii) Current + Official Plan (+OP), (iv) Current + Official Plan + enhanced Natural Heritage System (+NHS), and Current + Official Plan + enhanced Natural Heritage System + Potential Urbanization (+Potential Urban)

4 Methods

The TIA focuses on assessing the impacts of different land use scenarios on the Carruther's Creek watershed and provide a better understanding of the implications on each of the four objectives (listed in the previous section). This is a component of the CCWP Phase II and provides important information to help protect and enhance terrestrial habitat and species in the Carruthers Creek watershed.

Section 4.1 and Table 2 summarizes the indicators and metrics used to represent the four key objectives. They help quantify the impacts and, ultimately, help set measurable targets for each objective (Box 1). Section 4.2 through 4.5 provides a detailed discussion of the methods used in this assessment. Further, Section 5 will discuss the results and Section 6 will outline a number of recommendations. This will inform target setting and taking actions on the ground that will help achieve Goal xx to protect and enhance terrestrial habitat and species.

Box 1: Target Setting for the CCWP

Targets set for each metric represent minimum targets and if the Carruthers Creek watershed already exceeds these targets under current conditions, strong attempts should be made to maintain and, if possible, surpass targets.

The natural cover target was based on Environment Canada's "How much habitat is enough?" guidelines (EC 2013) developed to provide science-based guidance to conserve and restore habitat for migratory birds, species at risk and other wildlife species within the settled landscapes of the lower Great Lakes and Mixedwood Plains.

Based on these guidelines and the recommendation to conserve existing habitat, the total natural cover target was set at 45% consisting of the 30% forest cover and 10% wetland cover guidelines as well as conserving the existing 2.8% meadow and 0.5% unclassified and beach/bluff natural cover types (successional could be considered forest if predicting 50-70 years into the future). The ability of each land use scenario to meet these minimum targets was evaluated in this study.

4.1 Indicators and Metrics

To represent the four key objectives TIA recognised the five major indicators and associated metrics to be used to assess the implications of the Current and three future land use scenarios on the terrestrial system (Table 2).

The indicator used to represent Objective 14 (to increase the amount of natural cover in the watershed) is natural cover, which is based on the TRCA orthophoto interpreted natural cover data layer. The overall total amount of natural cover (percent and hectares) as well as the amount of individual natural cover types (percent and hectares) – forest, wetland, meadow, successional, and beach bluff – are used as the specific metrics to quantify this indicator.

The indicator used to represent Objective 15 (to improve the quality of natural cover) are based on TRCA data on (i) Habitat patch quality based on Landscape Analysis Model (LAM) (TRCA 2007), and (ii) habitat connectivity (TRCA 2017). These indicators use specific metrics such as average patch size, shape, and surrounding matrix influence as well as percent overlap between areas identified as connectivity priority and NHS habitat connectivity at regional, watershed, and local scale. More discussion of each metric is provided in the Section 4.3.

The indicator used to represent Objective 16 (to protect and restore all native terrestrial community types and species) are based on field collected data on Ecological Land Classification (ELC) vegetation communities and the fauna points. The specific metrics used are number and hectares of vegetation communities of regional concern and number of fauna species of regional concern that are expressed in terms of L-ranks in TRCA. Further discussion of each metric is provided in Section 4.4.

The indicator used to represent Objective 17 (to manage and adapt to climate vulnerabilities of the terrestrial system) are based on the results of the TRCA terrestrial system climate change vulnerability assessment (CCVA) (TRCA 2018 draft report).The specific metrics used are the percent of coverage of highly vulnerable areas driven by the five criteria within the NHS. Further discussion of each metric is provided in Section 4.5.

Table 2. Objectives, indicators, and metrics for the terrestrial ecosystem of the Carruthers Creek watershed

Objective	Indicator	Metrics
Objective 14 Increase the amount of natural cover to a quantity that will protect long-term terrestrial biodiversity	Natural cover	▪ Percent of watershed that is ▪ natural cover ▪ forest ▪ wetland ▪ meadow
Objective 15 Protect natural system quality and function from the influence of surrounding land uses	Habitat Patch Landscape Analysis Model (LAM)	▪ Average, median, range of ▪ Patch size ▪ Patch shape ▪ Matrix influence ▪ Patch LAM total score
	Habitat connectivity	▪ Percent of overlap between areas identified as connectivity priority and NHS based on: ▪ Regional connectivity - R ▪ Regional connectivity - W ▪ Local connectivity between forests ▪ Local connectivity between wetlands and forests
Objective 16 Protect and restore all native terrestrial community types and species	Vegetation communities	▪ Number of ▪ L1-L3 Ecological Land Classification (ELC) community types* ▪ Hectares L1-L3 ELC community types*
	Fauna	▪ # of L1-L3 species (frogs, birds)* ▪ Other parameters based on further set-up of long-term monitoring plots to determine baselines such as: ▪ Number of species and individuals (meadow, forest, wetland-dependent birds)
Objective 17 Manage climate vulnerabilities of the terrestrial system	Climate vulnerability	▪ Percent of coverage of highly vulnerable areas in NHS for: ▪ Climate sensitive vegetation communities ▪ Patch quality ▪ Wetland cover ▪ Ground surface temperature** ▪ Soil drainage**

* Based on 2015/2016 inventory surveys (ensure survey area boundaries are comparable because only portions of the watershed were surveyed; 2014 L-ranks).

** Variables that extend outside of TNHS into urban built areas, thus may require different approach to decrease vulnerabilities.

4.2 Objective 14: Increase the amount of natural cover to a quantity that will protect long-term terrestrial biodiversity

Habitat loss and degradation is the single greatest threat to biodiversity and is the primary cause of species extinctions in Canada (Venter 2006). Recognizing these consequences, TRCA developed a target Terrestrial Natural Heritage System Strategy (TNHSS) in 2007 to protect and enhance natural heritage in its jurisdiction. This Strategy also delineated a target Terrestrial Natural Heritage System (TNHS), which delineated target areas for protection, enhancement and restoration and includes both existing natural cover and that has potential to be restored to natural cover in future (TRCA 2007). The Strategy and the TNHS are both supported in principal by TRCA's the Living City Policies (TRCA 2014) in line with the municipal partner's natural heritage objectives. In addition, the Strategy recognizes that the quantity, quality, and distribution of natural cover and biodiversity is closely linked to various ecosystem functions and services such as water, air quality and climate regulation that are important for a sustainable and resilient ecosystem and human well-being (Millennium Ecosystem Assessment 2005). It provides extensive data, scientific models, mapping and guidance for TRCA staff, TRCA's partner municipalities and community groups to assist in achieving natural heritage objectives (TRCA 2007). The watershed planning process has utilized the information from the TNHSS over the past decade and continues to do so with the CCWP with appropriate updates to the technical data and information.

To assess the amount of overall natural cover and specific natural cover or habitat types (forest, wetland, meadow, successional and beach/bluff) the TIA used the information from a number of sources. This includes the TNHS (2007), natural cover data (2013), 2017 refined natural cover using orthophoto interpretation and expert knowledge, and other secondary data sources that could help inform the type of habitat that could be targeted at a particular location across TRCA jurisdiction (based on TRCA Restoration Opportunity Planning (ROP) process (TRCA 2018b and Box 2). The total amount of natural cover under the Current land use (Current) and three future land use scenarios (+OP, +NHS, and +Potential Urban) were examined to infer the implications of each on overall natural cover and each habitat type. The results are discussed in Section 5.2.

Due to differences in data sources for natural cover and land use information, there were some areas of existing natural cover defined in the land use scenarios that were outside of areas of TRCA's existing natural cover layer. These areas were not defined to natural cover type (forest, wetland, etc.) and occupied less than two percent of the total natural cover in the watershed. These areas were called "unclassified" and could slightly underestimate the amount of natural cover for specific natural cover types. This should be considered when assessing movement towards or away from targets under various land use scenarios.

In addition, a deep dive into the wetland habitat was undertaken using a Wetland Catchment Analysis to better understand where future urban development has the potential to significantly alter the water balance of wetlands, thereby compromising its function. Changes to the proportion of impervious cover and size of a wetland's catchment can alter the timing and magnitude of water level conditions throughout the year, which in turn can lead to degradation or loss of wetland plant and animal species if conditions are too dry or wet at particular times of year. The further details on this deep dive on Wetland Catchment Analysis is provided in Appendix 2.

The results are discussed in the Section 5.2 in the Results chapter of this document.

Box 2: Restoration Opportunity Planning (ROP) Process

ROP process provides a strategic and repeatable approach to identifying where and what to restore. Terrestrial ROP involves an initial desktop analysis followed by field surveys to identify opportunities for wetland, riparian, forest and meadow restoration. The following represents guidelines used to identify areas for restoration of each habitat type.

a. Wetlands – identified in areas of altered head water drainage (tiles, ditches, drains, etc.) with wetland supporting topography (flat or basin like). These areas have typically been drained for agriculture or development.

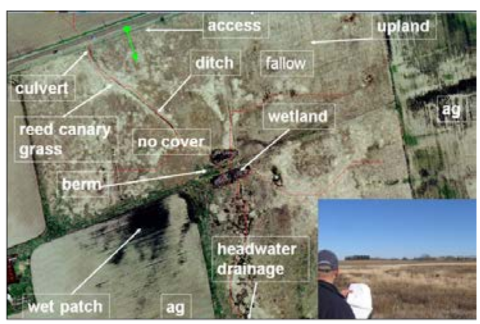
b. Riparian – Areas where vegetation cover provides influence to headwater drainage lines (topography does not support a wetland) or provides influences to a watercourse (often 30 m wide but where topography changes to higher elevations, forest is utilized).

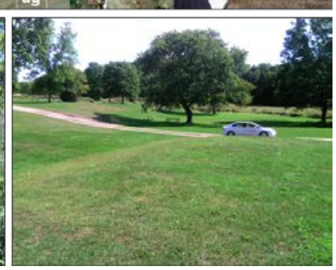
c. Forest – Outside of 30 m riparian areas or wetlands where topography and soils are likely drier and does not directly influence watercourse/2.5 ha drainage lines.

d. Meadow – Reserved for areas where historic native meadows were present or where ongoing management of preventing forest succession is required or as directed by Ontario’s Endangered Species Act.

For the Carruthers Creek watershed only the desktop portion of ROP was completed. This uses ArcGIS software to interpret orthophotos and digital elevation models and delineate drainage patterns. Once restoration opportunities are identified through desktop analysis, they are typically investigated through field visits. Data collected during field visits include surrounding/existing land use, access for implementation, existing habitat features, drainage features, habitat opportunity type (riparian, wetland, forest, wet/dry meadow) and site dimensions, other indicators of site suitability (soils, topography), site quality, ease of implementation and invasive species (TRCA 2018b). Prior to restoration, detailed site specific restoration plans are completed which generally include planting native, early successional species appropriate for the soil and hydrology along with considering existing flora species and surrounding vegetation community types. The final product is a digital layer file of ROP polygons that can be overlaid with the enhanced NHS. For this analysis, any areas in the enhanced NHS that did not have a ROP overlaid were considered to be restored as forest.

Natural cover types identified through ROP were assumed to be the later successional stage communities intended for the area (e.g. successional forest with younger trees are assumed to succeed to eventually mature forest). Areas designated as riparian for the ROP were classified as successional for the natural cover analysis. If there was no ROP for the potential areas in the enhanced NHS, they were assumed to be forest for analyses.





4.3 Objective 15: Protect natural system quality and function from the influence of surrounding land uses

For terrestrial system and habitats to function at its highest level it is important to manage for the habitat quality, in addition to the quantity. In CCWP the habitat quality is assessed based on two major indicators (i) Habitat patch quality evaluated by Landscape Analysis Model (LAM) (TRCA 2007), and (ii) habitat connectivity (TRCA 2017). More discussion of each indicator is provided in the following sections.

4.3.1 Habitat patch quality based on Landscape Analysis Model (LAM)

TRCA's TNHSS (2007) recognized that in an urban region such as TRCA's jurisdiction, ongoing changes in habitat quality is expected. However, the TNHSS established that an overall increase in "good" quality habitat patches across the entire jurisdiction can result in more resilient terrestrial habitat and biodiversity. The Landscape Analysis Model (LAM) developed by TRCA evaluates individual mosaics of habitat patches and ranks them from "poor" to "excellent" quality based on three structural metrics; size, shape, and matrix influence (TRCA 2007). The target TNHS was then developed to have in general majority of habitat patches scoring as "good", recognizing that there are some opportunities for "excellent" patches and other areas may have limited opportunity to improve based on the LAM assessment method.

4.3.1.1 Patch size

The LAM method emphasizes that structural metric such as patch size is helpful because the larger patches of natural cover may have higher conservation value. The larger patches can support larger populations of species, thus promoting their viability; have the capacity to support area-sensitive and forest interior species; are better buffered from negative external influences; likely include a greater diversity of habitat types; and, they have a greater capacity to maintain and promote a variety of natural ecological processes (see Forman 1995; Bennett 1999, Matthews et al. 2005). Size is the number of hectares occupied by a habitat patch (polygon). Even when patches straddle the boundary of the study area, size is calculated for the entire patch, not just the portion that falls within the study area. The study area boundary was used for this analysis and includes a small section of land in the East Duffins Creek subwatershed immediately adjacent to the Carruthers Creek watershed and outside the provincial Greenbelt.

4.3.1.2 Patch shape

Patch shape metric considers external influences on the patch, especially the negative "edge effects" resulting from habitat fragmentation. Generally, the more convoluted or linear the habitat patch, the higher the ratio of edge to area and the higher will be its exposure to these matrix influences (Saunders et al. 1991, Forman 1995), thus lower habitat quality. Edge environments are known to cause "edge effects" which are often caused by a change in the microclimate between the habitat of interest and the surrounding landscape. This influences the habitat's physical characteristics (temperature, light, moisture, wind) and subsequently the presence of species (Yahner 1988, Saunders et al. 1991). These changes are widely recognized to have negative impacts on species residing in remnant habitat, especially when the surrounding landscape matrix consists of incompatible urban and/or agricultural land uses (Knutson et al. 1999, Duguay et al. 2007). Shape is calculated as a patch's perimeter (edge)-to-area ratio (P/A). To compensate for the increase in perimeter with increasing patch size, a corrected shape calculation is used: (0.282 x Perimeter)/(Area) ^{½} (Baker 1997). The resulting scores for each habitat patch are multiplied by a factor of 10 to provide numbers that are easier to interpret. For example, a perfect circle (the best possible shape for reduction of edge to area) would be P/A = 100. Similar to patch size measurements, patches that extend outside of the study area boundary are measured in their entirety, not just the portions of the patch that fall into the study area.

4.3.1.3 Matrix Influence

Matrix influence metric is a measure of the positive or negative influence that a patch receives from its surroundings. Land uses, especially urbanization, adjacent to a patch can exert impacts that have a profound effect on its biodiversity (Lindenmayer and Franklin 2002). Conversely, a patch can have a synergistic and beneficial relationship with natural cover in the surrounding area, and to a lesser degree with agricultural lands. The matrix influence is measured as the relative percentage of each land cover type (natural, agricultural, and urban) within a 2 km radius of the outside edge of each habitat patch. The 2 km radius of influence extends beyond the limit of the study area (region or watershed, for example) in situations where habitat is adjacent to the boundary. Higher matrix influence scores indicate more positive matrix influences, such as those from surrounding natural cover.

4.3.1.4 LAM L-Ranks and Scores

The raw metrics of patch size, shape, and matrix influence were scored based on the LAM methodology (TRCA 2007 Appendix E), which was then used to calculate the total score for each patch. These were then grouped into five local ranks (L-ranks), based on the range of possible total scores from 0 to 15 points. L1 is the highest rank (highest quality) and L5 the lowest rank (lowest quality) (Table 3). The purpose of ranking is to simplify the evaluation of the natural system and assist decision-making by breaking down the range of scores into categories of patches with similar function (TNHSS 2007).

Table 3. Patch scores and associated local rank and quality from Landscape Analysis Modelling

Patch score	Local rank	'Quality' condition
13-15	L1	Excellent
11-12	L2	Good
9-10	L3	Fair
6-8	L4	Poor
0-5	L5	Very poor

For the CCWP a few changes were made to the original LAM (TRCA 2007) to reflect the updated data and current needs of the updated CCWP.

- The 2013 natural cover layer was used for this analysis and similar to the natural cover type analysis, there were some areas of existing natural cover defined in the land use scenarios that were outside of areas of TRCA's existing natural cover layer. These areas were classified as meadow or left unclassified if areas looked to be slightly altered (e.g. land scraping). This could cause the LAM analysis to slightly underestimate size, shape and quality and should be considered when assessing movement towards or away from targets under various land use scenarios.
- The ROP polygons were used to classify the areas of enhanced natural cover in scenarios 4 and 5 (+NHS and +Potential Urban). Since land use scenarios predict 50-70 years into the future, riparian and meadow ROPs were classified as forest. If there was no ROP for areas defined as natural cover, these areas were considered forest.

- Matrix influence was calculated using the land cover classes of “urban”, “agriculture” and “natural” based on 2013 aerial photos. Field collected ELC data (2015 and 2016) were used to further refine orthophotography interpretation.
- Matrix influences were determined within a 2 km buffer of the patch edge. Golf courses, cemeteries, residential estates, open space and hydro corridors were not clearly defined as either “natural” or “urban” land uses so they were assigned to the “agriculture” land use category that reflects the medium negative matrix influence for the analysis.

The results are discussed in the Section 5.3. in the Results section of this document.

4.3.2 Landscape connectivity

Landscape connectivity refers to “the degree to which the landscape facilitates or impedes movement among resource patches” (Taylor et al. 1993). Landscape connectivity depends on the spatial configuration of habitat patches and the organisms’ movement behaviour in response to landscape characteristics (Merriam 1984, With 1997, Moilanen and Nieminen 2002). Landscape connectivity can be affected by anthropogenic activities such as urbanization, agriculture, and road construction, which often result in structural and/or functional fragmentation of natural cover patches. The effects of habitat fragmentation include alteration of physical and chemical properties of the habitat patch, wildlife road mortality, preventing movement among habitat patches, altering the abundance and distribution of food resources and affecting the ability to find mates. All of which can compromise overall population persistence (Trombulak and Fissell 2000, Jaeger et al. 2005).

In conservation planning, increased landscape connectivity, both at local and regional scales is considered crucial. Landscape connectivity at the local scale ensures that wildlife are able to move to appropriate habitat patches to maintain their short-term life history processes (e.g. seasonal movement between breeding and foraging areas). Regional scale landscape connectivity ensures that longer-term ecological processes (e.g. metapopulation dynamics, gene flow, and dispersal) are maintained in the face of changing climate and land use (Ricketts 2001, Calabrese and Fagan 2004). Landscape connectivity at all scales is particularly important in urban areas where the remaining habitat patches are small and both short-term and long-term ecological processes rely on the ability of wildlife to access neighbouring habitat patches (Hanski and Ovaskainen 2000). Connectivity is becoming increasingly important, especially from a climate change adaptation perspective where increasing connectivity between habitats can assist with species movements as species are forced to move to locations outside existing or historical ranges (Gleeson et al. 2011).

For the CCWP, the landscape connectivity analysis used the results from the regional and local connectivity modelling completed for TRCA’s Crossing Guidelines for Valley and Stream Corridors (TRCA 2015a).

4.3.2.1 Regional connectivity:

Regional connectivity refers broadly to connectivity among all high quality habitat patches in a particular region and/or watershed. The higher quality habitat patches (L1-L3) in the target TNHS (TRCA 2007) were defined as the targets for maintaining and, if possible, enhancing regional connectivity based on future land use conditions. This information was compiled from municipal OPs, natural heritage plans, secondary plans, etc., available at the time of analysis (2015) for the crossings guideline. A general resistance gradient was assigned to each land use or land cover class for wildlife movement ranging from one to five, with five (5) posing the greatest resistance to wildlife movement (i.e. urban impervious land uses) and one (1) posing least resistance (i.e. natural cover).

The relative contribution of each location in the watershed to the overall regional connectivity of all high quality habitat patches in the watershed was calculated using a connectivity metric called "current density" quantified with an analytical software, Circuitscape (McRae and Shah 2009, TRCA 2015a) at 100 m raster cell resolution. Circuitscape uses a circuit theoretic approach (McRae et al. 2008), which is widely used in North America for landscape connectivity analyses (Caroll et al. 2011, Urban et al. 2009, McRae et al. 2008, Beier et al. 2008). Higher cumulative current density values reflect a greater probability of movement, and hence greater contribution to regional connectivity of habitat patches within each watershed. The top 50th percentile of current density was identified as high priority areas for regional connectivity across TRCA's region. For more details on connectivity analysis refer to TRCA's *Crossings Guideline - Technical Report for Natural Heritage Objectives* (TRCA 2015a).

A similar regional connectivity analysis was completed for the Carruthers Creek watershed at a finer scale of 10 m raster cell resolution. The top 50th percentile current density values at the watershed scale reflects areas that are most important for the habitat patches within the watershed (plus a 2 km buffer to avoid the boundary effect). Both regional and watershed level priorities are assessed in the CCWP TIA to reflect both regional and watershed scale priorities for habitat connectivity.

4.3.2.2 Local connectivity:

Local connectivity refers broadly to connectivity among existing forest patches and forest-wetland habitat patches to facilitate daily and seasonal movements (e.g. foraging). Daily and seasonal movement among forest and wetland habitat patches is essential for many species to complete life cycle requirements. To assess local connectivity, existing data on two key habitat types, forests and wetlands, were compiled from orthophoto interpreted natural cover data (2013), ELC (2013), and evaluated wetlands using the 2011 MNR wetlands layer; all mapped wetlands and forests were included. These habitat patches were used to map specific "habitat networks" that have the potential to facilitate movements within a general daily and seasonal movement capacity of the focal species (D'Eon et al. 2002, Van der Grift and Pouwels 2006) that included low mobility species moving between (i) wetlands and forests (includes most amphibians) and (ii) between forests (includes most small mammals and salamanders). The resulting habitat network layers were identified as the priority areas for local connectivity. For more details on connectivity analysis refer to TRCA (2015a) *Crossings Guideline - Technical Report for Natural Heritage Objectives*.

For the CCWP, the impacts of the land use scenarios on the regional connectivity and local connectivity priority areas were calculated as follows:

a) First, the overlap area (in hectares and in percent of the priority) between regional and watershed scale regional connectivity priority areas and NHS (or natural cover) was calculated under each scenario.
b) Second, the overlap area (in hectares and in percent of the priority) between local connectivity priority areas and NHS (or natural cover) was calculated under each scenario.

The results are discussed in the Section 5.4. in the Results section of this document.

4.4 Objective 16: Protect and restore all native terrestrial community types and species

The Toronto Region is home to many species of plants and animals based on its geographic location, including its proximity to Lake Ontario and influences from the Carolinian zone in the southwest to the mixed forests to the north. Natural landscapes within the region provide habitat for numerous species, which use these areas for breeding, feeding, roosting and migrating. Outside of the intrinsic values of these species (the value of something "in-and-of-itself"), these species are valuable because they provide many, often unnoticed, ecosystem services such as nutrient deposition/cycling, seed dispersal, pollination, predation (e.g. controlling pest populations), carcass removal (e.g. scavengers) and controlling disease vectors (e.g. frogs consuming mosquito larva or birds and bats feeding on adult mosquitoes) (Sekercioglu 2006, Hocking and Babbitt 2014). In addition to these ecosystem services, flora and fauna are often integral to many other parts of our lives, such as recreation (e.g. birding, hiking) and culture (e.g. symbolism, medicinal, spiritual).

TRCA's Regional Watershed Monitoring Program (RWMP) was initiated in 2001 to provide a comprehensive assessment of the health of watersheds using a suite of environmental indicators. The RWMP monitors numerous indicators both spatially and temporally throughout the watershed, including water quality, fish, benthic invertebrates, terrestrial flora, fauna and vegetation communities, among many others. These data are then used for many purposes including watershed reporting, informing the Toronto and Region Remedial Action Plan, fisheries management plans, land management planning, municipal OPs and watershed planning. The Terrestrial Monitoring Program collects data on flora, fauna and vegetation communities using both long-term monitoring plots and inventory surveys. Inventory surveys are conducted by biologists between April and October depending on species phenology. Biologists map the locations of species detections and ELC polygons. These data are a good representation of the species present at the time of the surveys (a "snap shot") but are by no means a complete list and therefore likely underestimate both species richness and abundance.

The terrestrial monitoring team has created a system for scoring and ranking flora, fauna and vegetation communities called the Local-rank (L-rank) system (TRCA 2017b). The L-rank system is a species scoring and ranking system (similar to an Index of Biotic Integrity or provincial/federal species ranks) developed at TRCA to provide guidance for natural heritage protection and management within the jurisdiction. The L-rank system uses simple ranks to convey the ecological needs and sensitivities of individual species and communities, rather than just "rarity", in order to portray such complexities on a simple ordinal scale (TRCA 2017b). Fauna L-ranks are based on scores for six criteria including local occurrence, population trends, habitat dependence, area sensitivity, mobility restriction and sensitivity to development. For example, species ranked L1 would have: a limited local occurrence, declining population trends, habitat specialist and area sensitive requirements, restricted mobility and a sensitivity to development. Species ranked L5 would have: a widespread local occurrence, increasing population trends, habitat generalist and non-area sensitive requirements, no mobility restrictions and a tolerance to development. These are extreme examples and species can be ranked L1, L2, L3, L4 or L5 based on the scores associated with this combination of ecological needs and population status assessments. Species ranked L1, L2 or L3 are considered by TRCA as species of concern regionally and additionally those ranked L4 are considered species of concern in the urban land use zone. Non-native species are ranked as L+. A similar approach is used for flora species, though only four criteria are used: local occurrence, population trend, habitat dependence, and sensitivity to development impacts. Vegetation communities are scored only on local occurrence and habitat dependence, which reflects basic geophysical requirements (TRCA 2017b).

For the CCWP TIA, the inventory data collected in 2015/2016 for fauna and vegetation communities (ELC data) were mapped under current land uses. To estimate the impact of future land use scenarios, these data were overlaid with each land use scenario and areas with notable species/community losses and potential species/community gains were identified. The results are discussed separately for areas north and south of Taunton Road to specifically reflect the different landscape context in these sections.

In addition, specific species listed as terrestrial Species at Risk in Ontario (SARO) were identified using the most current fauna layer (June 2018) to ensure that the needs of these regulated species are also captured in this analysis. The results associated with SARO are discussed as a case study that lists known SARO in the watershed and implications for habitat protection and restoration.

The results are presented and discussed in the Section 5.5. of the Results section of this document.

4.5 Objective 17: Manage climate vulnerabilities of the terrestrial system

Climate change science has unequivocally highlighted that there has been an increase in average global temperatures and if emissions are not reduced, warming trends will continue along with associated extreme and devastating weather events (Intergovernmental Panel on Climate Change (IPCC) 2014). Even though the changes to climate are expected to be “severe, pervasive, and irreversible” (IPCC 2014), a target has been set through the 2015 Paris Agreement to try to limit warming to an increase of 2°C globally by 2050. To achieve this outcome, the IPCC has emphasized that adaptation by governments at all levels is essential for achieving this goal (United Nations 2015). In Ontario, including the Greater Toronto Area, various local and regional municipalities have recognized this global challenge, which has severe local implications, and have led many initiatives that specify mitigation and adaptation measures. Durham Region committed to a Community Climate Change Local Action Plan in 2012 (Durham Region 2012) as well as a Climate Adaptation Plan in 2016 (Durham Region 2016) that attempts to prepare Durham Region for a better and resilient climate future. The goal of these initiatives was to assess if the existing systems are sufficiently robust to continue to deliver desired results if subjected to the projected future climate conditions and extreme weather. By recognizing the potential risks today, appropriate strategic decisions can be made to ensure continued robustness of various identified sectors including natural environment (Durham Region 2012, 2016).

In 2016, TRCA in partnership with the Ontario Climate Consortium (OCC) and the Region of Peel developed a framework to assess the vulnerabilities of existing natural systems to climate change impacts and to identify priority areas for adaptation (Tu et al. 2017). A Climate Change Vulnerability Assessment (CCVA) of the terrestrial system has been applied to the entire TRCA jurisdiction using a similar framework (TRCA 2018a). In summary, the framework identified the level of vulnerability of each component of the terrestrial system (forest, wetlands, meadows) based on a number of “Vulnerability Factors” (VF). The VFs reflect the physical, chemical and biological factors that cause the natural component to be more or less vulnerable to a given climatic condition (Tu et al. 2017). Each VF was represented by a specific “Vulnerability Indicator” (VI) based on their importance (how widely applicable an indicator is), scientific validity (current understanding, measurability and sensitivity to changes in vulnerability factors) and feasibility (data availability) (Tu et al. 2017). Further details on the exact methodology for Peel Region is provided in Tu et al. (2017).

The Peel Region framework was applied to the TRCA jurisdiction including several modifications to account for the changes in the spatial area covered as well as data availability. The main difference is that only five of eight VIs used for the Peel Region were applied to the TRCA jurisdiction-scale assessment. This was mainly due to redundancy among VIs and a lack of available data. Indicators used in this assessment were

a) habitat patch quality,
b) climate sensitive ELC vegetation community type,
c) wetland hydrological vulnerability,
d) mid-afternoon ground surface temperature, and
e) soil drainage,

A complete description of VIs, including ecosystem services and relationships to climate drivers and impacts can be found in Appendix 3. Each indicator was assigned a score of low (0), medium (1) or high (2) vulnerability based on criteria outlined in Appendix 4. For each VI, their climate vulnerability scores and vulnerability maps were produced.

For this assessment, each of the climate change VIs are compared under each land use scenario to identify how much of the high and medium vulnerability areas driven by the particular indicator is within the natural heritage system (natural cover), which can help manage climate vulnerabilities.

Results are presented and discussed in Section 5.6 in the Results section.

5 Results and Discussion

5.1 Land use scenarios

The total area (hectares) and the percent of the watershed area (%) for each land use type class under each scenario are presented in Table 4. This analysis was completed using the CCWP watershed boundary.

It is worth noting that given the methodological differences in the ways that some of the land use data were produced, these estimates are approximate and further discussion is provided in the following sections.

Table 4. Summary of land use type and percent cover under each land use scenario for the Carruthers Creek watershed

Land use type	% of watershed boundary				
	Hist.	**Curr.**	**+OP**	**+NHS**	**+Pot Urban**
Natural Cover	28	23	24	25	25
Natural Cover (potential)$^{\Psi}$	-	0	0	11	11
Agricultural	53	34	29	19	4
Cemetery	-	<1	<1	<1	<1
Golf Course	6	4	4	4	4
Hydro Corridor*	-	<1	<1	<1	<1
Recreational	-	2	2	2	2
Water**	-	1	1	1	1
Urban***	12	-	-	-	-
Future Urban	-	0	0	0	19
Residential High	-	<1	<1	<1	<1
Residential LowMed	-	10	12	12	12
Estate Residential	-	2	3	3	3
Rural Residential	-	1	1	<1	<1
Commercial	-	3	4	4	4
Industrial	-	1	5	5	5
Institutional	-	1	1	1	1
Open Space (Construction)	-	4	<1	<1	0
Railway	-	0	0	0	0
Road (ROW)	-	11	11	11	10

$^{\Psi}$ Natural cover (potential) is delineated only in scenarios with updated enhancements to the NHS

* Hydro corridor in the historical scenario is aggregated with other classes; for the rest of the scenarios it is a separate class

** Water in the historical scenario is aggregated with natural cover; for the rest of the scenarios it is a separate class

*** Urban in the historical scenario is aggregated; for the rest of the scenarios it is broken down by specific classes

5.1.1 Historical verses Current scenario

The historical land use data shows that the Carruthers Creek watershed had approximately 28% (1036 ha) natural cover in 1999 (including water features) and approximately 53% (1958 ha) agricultural lands. This was reduced to approximately 25% of overall natural cover (including natural cover class of 23%, water class of 1%, and hydro corridor class of about 1%) and 34% of agricultural lands. Subsequently there was an increase of urban land use from 12% (444 ha) in 1999 to 37% (1381 ha) (including all built urban land use classes as well as recreational and cemetery) in 2015. These results suggest that the natural and agricultural lands were likely converted to urban land uses during this period. This is supported by the visual comparison of the 1999 land cover and land use information and the 2015 land cover and land use information that allows for the identification of some specific changes that explains natural cover decrease.

A few examples of these changes are listed below and are further referenced in the recommendations discussion in Section 6.2. The following list is not an exhaustive list of all changes, but instead provides examples of the some of the broad types of changes that occurred.

- Loss of agricultural land and natural cover south of Taunton Road north of the Ajax Warbler Swamp.
- Conversion of open/fallow field areas that were mapped as natural cover in 1999 to agricultural by 2015.
- Loss of natural cover (including potential connectivity) for the Highway 407 expansion.
- Conversion of natural cover in southwest Ajax (south of the Rossland Road wetland) to industrial land use.
- Conversion of a large amount of agricultural land to residential area east of Carruthers Creek between Rossland Road in the north and Kerrison Drive East in the south
- Completion of riparian restoration planting by TRCA for Redside Dace (*Clinostomus elongatus*) compensation along Carruthers Creek in the Deer Creek golf course just north of Taunton Road along with one wetland and one forest compensation (completed in May 2018) project north of Bayly Street East (at Shoal Point Road) and near the Rossland Road wetland, respectively.
- Indication of tree planting and natural succession occurring in the middle portion of the watershed.

5.1.2 Current verses future scenarios

A comparison between the Current and +OP scenario indicates small changes in land use types, mostly within 5% margin This includes agriculture (5% decrease), open space (3% decrease), residential and commercial (1% increase), and industrial (4% increase). This is not surprising given that most of the land use change within the urban boundary had already happened in the watershed by 2015, which is reflected in the Current land use scenario. Small increase of about 1% was observed in the amount of existing natural cover between the Current (860 ha) and +OP (885 ha) scenarios. This is largely due to the two areas in Carruthers Creek watershed that were assumed to be and designated as existing natural cover in +OP scenario based on information available in Official Plan documents used in the assessment in 2016. This includes an open space area north of Highway 401 and east of Salem Road designated as an environmental protection special study area and areas near a stormwater management pond south of Rossland Road and east of Salem Road.

When +OP is compared to the +NHS scenario, there is a substantial increase in existing and potential natural cover from 25% (860 ha) to 36% (1770 ha). This is mostly driven by the additional 11% areas (398 ha) that are targeted as potential areas that could be restored to natural in the target enhanced NHS.

There is another small increase of about 1% in existing natural cover between the +OP (885 ha) and +NHS (910 ha) scenarios. This is attributed to the updated data produced using orthophotos and expert knowledge based information that was used while developing the enhanced NHS in 2017. In addition, there were other minor changes in water, cemetery, railway and road ROWs between scenarios, mainly attributed to the data digitization errors as well as reclassification of some areas as potential natural cover in the targeted enhanced NHS (e.g. some ROW). Appendix 1 presents more information on GIS techniques used for land use delineation.

When comparing the +NHS to +Potential Urban scenarios, there was a 19% increase in urban land cover and a 15% decrease in agricultural cover, with an assumption that the same enhanced NHS is implemented in the watershed. No further assumptions could be made in terms of specific land use types beyond high level potential urbanization land use type.

5.2 Quantity of natural cover and natural cover types

The total area (hectares) and the percent of the watershed area (%) for overall natural cover and each natural cover type under each scenario are presented in Table 5. This analysis was completed using the CCWP watershed boundary.

Table 5. Summary of natural cover quantity indicators under historical, current and three future land use scenarios for the Carruthers Creek watershed

Natural cover type	Total areas (in hectares)					Percent cover (% of total watershed)				
	Hist.	Current	+OP	+NHS	+Pot. Urban	Hist.	Current	+OP	+NHS	+Pot. Urban
Forest	503	341	343	584	584	14	9	9	16	16
Wetland	88	240	241	257	257	2	7	7	7	7
Meadow	384	105	107	123	123	10	3	3	3	3
Successional	60	164	164	329	329	2	4	4	9	9
Beach/bluff	<1	2	3	3	3	<1	<1	<1	<1	<1
Open water	n/a	6	6	7	7	n/a	<1	<1	<1	<1
Unclassified	n/a	2	21	5	5	n/a	<1	<1	<1	<1
Total natural cover	1036	860	885	1308	1308	28	25	25	36	36

5.2.1 Total natural cover

Changes in natural cover between the historical and Current land uses suggest that there was a loss of approximately 3% of natural cover from 28% (1036 ha) to 25% (860 ha). Most of these losses seem to have occurred primarily in the southwest portion of the watershed where some residential and industrial development occurred. Gains in wetlands in Current scenario seem to be spurious and are mostly due to the availability of more refined information on wetlands using a more detailed data (e.g. TRCA ELC data, MNR wetland layer) that was previously unavailable. Using ELC data provides on-the-ground information that identified some of the forest as wetland (e.g. swamp) which was interpreted in 1999 through orthophotos as forest. The decline in meadow and increases in successional in the Current scenario could be due to meadows succeeding into later successional communities or losses of meadow cover during land use conversion.

The Current and +OP scenarios contain approximately 25% (860 ha) natural cover while the +NHS and +Potential Urban scenarios encompass 36% (1308 ha) natural cover, mostly driven by the enhanced NHS, which includes existing natural cover (25%; 860 ha) and additional areas that have potential to be restored to natural cover (11%; 448 ha). Most of these enhancements are located in the north portion of the watershed (Figure 1), where there are currently agricultural land uses that could be targeted for restoration through appropriate land use, natural heritage, and restoration planning processes. If these targeted potential areas for enhancement are restored, it will clearly increase natural cover quantity and also contribute to improving habitat quality that allows for enhanced ecological functions across the watershed.

When comparing the +NHS to +Potential Urban scenarios, natural cover remained constant as both scenarios used the same enhanced NHS, however there was a substantial increase in future urban land use and a decrease in agricultural cover as most of these areas are assumed to be built (as indicated in Table 4 and Section 5.1.).

5.2.2 Natural cover types

Table 5 indicates that under the Current scenario there was approximately 9% (341 ha) forest cover, 7% (240 ha) wetland cover, 3% (105 ha) meadow cover, 4% (164 ha) successional cover and <1% cover of beach/bluff (2 ha), open water (6 ha), and unclassified (2 ha) natural cover types.

Between the Current scenario and the +OP scenario, there is minimal changes in natural cover type, mainly because most of the land use changes are from agricultural or open space to built areas and do not include losses in natural cover. Even though these changes did not directly remove natural cover, eliminating open space does decrease opportunities for urban forest enhancement. Between the +OP and +NHS scenarios the increase in natural cover is approximately 11% of the watershed area. This is mainly attributed to the addition of more than 10% forests and successional habitat types and some wetland and meadows as assessed through TRCA ROP analysis. As discussed in Section 4.2. and Box 2 ROP analysis assumes that most of the future restored sites are ultimately targeted to be a forested ecosystem.

This indicates that the target enhanced NHS has the potential to increase overall habitat quantity as well as major habitat types substantially in the Carruthers Creek watershed. Though forests and successional patches are the habitat types that seem to have the highest restoration potential, there are a few opportunities for wetlands and meadows as well. The wetland opportunities are distributed throughout the watershed including the headwaters while meadow opportunities are primarily located near the Gatineau hydro corridor in the south. Further evaluation should be undertaken beyond the desktop analysis for wetlands and meadows to enhance these habitat types.

In terms of wetlands specifically, the results of the wetland catchment analysis (Appendix 2) indicated that in the +OP scenario, only one of the wetlands north of Taunton Road was projected to be impacted by new urban development. The single impacted wetland, located immediately south of the Highway 407 corridor, was however projected to be heavily impacted, with 61.8% of the catchment slated for new urban development. Impacts to this wetland via altered water balance would be very likely without consideration of mitigation measures using feature-based water balance in the design.

By contrast, in the +Potential Urban scenario, over 60% of the wetland catchments were projected to have high impact from the new urban areas as they overlap more than 10%, which is the threshold for significant impact. Furthermore, more than 30% of the wetland catchments analyzed (16 catchments) are projected to have >50% new urban area, meaning that extensive alteration of the wetland hydrology would be likely in the absence of design measures to help mitigate the impacts to wetland water balance. The most heavily impacted wetland catchments are generally in the areas along Westney Road, both north and south of Highway 7, and in the northernmost part of the watershed between Concession Road 7 and Concession Road 8. More data on the ecology and hydrological sensitivity of wetlands in this area, as well as on the form of urban development that might be proposed, would be needed to scope FBWB studies appropriately, should this part of the watershed be deemed appropriate for development. Development of this area of Carruthers Creek watershed, which contains many wetlands and headwater drainage features, may require municipal investment in proactive monitoring and subwatershed studies to avoid degradation of wetlands and adjacent natural heritage features via altered hydrology.

This analysis excluded consideration of wetlands in the more urbanized areas of the watershed south of Taunton Road. However, there may still be some benefit to considering FBWB in the design of infill developments and infrastructure retrofits within the area draining to these wetlands, where opportunities to restore hydrology or improve ecological function may exist.

5.3 Quality of natural cover

In CCWP the habitat quality is assessed based on two major indicators (i) Habitat patch quality evaluated by Landscape Analysis Model (LAM) (TRCA 2007), and (ii) habitat connectivity (TRCA 2017). Section 5.3.1. and Section 5.3.2. presents and discusses the implications of each land use scenario on the individual metrics used for LAM evaluation and habitat connectivity analysis respectively.

5.3.1 Habitat patch quality based on Landscape Analysis Model (LAM)

Table 6 provides an overview of the average and median values calculated for five specific metrics used in the LAM evaluation; total number of patches, patch size (ha), patch shape, surrounding matrix influence, and total LAM score and rank. Each of the metric and changes under each land use scenario is discussed in the following sections.

Table 6. Summary of natural cover quality indicators under four land use scenarios for the Carruthers Creek watershed

Parameter	Average				Median			
	Current	+OP	+NHS	+Pot. Urban	Current	+OP	+NHS	+Pot. Urban
Number of patches (#)	734	735	536	538	734	735	536	538
Patch size (ha)	1.3	1.3	2.7	2.6	0.2	0.2	0.2	0.2
Patch shape (PAR)	244	244	246	247	204	203	201	202
Matrix influence (score)	7.7	4.4	13.4	5	15	14	30	6.6
Total LAM score (score)	7.6	7.5	7.9	7.6	8	8	8	8
L-Rank	L4 poor	L4 poor	L4 poor	L4 poor	L4 poor	L4 poor	L4 poor	L4 poor

5.3.1.1 Patch number

In general, the average number of patches remains the same between the Current and +OP scenarios as they are using the same natural cover data, but decreases substantially under the +NHS and +Potential Urban scenarios, both of which include the enhanced NHS. This decrease may reflect the overall decrease in fragmentation as the patches are more cohesive under the enhanced NHS that attempts to increase the overall size and shape of the patches. Alternatively, this decrease may also be reflective of the method used in this analysis where most future natural cover patches (including meadow and riparian) were assumed to have succeeded into a mature forest patch after 50 to 70 years. Given the changing landscape conditions and other drivers this may or may not happen, especially under the +Potential Urban scenario.

5.3.1.2 Patch size

In terms of patch size, the land use scenarios with the enhanced NHS (+NHS and +Potential Urban) have almost double the average patch size compared to the Current and +OP scenarios. This supports the previous notion that if target areas in the enhanced NHS is restored to natural cover, it has potential to maintain larger habitat patches in the watershed, which are relatively more functional than the smaller fragmented ones. The average patch shape is also slightly better in the two land use scenarios with the enhanced NHS, further contributing to improve the quality of habitat patches.

5.3.1.3 Patch shape

The patch shape value (perimeter to area ratio) stays relatively similar among scenarios indicating that there is not much improvement in the overall shape of the habitat patches. The +NHS and +Potential Urban scenarios have slight increases in average value indicating that even though the potential natural areas are added under these scenario, they have done little to enhance the overall shape of the habitat patches in the entire watershed. This stand alone metric reveals that the additional areas in the enhanced NHS are not effective in reducing the ecological impacts (e.g. edge effects) in the existing areas as much, which makes sense as most of the enhancement is in the North where there is little existing natural cover.

5.3.1.4 Matrix influence

The average matrix influence result shows an interesting, but not surprising, trend. It decreases substantially from the Current (7.7) to +OP scenario (4.4) indicating that the positive influences are decreasing as additional areas are built in the watershed. However, as the NHS is enhanced in the +NHS scenario, the positive matrix influence increases almost threefold and decreases again as the remainder of the watershed is assumed to be built under the +Potential Urban scenario. These findings suggest that enhancing the NHS improves the physical structure of the patches and minimizes matrix influences on existing natural cover patches in the Current scenario; however, the build out in the +Potential Urban scenario contributes to a total patch score and matrix influence similar to the Current scenario.

5.3.1.5 Patch score and L-rank

Lastly, the overall habitat patch quality summarized as per the TRCA LAM (TRCA 2007) scores and L-ranks suggest that overall patch quality was on average “Poor” in the Carruthers Creek watershed although there was variation in size, shape and matrix influence as discussed above. Given that the overall score and L-rank takes into account the information provided by all of the size, shape, and matrix influence discussed above more comprehensively, it allows for the rapid but more robust assessment of the habitat patch quality.

Figure 2 shows the distribution of the L-ranks of the habitat patches and also demonstrates how the additional built areas can decrease the quality of a habitat patch from a higher quality rank to a lower quality rank through matrix influences without any changes in the structural attributes of the habitat patch itself. An example of this is in the Rossland Road wetland patch (blue circles), which changed from L3 to L4 between the Current and +OP scenarios south of Taunton Rd. Another example is the L2 patch (red circles) that changed from L2 to L3 between the +NHS and +Potential Urban scenarios north of Taunton Rd.

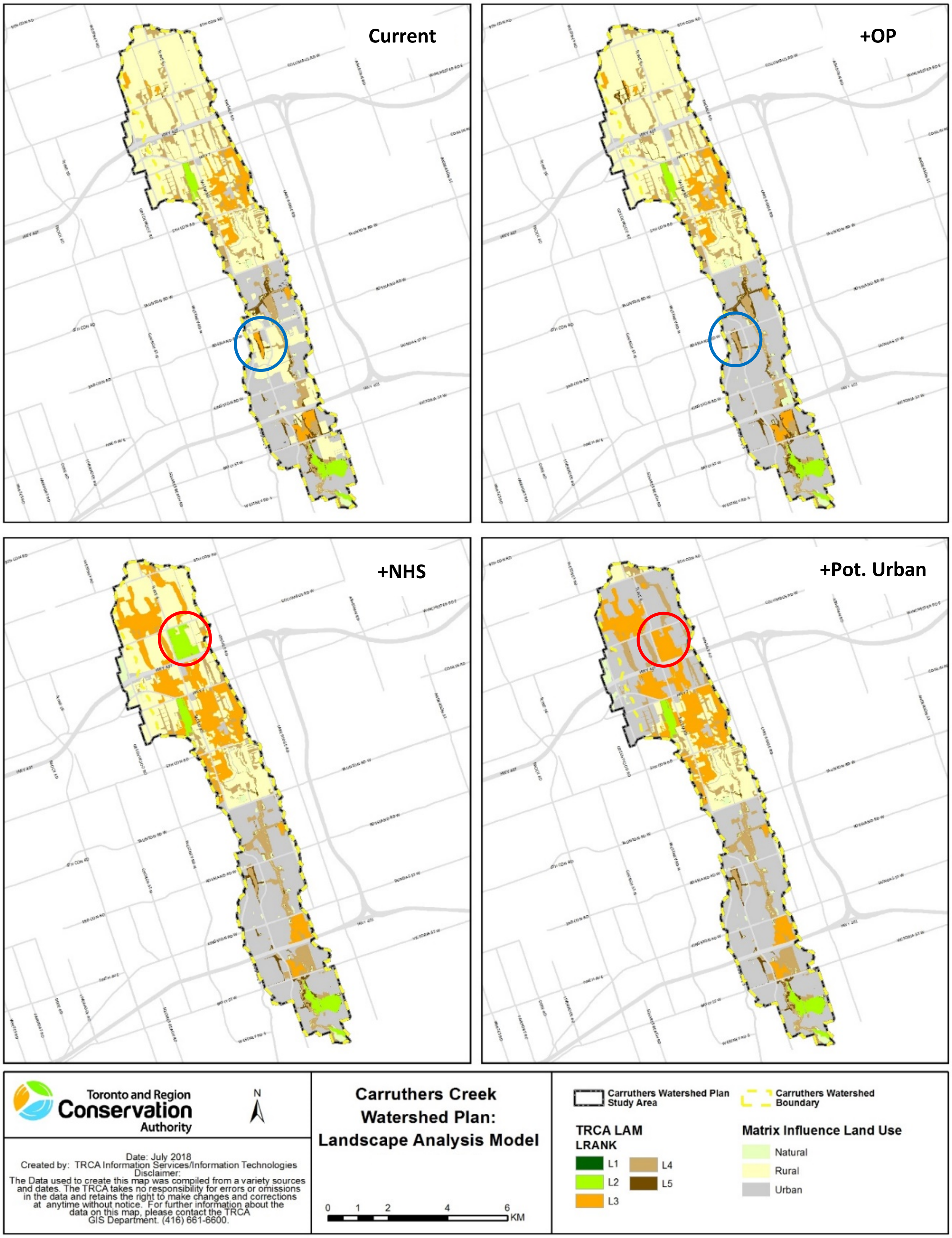


Figure 2. Overall habitat patch quality ranks (L-ranks) in the Carruthers Creek watershed under the Current, +OP, +NHS, and +Potential Urban land use scenarios (with examples of changes in L-ranks in Blue and Red circles).

5.3.2 Landscape connectivity

The results of the habitat connectivity model that shows the priority areas for the (a) regional connectivity at TRCA region scale, (b) regional connectivity at watershed scale (study area boundary), (c) local connectivity for wildlife moving between forests, and (d) local connectivity for wildlife moving between forests and wetlands are displayed in Figure 3a through d.

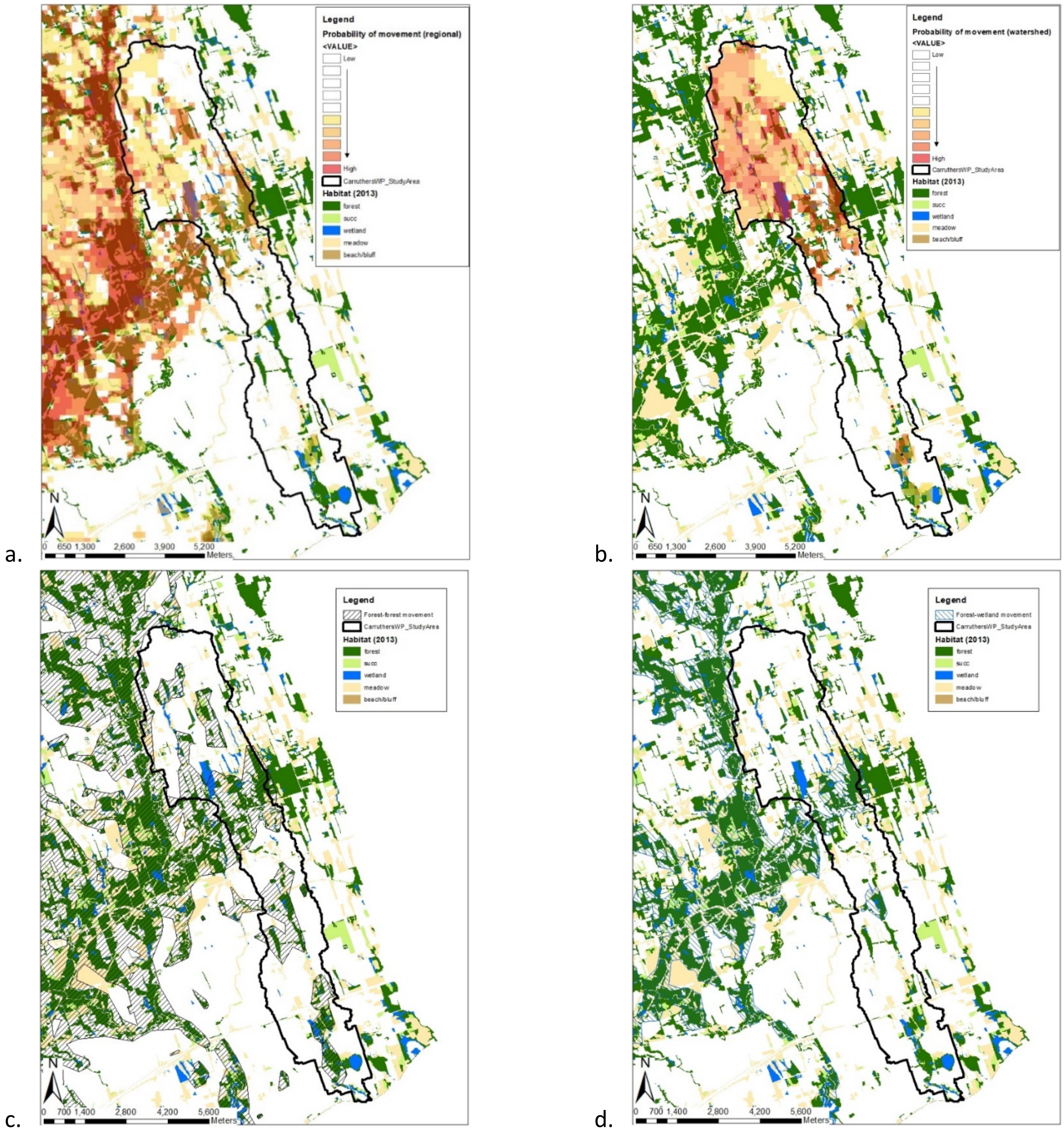


Figure 3. Habitat connectivity priority areas (TRCA 2015) for (a) regional connectivity at TRCA region scale, (b) regional connectivity at watershed scale, (c) local connectivity for wildlife moving between forests, and (d) local connectivity for wildlife moving between forests and wetlands.

The habitat connectivity priority areas are overlaid with the natural heritage areas under each land use scenario and estimates of total area (ha) and percent of total habitat connectivity priority areas under protection of the NHS within the Carruthers Creek watershed are summarized in Table 7 and discussed in the following sections. Furthermore, a deep dive into the opportunities for improving habitat connectivity in the urbanized sections (south of Taunton Road) and the rural section (North of Taunton Road) of the watershed are also discussed separately in the Section 5.3.2.3.

Table 7. Habitat connectivity priorities overlapping with the NHS areas in the Carruthers Creek watershed under the Current, +OP, +NHS, and +Potential Urban land use scenarios.

Habitat Connectivity	Total area (ha)	Total area (in hectares) of Habitat Connectivity Priority Area in NHS				% of Habitat Connectivity Priority Area in NHS			
		Current	+OP	+NHS	+Pot. Urban	Current	+OP	+NHS	+Pot. Urban
Regional Connectivity (TRCA scale)*	1628	450	450	756	756	28	28	46	46
Regional Connectivity (Watershed-scale)*	2259	628	630	1009	1009	28	28	45	45
Local Connectivity (Forest-forest)	1363	591	612	805	805	43	45	59	59
Local Connectivity (Forest-wetland)	317	189	189	209	209	60	60	66	66

* Top 50th percentile of cumulative current density value relative to the TRCA region and the Carruthers Creek watershed respectively

5.3.2.1 Regional connectivity

Figures 3a and 3b show that the regional connectivity priorities at both the TRCA-wide scale and watershed scale are mostly located in the north and the middle sections of the watershed, where there is more natural cover and/or close proximity to natural features. This is not surprising given that the regional connectivity model prioritizes areas where habitat patches are closer, are surrounded by a more hospitable matrix, and are often the critical pathways such that if it is lost then there are major implications to regional habitat connectivity. The distribution of the priority areas captures the important east-west corridors including areas along the Lake Iroquois shoreline and areas along the northwestern edge of the watershed. Areas along the Lake Iroquois shoreline are important for movements to the west towards the Rouge National Urban Park and to the east into the Lynde Creek watershed. Areas along the Lake Iroquois shoreline and the northwestern edge of the watershed are important for movements between the Carruthers Creek watershed and the adjacent Duffins Creek. Duffins Creek has been identified regionally as an important north-south corridor connecting to the Oak Ridges Moraine in the north and Lake Ontario in the south with additional connections to the Lake Iroquois shoreline corridor.

A comparison of the habitat connectivity priorities coverage within the NHS under each land use scenario (Table 7) indicates that there is a substantial increase in areal coverage of priority areas under the enhanced NHS scenarios (+NHS and +Potential Urban) compared to the Current and +OP scenarios. The coverage of regional connectivity priorities at both the TRCA scale and watershed scale almost doubles (from 28% to 46%) once the NHS is enhanced. This is an important ecological gain for natural heritage, as this suggests that the enhanced NHS is contributing to facilitate the long-term dispersal movements between patches that will allow wildlife to adapt to the habitat change induced by changes in land use and/or climate. These may be infrequent movements but important for wildlife to persist in the landscape and deal with uncertainties. However, it is worth noting that as the built portions of the watershed increase (+Potential Urban scenario) there will be more inhospitable areas for these wildlife (e.g. roads, buildings) that will have additional adverse impacts, which will compromise the estimated gains in connectivity through the enhanced NHS.

5.3.2.2 Local connectivity

Figures 3c and 3d show that the local connectivity priority areas that reflect the movement between forests and between forest and wetlands are also concentrated in the north and the middle sections of the watershed. Nevertheless, there are also large areas in the southern section, where there are existing forests and wetlands. Some of these areas include connections between the Rossland Road wetland and the central riparian corridor along with the riparian corridor south of Kingston Road to Carruthers Marsh. These areas are important to consider for restoration planting or urban forest enhancement to contribute to wildlife movement opportunities (Urban Forest Assessment, TRCA 2019).

The coverage of the priority areas for the local connectivity between forest patches increases from about 45% to 60% and between forests and wetlands increases slightly from 60% to 66% under the enhanced NHS scenarios (+NHS and +Potential Urban). Given that the local connectivity priority areas are located immediately around the existing features, it is not surprising that the extent of increase in coverage is relatively low. Most of these areas are likely to be already within the NHS in the Current and +OP scenarios due to various regulations and feature-based assessments (e.g. buffers). The increase in coverage, however, does indicate filling the gaps by creating habitat, widening corridors, and decreasing the distance between habitat patches, which when combined enhances the corridor function that lies beyond already included areas. This increased coverage of local connectivity will ensure that the immediate daily and seasonal movements that often result in direct impacts, such as road mortality, will be reduced substantially.

Nevertheless, under the +Potential Urban scenario, which primarily affects the north sections of the watershed, the build out creates a less hospitable matrix for movements compared to the existing agricultural/open country matrix (EC 2013). The enhanced NHS facilitates movements in corridors that were completely connected, and lessens the distance between natural cover patches; however, movements between unconnected patches will be challenging for the wildlife unless measures are taken to enhance connectivity through other means (e.g. wildlife crossing structures, eco-passages).

In all scenarios, the heavily used Lake Iroquois shoreline is preserved and provides continued east-west large-scale movement opportunities to areas outside the watershed and small-scale movement opportunities within the watershed. The land use and infrastructure planning processes should take into consideration various connectivity guidelines including those provided in the TRCA *Crossings Guideline for Valley and Stream Corridors* (TRCA 2015), CLOCA's *Wildlife Corridor Protection and Enhancement Plan* (2015), as well as those outlined in the Greater Golden Horseshoe Growth Plan (2017), which states that "connectivity along the system and between key natural heritage features and key hydrologic features located within 240 m of each other will be maintained or, where possible, enhanced for the movement of native plants and animals across the landscape" (MMA 2017).

In addition to the watershed level discussion, the following sections discuss specific opportunities within the watershed for regional and local connectivity enhancement. The results are discussed separately for (i) the more urbanized areas south of Taunton Road and (ii) the relatively rural areas North of Taunton Road.

5.3.2.3 Habitat connectivity improvement opportunities

a. South of Taunton Rd. (Urban context)

Specific areas for regional and local connectivity enhancement are provided for the more urbanized region of the Carruthers Creek watershed (south of Taunton Road) in Figure 4 and discussed in this section. The small strip of natural cover maintained between the Rossland Road wetland and Carruthers Creek in the +OP scenario is very important to maintain because this wetland is otherwise isolated. Under the +NHS scenario this area is enhanced with additional natural cover and this is necessary since under the OP the previously open areas surrounding the wetland are being converted to commercial/industrial. There is an existing culvert under Salem road along this corridor which should allow for wildlife passage but this should be confirmed (Figure 4a).

Significant commercial development is expected under the OP for the area near Salem Road North immediately south of the railway line (just north of Rossland Road). There is a wetland in this area with good connectivity to other natural cover patches to the east; however, connections to the west and to areas outside of the watershed should be maintained (and likely will be along the railway line). Another change under the +OP scenario includes some additional residential development south of Bayly Street East and just north of the Ajax Warbler Swamp. This area is agriculture under the Current scenario and it is likely that some movements are occurring. Residential development makes movements more difficult with numerous changes to the landscape structure (e.g. paved roads, predator community changes, physical barriers). If not already present, a wildlife passage should be created along Shoal Point Road between the Ajax Warbler Swamp and the main Carruthers Creek.

It is important to note that this section highlights changes under the various land use scenarios and is not an exhaustive list of connectivity improvements and mitigation measures that could be made in the watershed. It is recommended that road mortality studies are conducted to determine areas that pose the greatest current mortality threats to reptiles, amphibians and small mammals specifically related to road mortality and choose several of the most heavily impacted sites to mitigate current impacts.

b. North of Taunton Rd. (Rural context)

Specific areas for regional and local connectivity enhancement are provided for the more rural region of the Carruthers Creek watershed (North of Taunton Road) in Figure 5 and discussed in this section. Between the Current and +OP scenarios in the north, the major changes involve the conversion of open space to industrial or residential. Conversion from open space to industrial has already occurred under the OP for an area immediately to the east of Salem Road and south of the Highway 407 extension. This conversion created several structures, a parking lot, a road and what appears to be several industrial ponds. Also, a small portion of the woodlot to the east appears to have been cleared. While the majority of these changes do not directly remove natural cover and are generally minimal in this situation, structural changes to the landscape that create a more inhospitable landscape (e.g. paved areas, vehicular traffic) are additive and when considered over a larger area or longer time period these minor changes can cause major connectivity impacts for wildlife (Theobald et al. 1997). Connectivity is improved in this area under the +NHS scenario where the area is now bordered by natural cover instead of agriculture. Under the +Potential Urban scenario, this area maintains the enhanced natural cover but loses any remaining agricultural areas nearby.

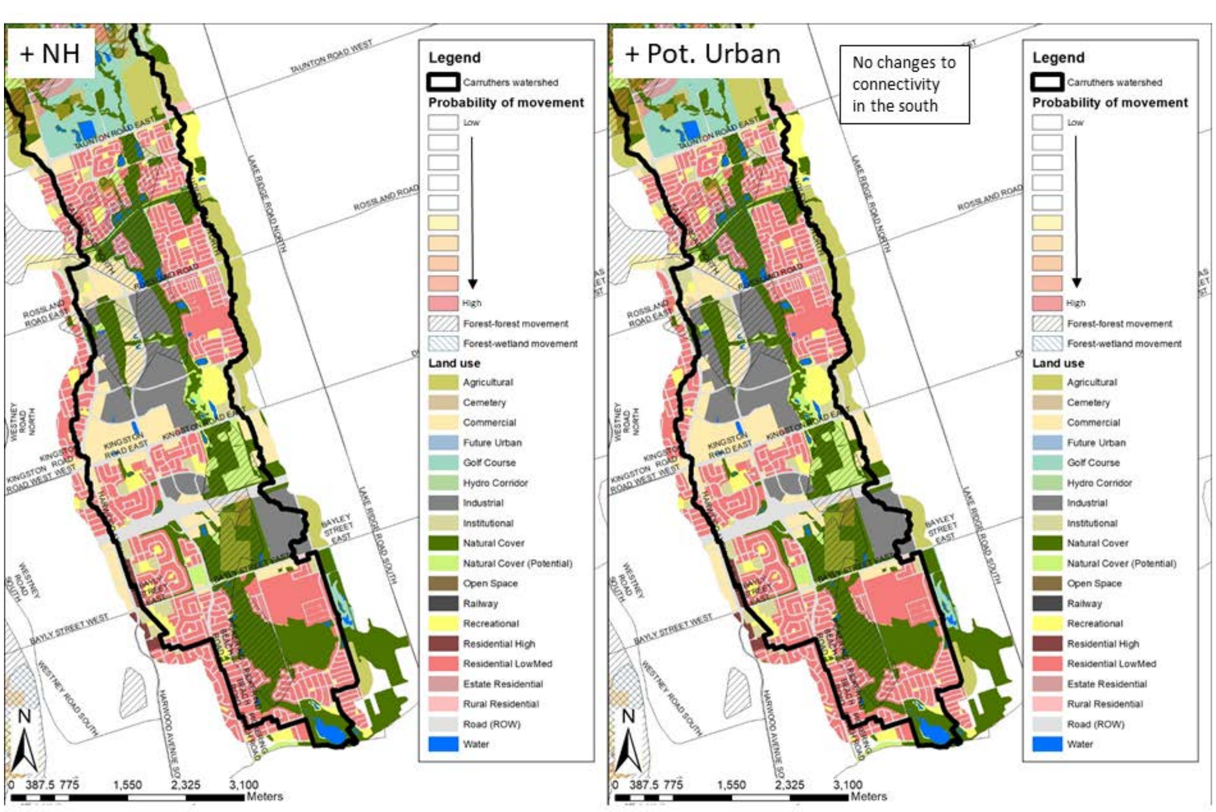
A portion of the Deer Creek Golf Club and several areas just to the north of the golf course (off of Sideline 4) change from open space to estate residential under the +OP scenario. These changes pose similar challenges to wildlife as those just mentioned including primarily the creation of a less hospitable environment and cumulative effects over larger areas or longer time periods. If still possible, integrating restoration opportunities (through the ROP process) within the new estate residential areas and adding wildlife passage opportunities in areas where roads are planned (if not able to create the road around natural cover features) or retrofitting roads could be considered.

When comparing general connectivity north of Taunton Road between the +OP and +NHS scenarios, connectivity is greatly improved specifically for forest-forest movements (Figure 5). Enhancements to natural cover generally do not overlap roads except for at a few specific locations such as the intersection of the 8th Concession and Sideline 6 in the far north of the watershed. It would be important to consider a wildlife passage structure in this area because there are potentially some wet areas just north of the 8th Concession and movement could occur between these areas and the enhanced areas just to the south. Enhancements in natural cover under the +NHS scenario also create a new movement corridor crossing the 7th Concession west of Balsam Road and east of Sideline 6. The habitat to the south of the 7th Concession that would be connected to enhanced natural cover to the north of the 7th Concession is currently being used by many bird species along with spring peepers (*Pseudacris crucifer crucifer*), wood frogs (*Lithobates sylavatica*) and American toads (*Anaxyrus americanus*); species that would cross roads to get to habitat required for their life cycle and that are particularly vulnerable to road mortality (Trombulak and Frissell 2000). New connections are also created across Salem Road just north and south of the 6th Concession and this would require wildlife passages for a similar suite of species as just mentioned, along with the common snapping turtle (*Chelydra serpentine serpentina*) that was found using natural cover adjacent to Salem Road in this area. There is also a new natural cover connection formed intercepting Salem Road just north of Buggey Lane that could be considered for a wildlife passage structure.

Under the +Potential Urban scenario, connectivity is maintained through the enhanced NHS; however, any movements that were occurring in agricultural areas are now greatly impeded, if not eliminated. This loss of connectivity through urban development makes the creation of wildlife passages connecting the enhanced NHS essential under this scenario. In addition to wildlife passages, several measures could be considered to lessen the impacts of development on connectivity such as using ROPs to create areas of connected natural cover throughout developments, identifying and implementing green infrastructure capable of supporting species identified in the area and/or considering the density and pattern of urban development that minimize impacts on connectivity (e.g. compact/clustered/land sparing patterns of development; Tannier et al. 2016, Villansenor et al. 2017, Geschke et al. 2018).

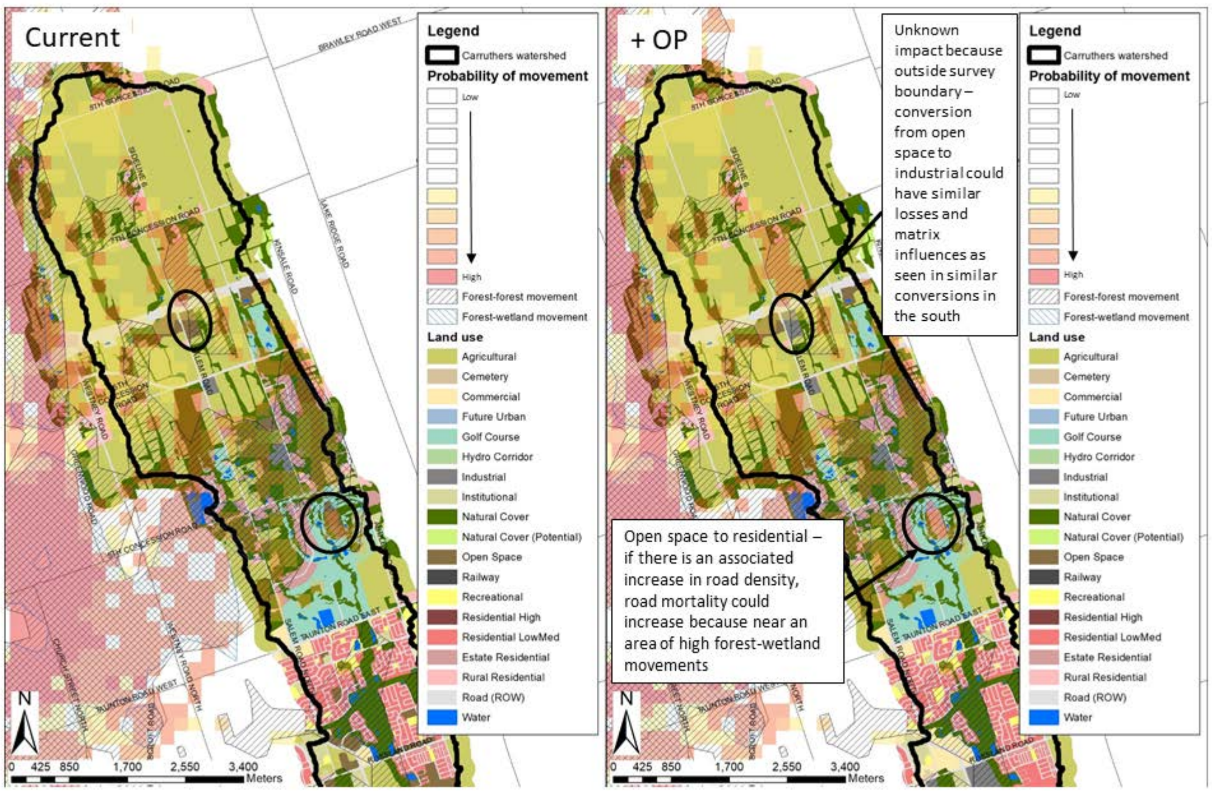
(a)

(b)

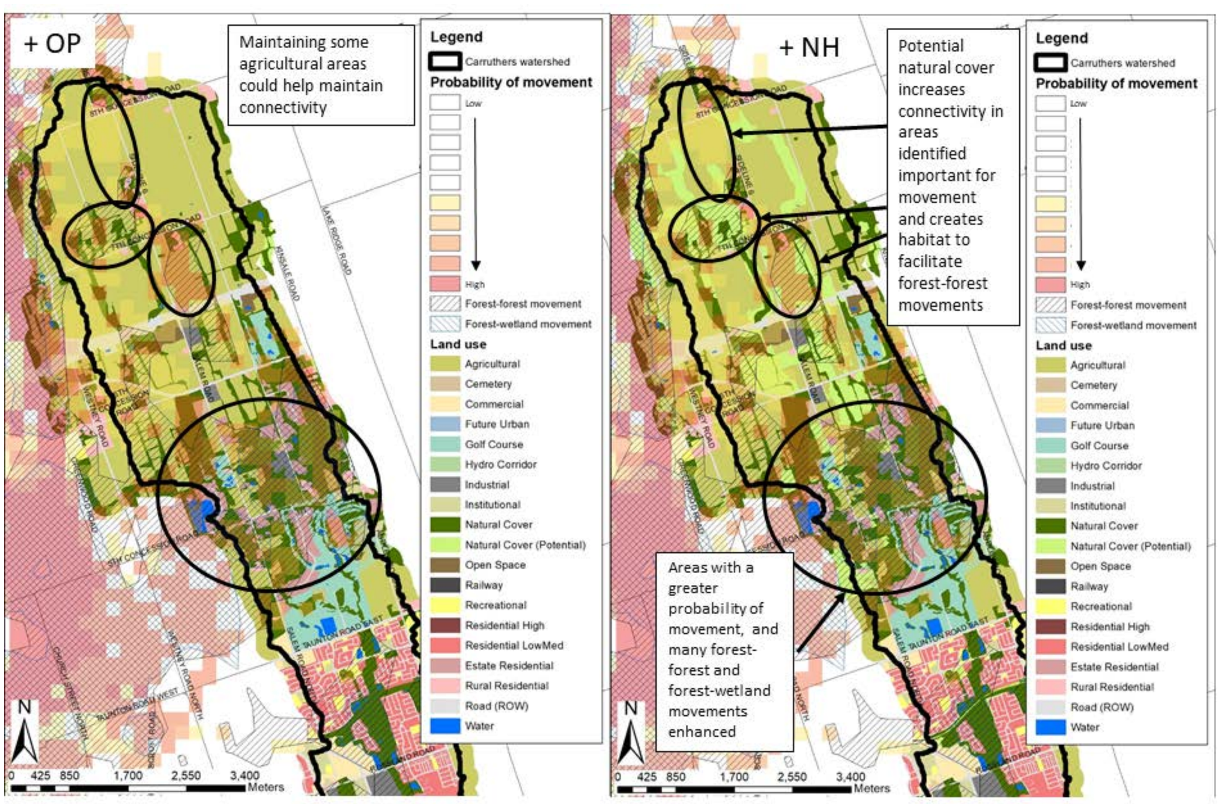


(c)

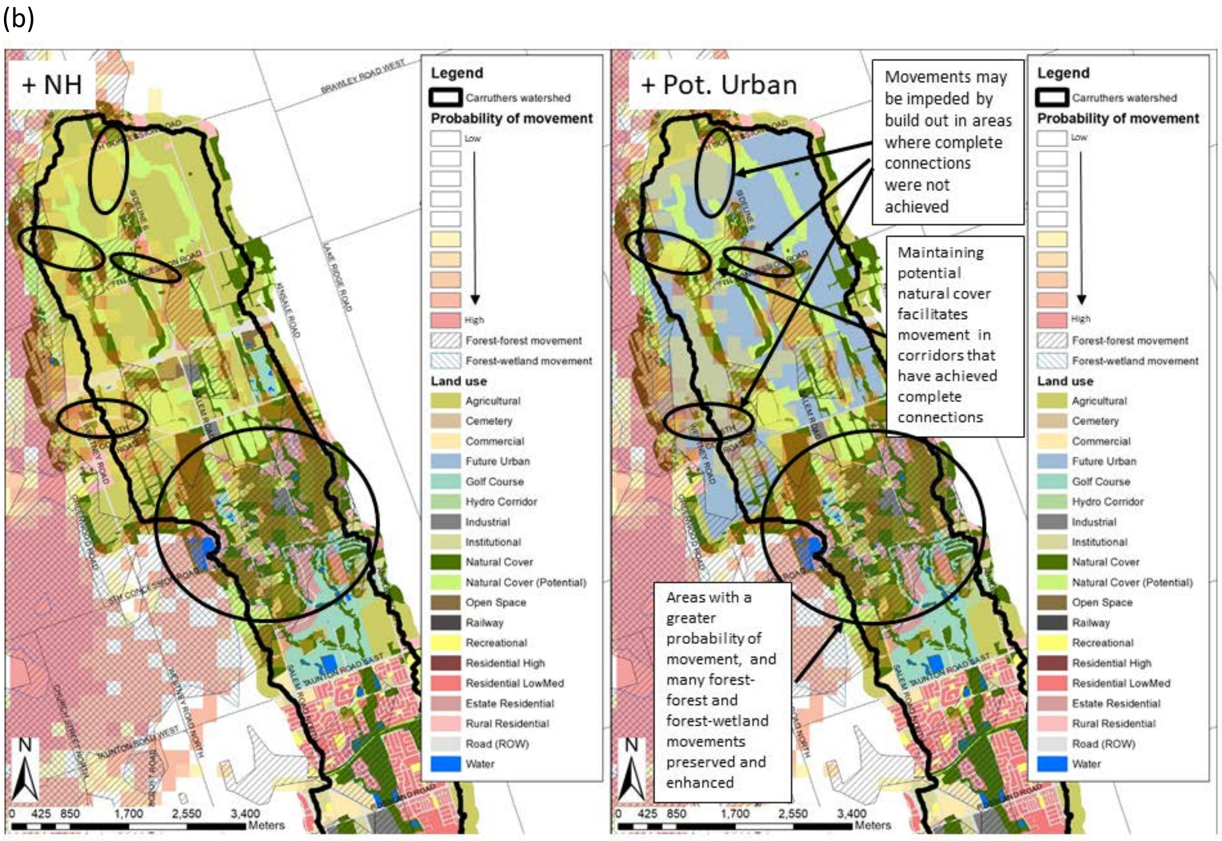
Figure 4. Predicted changes in habitat connectivity south of Taunton Road between (a) Current and +OP, (b) +OP and +NHS and (c) +NHS and +Potential Urban scenarios



(a)



(b)



(c)

Figure 5. Predicted changes in habitat connectivity north of Taunton Road between (a) Current and +OP, (b) +OP and +NHS, and (c) +NHS and +Potential Urban scenarios

5.4 Fauna and vegetation communities

In 2015 and 2016, approximately 760 ha of natural cover was surveyed throughout the watershed to create an in-depth biological inventory of fauna and ELC vegetation communities. The summary of the results are presented in Section 5.5.1 and 5.5.2 for fauna and vegetation communities respectively. More detailed discussion on the results of inventory can be found in TRCA (2017a) along with results from previous inventory surveys.

For the CCWP TIA, the expected impacts on fauna species and vegetation communities under each of the three land use scenarios was assessed separately for the more urbanized section (south of Taunton Road) and the relatively more rural section (North of Taunton Road) of the watershed. The results and discussion are provided in more detail in Sections 5.5.3.

This analysis was conducted using the CCWP watershed boundary. Furthermore, to complement this comprehensive analysis that takes a regional species of conservation concern approach (TRCA 2007), a separate but related discussion on Species at Risk in Ontario (SARO) is provided in Box 3 (p. 47) to inform the watershed planning process.

5.4.1 Fauna species of conservation concern

Surveys conducted in 2015 and 2016 found 113 fauna species including 43 species of conservation concern (Table 8).

Table 8. Fauna species of conservation concern (L1, L2, L3) detected in 2015/2016 Carruthers Creek watershed inventory

Common name	Scientific name	Species code	2014 L-rank
black and white warbler	*Mniotilta varia*	BAWW	L2
bobolink	*Dolichonyx oryzivorus*	BOBO	L2
common snapping turtle	*Chelydra serpentina serpentina*	SNTU	L2
grey treefrog	*Hyla versicolor*	TGTF	L2
ovenbird	*Seiurus aurocapillus*	OVEN	L2
ruffed grouse	*Bonasa umbellus*	RUGR	L2
spring peeper	*Pseudacris crucifer crucifer*	SPPE	L2
wood frog	*Lithobates sylvatica*	WOFR	L2
alder flycatcher	*Empidonax alnorum*	ALFL	L3
American redstart	*Setophaga ruticilla*	AMRE	L3
American woodcock	*Scolopax minor*	AMWO	L3
bank swallow	*Riparia riparia*	BANS	L3
black-billed cuckoo	*Coccyzus erythropthalmus*	BBCU	L3
black-throated green warbler	*Setophaga virens*	BTNW	L3
brown creeper	*Certhia americana*	BRCR	L3
brown thrasher	*Toxostoma rufum*	BRTH	L3
chestnut-sided warbler	*Setophaga pensylvanica*	CSWA	L3
clay-coloured sparrow	*Spizella pallida*	CCSP	L3
eastern meadowlark	*Sturnella magna*	EAME	L3
eastern towhee	*Piplio erythrophthalmus*	EATO	L3
ermine	*Mustela erminea*	ERMI	L3
great blue heron	*Ardea herodias*	GBHE	L3
hairy-tailed mole	*Parascalops breweri*	HTMO	L3
hooded merganser	*Lophodytes cucullatus*	HOME	L3
horned lark	*Eremophila alpestris*	HOLA	L3
least flycatcher	*Empidonax minimus*	LEFL	L3
meadow jumping mouse	*Zapus hudsonius*	MJMO	L3
midland painted turtle	*Chrysemys picta marginata*	MPTU	L3
mourning warbler	*Geothlypis philadelphia*	MOWA	L3
northern harrier	*Circus cyaneus*	NOHA	L3
northern leopard frog	*Lithobates pipiens*	LEFR	L3
northern waterthrush	*Parkesia noveboracensis*	NOWA	L3
osprey	*Pandion haliaetus*	OSPR	L3
pileated woodpecker	*Dryocopus pileatus*	PIWO	L3
scarlet tanager	*Piranga olivacea*	SCTA	L3
star-nosed mole	*Condylura cristata*	SNMO	L3
veery	*Catharus fuscescens*	VEER	L3
vesper sparrow	*Pooecetes gramineus*	VESP	L3
Virginia rail	*Rallus limicola*	VIRA	L3
wild turkey	*Meleagris gallopavo*	WITU	L3
winter wren	*Troglodytes hiemalis*	WIWR	L3
wood thrush	*Hylocichla mustelina*	WOTH	L3
yellow-billed cuckoo	*Coccyzus americanus*	YBCU	L3

5.4.2 Vegetation communities of conservation concern

Surveys conducted in 2015 and 2016 found 140 vegetation community types, including 39 community types of conservation concern (ranked L1, L2 or L3) covering 41.9 ha (Table 9).

Table 9. ELC communities of conservation concern (L1, L2, L3) mapped in 2015/2016 Carruthers Creek watershed inventory

ELC name	ELC code	Hectares	2014 L-rank
Treed Sand Barren	SBT1	13547	L2
Mineral Fen Meadow Marsh	MAM5-1	9356	L2
Sea Rocket Open Sand Beach	BBO1-1	5221	L2
Dry-Fresh White Pine - Oak Mixed Forest	FOM2-1	4616	L2
White Cedar - Scots Pine Low Treed Mineral Fen	FET2-B	2345	L2
Shrub Clay Barren	CBS1	2058	L2
Bladderwort Mixed Shallow Aquatic	SAM1-6	1502	L2
Dropseed Open Sand Barren	SBO1-A	1469	L2
White Cedar Treed Bluff	BLT1-A	962	L2
Flat-stemmed Bluegrass - Forb Open Sand Barren	SBO1-B	910	L2
Willow Shrub Mineral Fen	FES2-A	803	L2
Willow Shrub Beach	BBS1-2A	758	L2
Red Maple Organic Deciduous Swamp	SWD6-1	743	L2
White Cedar Low Treed Mineral Fen	FET2-A	500	L2
Broad-leaved Cattail Organic Shallow Marsh	MAS3-1A	180100	L3
Fresh-Moist Beech - Hardwood Deciduous Forest	FOD9-D	38339	L3
Fresh-Moist Sugar Maple - Yellow Birch Deciduous Forest	FOD6-3	35265	L3
Pondweed Mixed Shallow Aquatic	SAM1-4	18169	L3
Fresh-Moist Cottonwood Tall Treed Woodland	CUW1-A4	16498	L3
Nannyberry Mineral Thicket Swamp	SWT2-10	11142	L3
Dry-Fresh Oak - Red Maple Deciduous Forest	FOD2-1	9004	L3
Dry-Fresh Poplar Mixed Forest	FOM5-2	7906	L3
Paper Birch - Poplar Organic Deciduous Swamp	SWD7-1	7361	L3
White Cedar - Conifer Mineral Coniferous Swamp	SWC1-2	6639	L3
Red Oak Non-tallgrass Woodland	CUW1-2	5193	L3
Broad-leaved Sedge Mineral Shallow Marsh	MAS2-4	5011	L3
Forb Organic Meadow Marsh	MAM3-9	4387	L3
Rush Mineral Meadow Marsh	MAM2-C	4136	L3
Fresh-Moist Poplar Mixed Forest	FOM8-1	4107	L3
Broad-leaved Sedge Mineral Meadow Marsh	MAM2-6	3933	L3
Narrow-leaved Sedge Mineral Meadow Marsh	MAM2-5	3556	L3
Fresh-Moist Hemlock - Hardwood Mixed Forest	FOM6-2	3402	L3
Fresh-Moist Paper Birch Mixed Forest	FOM8-2	2920	L3
Bluejoint Mineral Meadow Marsh	MAM2-1	2307	L3
Mineral Treed Beach	BBT1-A	2023	L3
Dry-Fresh Hardwood - Hemlock Mixed Forest	FOM3-1	1515	L3
Bur-reed Mineral Shallow Marsh	MAS2-7	1244	L3
Sumac - Willow - Cherry Shrub Bluff	BLS1-A	355	L3
Horsetail Mineral Shallow Marsh	MAS2-C	300	L3

5.4.3 Fauna and vegetation improvement opportunities

5.4.3.1 South of Taunton Rd. (Urban context)

Most areas south of Taunton Road have already been developed under the Current land use scenario and the predicted future changes are minimal. One notable change is between the Current and +OP scenarios, where some of the open space designated areas are converted into built land uses. These areas are discussed in this section.

a. Fauna Species

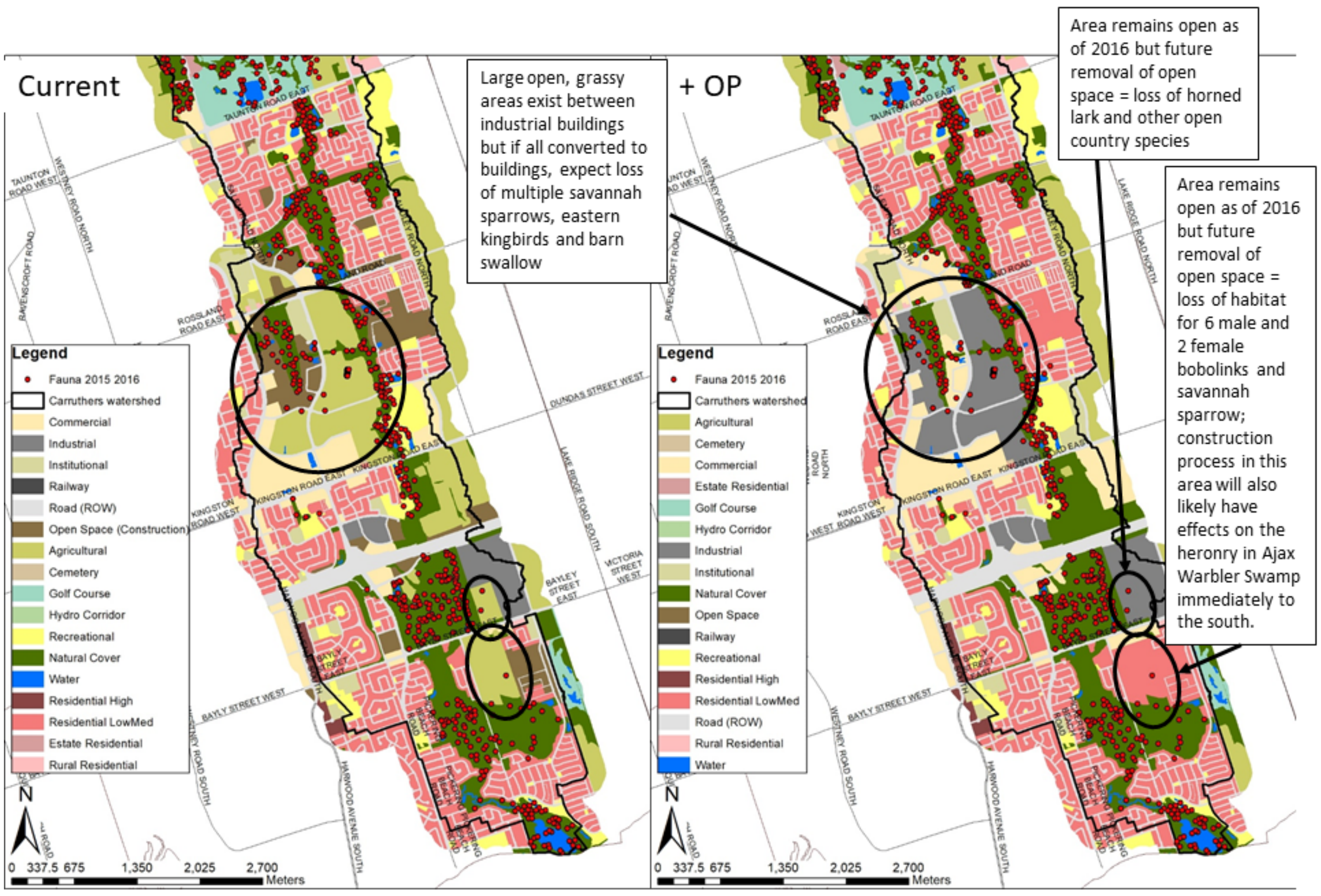
The conversion of open space areas to industrial or residential land uses (from Current to +OP scenario) could lead to the loss of habitat for at least six species: bobolink (*Dolichonyx oryzivorus*), common raven (*Corvus corax*), horned lark (*Eremophila alpestris*), willow flycatcher (*Empidonax traillii*), savannah sparrow (*Passerculus sandwichensis*), northern flicker (*Colaptes auratus*), eastern kingbird (*Tyrannus tyrannus*) and gray catbird (*Dumetella carolinensis*) (Figure 6a). An urban matrix often has more negative consequences for wildlife using natural cover patches compared to an agricultural matrix because the predator community and density are different with areas of higher housing densities containing a higher abundance of blue jay (*Cyanocitta cristata*), domestic cats (*Felis catus*), raccoons (*Procyon lotor*) and opossum (*Didelphis virginiana*; Haskell et al. 2001). An increase in nest predators is an important consideration for breeding songbirds because nest predation is the leading cause of nest failure in birds and this affects recruitment to the population (Martin 1995). Urban noise is another issue for birds because urban noise can interfere with avian communication methods and lead to lower densities of breeding birds near roads (Reijnen et al. 1995). As shown in Figure 6b, enhancements to the NHS under +NHS scenario can buffer some of these impacts and should be strongly considered for these areas.

It is important to note that areas with natural cover were the focus of inventory surveys. The areas circled in Figure 6b were not thoroughly surveyed and were surveyed by biologists from the edge using long distance aural and visual detection methods. Based on this, the loss of habitat and associated species should be considered an underestimate and it is likely that more species were using these habitats.

b. Vegetation Communities

As depicted in Figure 7a, land use changes between Current conditions and +OP were minimal but there were direct community losses and additional matrix influences that could contribute to community loss or degradation. The Rossland Road wetland could respond negatively to an increase in industrial areas adjacent to the wetland if more surfaces become impervious. Impervious surfaces do not allow for natural infiltration and water runs off into adjacent natural areas along with road salts, sediments and associated nutrients and contaminants (Dietz and Clausen 2008). This wetland also contains numerous sensitive species such as twig-rush (*Cladium mariscoides*; L2), a seepage fen specialist (TRCA 2017a, Pennsylvania Natural Heritage Program 2018). Conserving habitat for this species and other fen specialists would involve enhancing buffers, controlling invasive species and protecting the natural hydrology of the wetland (Pennsylvania Natural Heritage Program 2018). Figure 7b shows the extent to which some of these impacts could be buffered using the enhanced NHS under the +NHS scenario and should be strongly considered for these areas.

Also, it is important to note that this assessment of vegetation communities was based on ELC data that are mostly within the natural areas that will likely not be removed for development under any of the land use scenarios. However, substantial changes could occur in vegetation through urban matrix influences.



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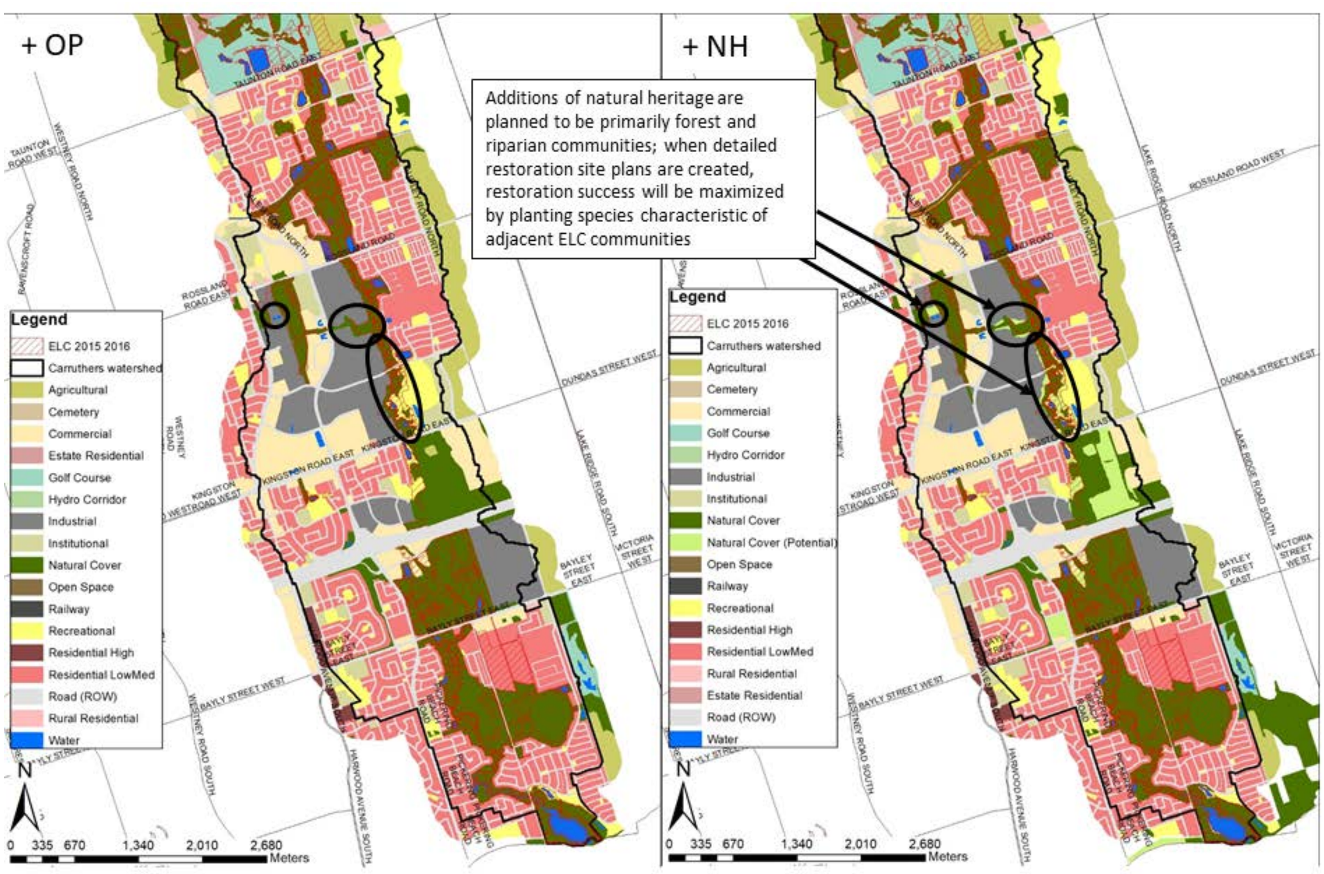

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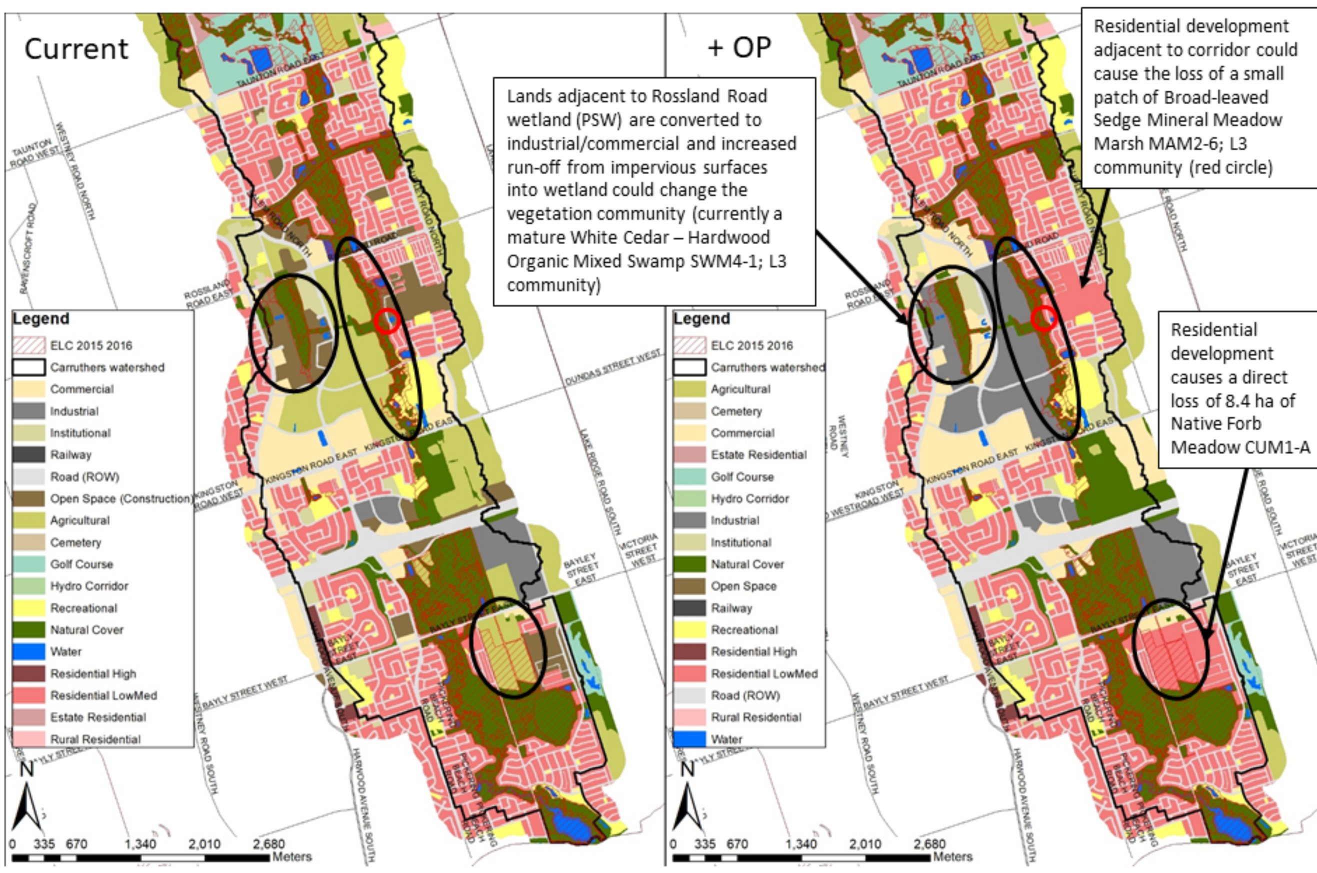
Figure 6. Predicted changes in fauna south of Taunton Road between (a) Current and +OP, (b) +OP and +NHS, and (c) +NHS and +Potential Urban scenarios



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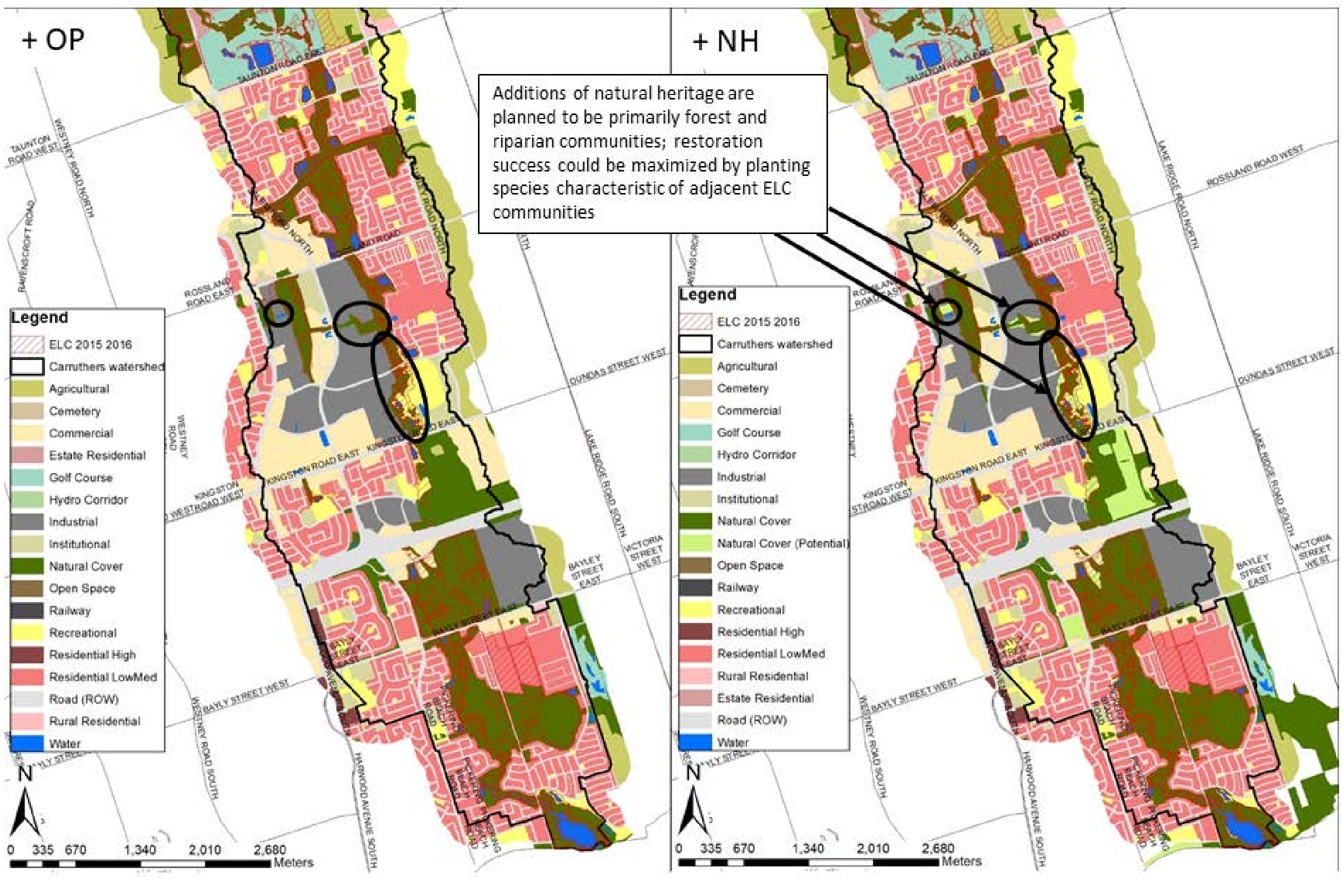

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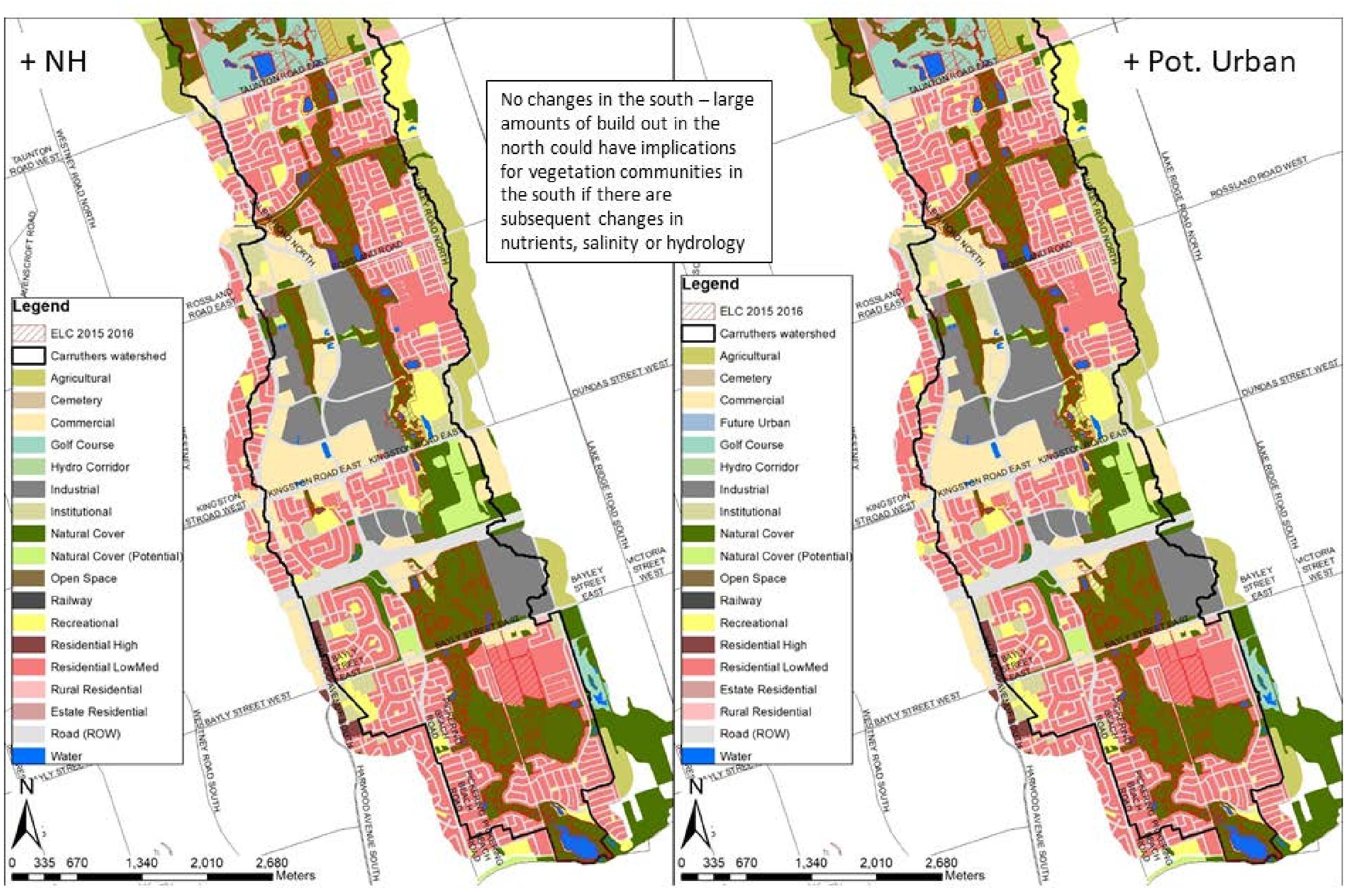

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Figure 7. Predicted changes in vegetation communities south of Taunton Road between (a) Current and +OP, (b) +OP and +NHS, and (c) +NHS and +Potential Urban scenarios

5.4.3.2 North of Taunton Rd. (Rural context)

Areas north of Taunton Road are generally rural with a mix of natural cover, agriculture and rural residential lands under the Current land use scenario. These areas may undergo substantial land use conversion, especially under the +Potential Urban scenario, which will have significant negative impacts on wildlife populations and vegetation communities.

a. Fauna Species

Figure 8 shows the fauna species points North of Taunton Road overlaid on each of the four land use scenarios used for the CCWP TIA. Based on the fauna species that are present currently in the landscape, predictions are made in terms of potential impacts of the future land uses on these species.

As illustrated in Figure 8 there are many fauna species using the more linear habitat patches North of Taunton Road. These patches include small numbers of wood thrush (*Hylocichla mustelina*), white-breasted nuthatch (*Sitta carolinensis*), red-eyed vireo (*Vireo olivaceus*), rose-breasted grosbeak (*Pheucticus ludovicianus*), mourning warbler (*Geothlypis philadelphia*), least flycatcher (*Empidonax minimus*), indigo bunting (*Passerina cyanea*), gray catbird, brown thrasher (*Toxostoma rufum*) and American redstart (*Setophaga ruticilla*) among many others. These species can be found using woodlots throughout southern Ontario, but even though these species are relatively common, they are negatively affected by habitat loss and land use change (Austen et al. 2001). Additionally, the wood thrush is listed as a threatened species under the Federal Species a -Risk Act primarily due to significant population declines since the 1970s due to habitat loss and degradation (Species at Risk Act 2002, COSEWIC 2012). Under the +OP scenario, most of the current fauna species are likely not directly impacted, as not much is being proposed in terms of habitat loss or fragmentation in these rural parts of the watershed. However, a small portion of the land that may change from open space to industrial may have increased matrix influence that may affect the surrounding habitat patches (Figure 8a). In general, the creation of larger habitat patches is recommended for the rural parts of the watershed as there are opportunities as shown in Figure 8b under the +NHS scenario. The enhanced NHS identified in the +NHS scenario should create future forested natural cover that would subsequently provide habitat for more forest-dependent and area-sensitive species. These species would likely be similar to those existing in the large forest patch just north of the 5th concession such as ovenbird (*Seiurus aurocapillus*), veery (*Catharus fuscescens*), winter wren (*Troglodytes hiemalis*), pileated woodpecker (*Dryocopus pileatus*) and black-and-white warbler (*Mniotilta varia*) that all require large forest tracts.

Under the +OP and +NHS scenarios (Figure 8b and 8c), agricultural lands in the north are maintained, which should continue to provide habitat for numerous species, such as those dependent on open and/or agricultural landscapes. Some open country species currently found using these agricultural areas include vesper sparrow (*Pooecetes gramineus*), savannah sparrow, wild turkey (*Meleagris gallopavo*), eastern meadowlark (*Sturnella magna*), bobolink, northern harrier (*Circus cyaneus*), horned lark and field sparrow (*Spizella pusilla*). Restoring some of the agricultural areas to forested natural cover will change the species communities from grassland-associated species to more forest-associated species.

Under the +Potential Urban scenario, if the agricultural lands are converted into built surfaces then it will cause a direct loss of habitat for numerous species currently using these areas. These include several threatened or endangered species listed under the Ontario Endangered Species Act including bobolink, eastern meadowlark and barn swallow (*Hirundo rustica*) (Government of Ontario 2007, Table 10, Figure 8c). While the addition of natural cover may provide benefits such as larger patch sizes and connectivity for fauna, the negative matrix influences associated with urban areas may offset the gains from the enhanced NHS. It is likely that any potential gains of area-sensitive species in the +NHS scenario will be greatly minimized with development in adjacent areas. Fauna using natural cover patches within an urban matrix are subject to a wide range of matrix influences and these can differ from natural cover patches in an agricultural matrix (EC 2013). In an urban matrix, fauna are affected by different and often more abundant predator communities, nest parasites (e.g. brown-headed cowbirds), urban noise affecting communication and fragmentation and roads affecting dispersal and mortality (Martin 1995, Reijnen et al. 1995, Haskell et al. 2001). Several of these influences are also present in agricultural landscapes but are often less intense (Haskell et al. 2001, EC 2013).

Table 10. Species currently using lands designated as build out north of Taunton Road based on 2015/2016 fauna points (overlapping build out)

Common name	Scientific name	Species code	2014 L-rank
bobolink	*Dolichonyx oryzivorus*	BOBO	L2
wood frog	*Lithobates sylvatica*	WOFR	L2
alder flycatcher	*Empidonax alnorum*	ALFL	L3
American redstart	*Setophaga ruticilla*	AMRE	L3
brown thrasher	*Toxostoma rufum*	BRTH	L3
clay-coloured sparrow	*Spizella pallida*	CCSP	L3
eastern meadowlark	*Sturnella magna*	EAME	L3
horned lark	*Eremophila alpestris*	HOLA	L3
osprey	*Pandion haliaetus*	OSPR	L3
star-nosed mole	*Condylura cristata*	SNMO	L3
vesper sparrow	*Pooecetes gramineus*	VESP	L3
wild turkey	*Meleagris gallopavo*	WITU	L3
barn swallow	*Hirundo rustica*	BARS	L4
common yellowthroat	*Geothlypis trichas*	COYE	L4
coyote	*Canis latrans*	COYO	L4
eastern chipmunk	*Tamias striatus*	EACH	L4
eastern kingbird	*Tyrannus tyrannus*	EAKI	L4
field sparrow	*Spizella pusilla*	FISP	L4
green frog	*Lithobates clamitans*	GRFR	L4
gray catbird	*Dumetella carolinensis*	GRCA	L4
indigo bunting	*Passerina cyanea*	INBU	L4
northern rough-winged swallow	*Stelgidoptery x serripennis*	NRWS	L4
red-eyed vireo	*Vireo olivaceus*	REVI	L4
savannah sparrow	*Passerculus sandwichensis*	SAVS	L4
spotted sandpiper	*Actitis macularia*	SPSA	L4
turkey vulture	*Cathartes aura*	TUVU	L4
white-breasted nuthatch	*Sitta carolinensis*	WBNU	L4
cliff swallow	*Petrochelidon pyrrhonota*	CLSW	L5
eastern phoebe	*Sayornis phoebe*	EAPH	L5
killdeer	*Charadrius vociferus*	KILL	L5
orchard oriole	*Icterus spurius*	OROR	L5
striped skunk	*Mephitis mephitis*	STSK	L5

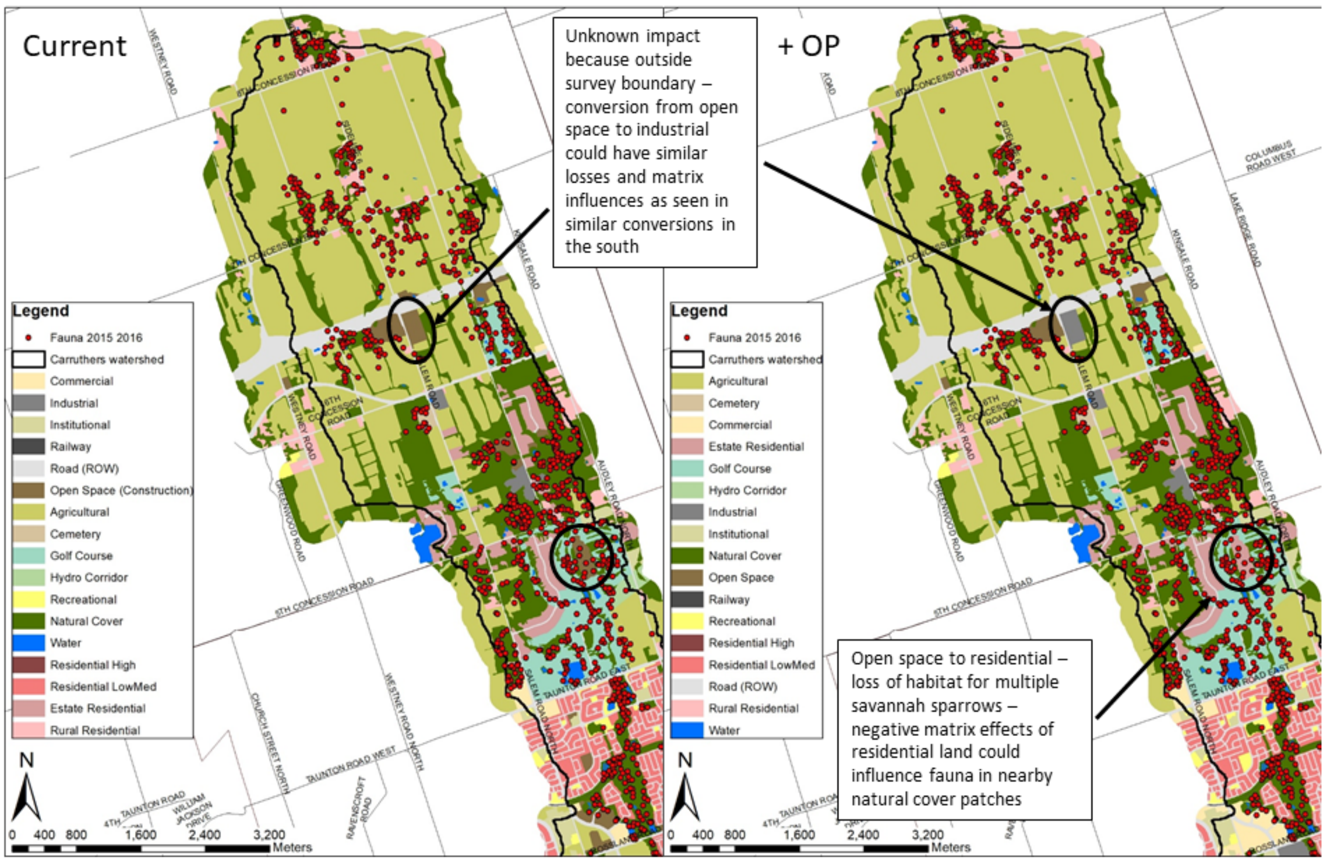
b. Vegetation Communities

Similar to the southern portion of the watershed, most of the vegetation communities surveyed were limited to areas of existing natural cover. Thus, under different land use scenarios minimal changes in terms of direct vegetation community loss are expected. However, under the +NHS scenario, enhanced NHS can create significant opportunities for future vegetation communities. Conversely, under the +Potential Urban scenario increased urban matrix influences can have significant impacts on the remnant vegetation communities.

As illustrated in Figure 9a minimal changes in vegetation communities are expected between Current conditions and +OP. One change that may affect vegetation communities is a transition of open space to estate residential. There are several communities close to these changes that could be negatively affected by development including: Mineral Fen Meadow Marsh (MAM5-1; L3), White Cedar – Scots Pine Low Treed Mineral Fen (FET2-B; L2), Treed Sand Barren (SBT1; L2) and Fresh-Moist Sugar Maple – Yellow Birch Deciduous Forest (FOD6-3; L3). These fen communities contain a large number of habitat specialists compared to other habitat types including shining ladies'-tresses (*Spiranthes lucida*; L2).

Under the +NHS scenario, the creation of natural cover in enhanced NHS areas results from the conversion of some existing agricultural areas to natural cover. This may include removal of known small amounts of Native Forb Meadow (CUM1-A) and Exotic Successional Savannah (CUS1-b) communities (Figure 9b). The restoration opportunities planning process identified the majority of the potential natural cover to be forest and riparian with scattered wetland opportunities in areas of altered head water drainage and wetland supporting topography (flat or basin like). Prior to restoration, detailed site specific restoration plans are completed which generally include planting native, early successional species along with considering existing flora species and surrounding vegetation community types. Continuing to incorporate existing flora species and those from adjacent vegetation communities facilitates restoration success because the species are likely appropriate for the physical and chemical conditions of the site.

Under the +Potential Urban scenario, where most of the agricultural lands are assumed to be built, there will be increased urban matrix influences. Similar to fauna species, the addition of potential natural cover could help to buffer some of the negative matrix influences of build out on vegetation communities (Figure 9c). Plant communities within an urban matrix generally consist of more non-native species and fewer sensitive species (TRCA 2015b). Urban matrix influences are quite variable and include limiting seed dispersal, changes in environmental variables (temperature, chemistry, hydrology) affecting species occurrence, competition from non-native species, generalists or species tolerant to more degraded environments, and trampling mortality from recreation pressures (Thurston and Reader 2001, Matthews et al. 2005, Duguay et al. 2007). The increase in impervious surfaces with build out could also affect vegetation communities downstream if there are changes in water quality and/or flow.



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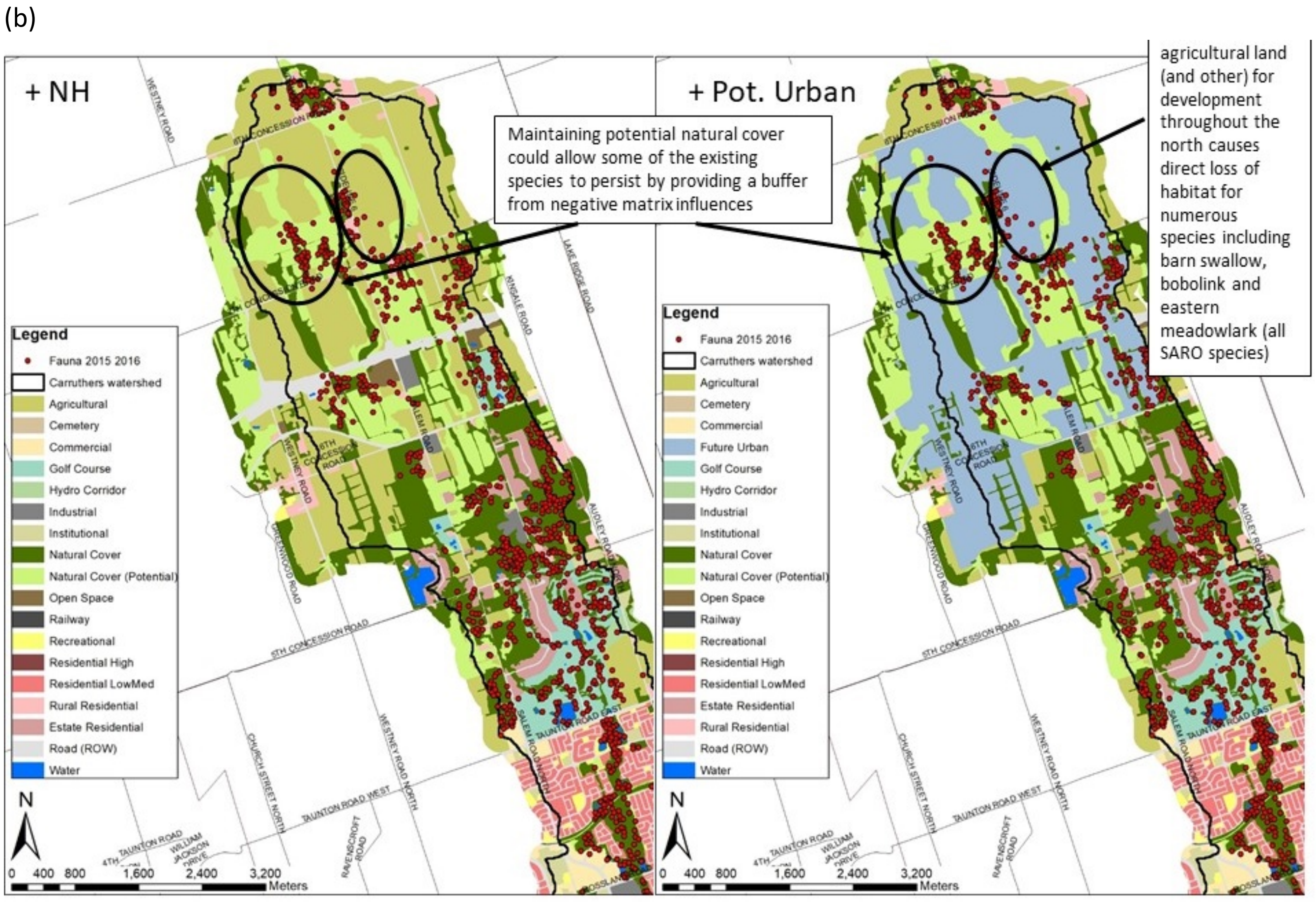

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Figure 8. Predicted changes in fauna north of Taunton Road between (a) Current and +OP, (b) +OP and +NHS, and (c) +NHS and +Potential Urban scenarios

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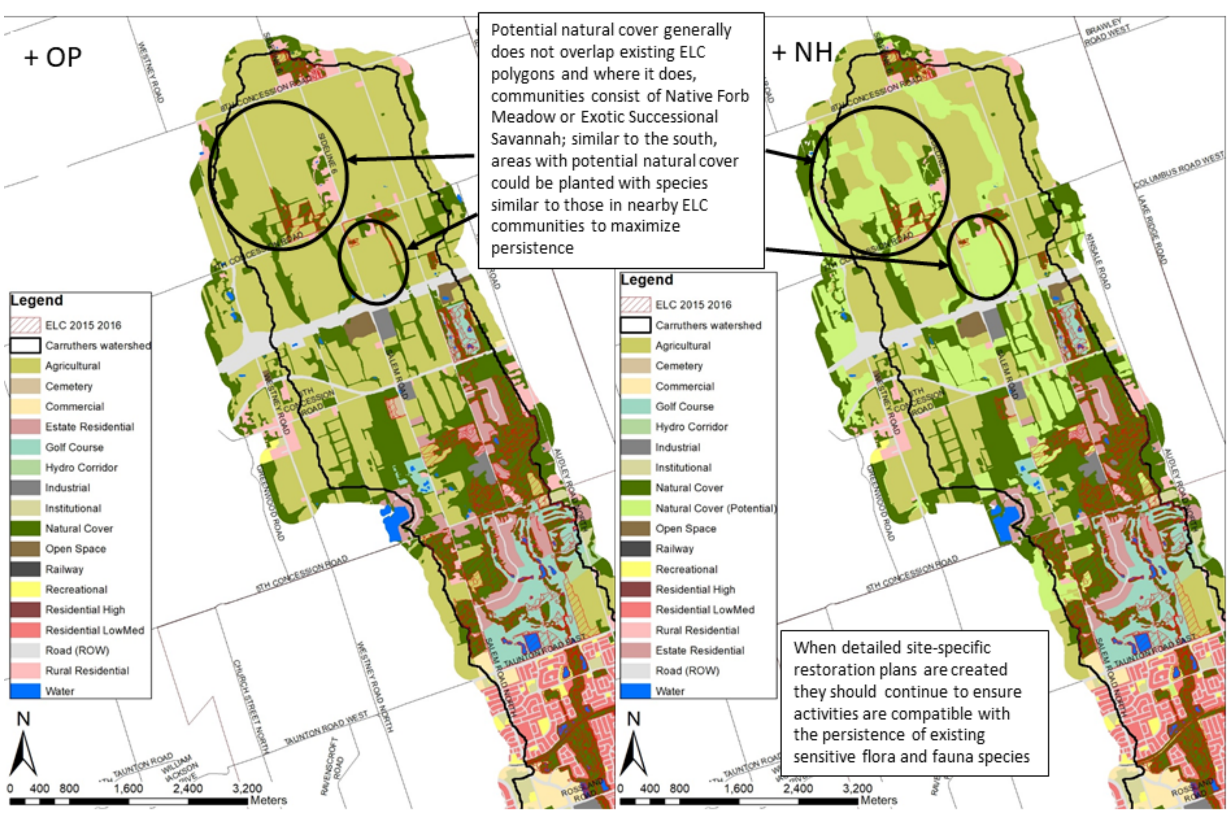

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Figure 9. Predicted changes in vegetation communities north of Taunton Road between (a) Current and +OP, (b) +OP and +NHS, and (c) +NHS and +Potential Urban scenarios

Box 3: Case Study: Species at Risk in the Carruthers Creek Watershed – Policy, protection and restoration

Carruthers Creek is currently home to at least five terrestrial species listed as threatened or endangered under Ontario's Endangered Species Act (Government of Ontario 2007, TRCA 2017a). These species include the bank swallow (*Riparia riparia*), barn swallow, bobolink and eastern meadowlark which are listed as threatened along with butternut (*Juglans cinerea*) listed as endangered. Species listed as endangered are facing imminent extinction or extirpation. Species listed as threatened are likely to become endangered unless steps are taken to address factors causing population declines. The presence of these species means that additional efforts must be made to protect their existing habitat under the Endangered Species Act if changes are suggested (development or restoration).

   

The bank swallow and barn swallow have been listed as threatened due to population declines across the northern portion of their breeding range. Both of these species are aerial foragers flying over open country (agriculture/farmland/grassland) or aquatic areas (wetlands/riparian areas) to catch insects (Heagy et al. 2014, Falconer et al. 2016). Bank swallows nest in large colonies along shorelines, in some aggregate extraction pits, or in eroded river banks (infrequent) while barn swallow nests are associated with buildings, bridges and/or road culverts (Heagy et al. 2014, Falconer et al. 2016). Recent (within three years) nest sites, foraging opportunities within 1000 m of the colony and nocturnal roost sites are considered regulated habitat for bank swallows (Falconer et al. 2016). Barn swallow nests, previous nests (within three years) and significant roost sites are considered regulated habitat for barn swallows (Heagy et al. 2014). At least two locations of bank swallow colonies and four barn swallow nests have been identified in Carruthers Creek since 2015.

The bobolink and eastern meadowlark are species that breed in native grasslands, pastures and hayfields (McCracken et al. 2013). These species have been listed under the ESA primarily due to widespread population declines. They have recently (2015 and 2016) been found in Carruthers Creek with the majority of individuals found north of the 6th Concession. Several observations of these species confirmed they were breeding or were recorded as probable breeders (based on criteria provided in the Ontario Breeding Bird Atlas). Their presence and confirmed/probable breeding status means that non-compatible activities (e.g. development, application of pesticides) within these areas are regulated (MNR 2016a, 2016b).

Butternut is a medium-sized, deciduous tree native to central and eastern United States reaching its northern limit in southeastern Canada (EC 2010). Butternut can be found in both upland and lowland forests and grow especially well on rich, well-drained loams but can also thrive in drier soil conditions particularly of limestone origin (EC 2010). Butternut is being severely attacked throughout its range by the butternut canker pathogen (*Sirococcus clavigignenti-juglandacearum*; TRCA 2017a) and this is the primary reason the species is endangered. Butternut trees are protected under the Endangered Species Act and must be assessed by a qualified Butternut Health Assessor and/or the Ontario Ministry of Natural Resources and Forestry to determine their health and subsequent habitat regulations.

5.5 Terrestrial system climate change vulnerability assessment

Table 11 and Figure 10 summarize the results of the desktop level terrestrial system CCVA. For each of the five Vulnerability Indicators (VI) total watershed area is categorized into the high, medium, and low vulnerability areas (Figures 10). The total area (ha) and the percent area (%) of the extent for which each VI data set is available for is presented in Table 11. Section 5.6.1. provides further details on the results and discussion. This analysis was conducted using the CCWP watershed boundary.

For the TIA, each VI's "high" vulnerability areas are overlaid with the four land use scenarios and estimates of total area (ha) and the percent (%) of total high vulnerability areas that are protected by NHS under each scenario is calculated and presented in Table 12 and Figures 11 to 15. This provides an understanding of the extent to which the NHS under each land use scenario protects the vulnerable areas (e.g. sensitive ELC communities and wetlands). Conversely, this also provides insights into potential areas where climate vulnerabilities may be exacerbated (e.g. by increasing urbanization across the watershed). Section 5.6.2 provides further details on results and discussion.

5.5.1 Current status of vulnerability indicators

Terrestrial system vulnerability to climate change varies across the Carruthers Creek watershed based on each of the five vulnerability indicators and their distribution within the watershed (Figure 10).

In general, the more urban areas south of Taunton Road were more vulnerable, mostly driven by the impacts of urbanization on indicators such as soil drainage and surface temperature across the urban matrix. The more rural areas north of Taunton Road were generally less vulnerable mainly due to the presence of lower ground surface temperatures, better drainage, larger habitat patches, and lower urban matrix influences. Nevertheless, there are multiple exceptions. There are high vulnerability areas in the north where natural cover patches are smaller and have more edge effects as well as where climate sensitive vegetation exists. The presence of urban matrix around these areas also increase vulnerabilities in some areas in the north. In the south some areas have succeeded in maintaining large natural features such as wetlands and larger natural cover patches, thereby having a lower vulnerability than their surrounding landscape. The breakdown of areas of high, medium, and low vulnerability based on the five underlying VIs are provided in Table 11 and discussed in more detail in the following sections.

Table 11. Summary of vulnerability for the Carruthers Creek watershed based on climate vulnerability indicators

Vulnerability indicator	% of	Total Area (ha)	Vulnerable Area (ha)			Vulnerable Area (%)		
			Low	Med	High	Low	Med	High
Ground surface temperature	Watershed	3690	1778	1163	740	48	32	20
Climate sensitive communities	Natural cover surveyed	312	200	109	3	64	11	<1
Habitat Patch quality	Natural cover	982	78	599	305	8	61	31
Soil drainage	Watershed	3690	2161	586	943	59	16	26
Wetlands	Natural cover surveyed	390	284	65	41	73	17	11

5.5.1.1 Ground surface temperature

Approximately 48% of the Carruthers Creek watershed was categorized as low vulnerability, 32% as medium vulnerability and 20% as high vulnerability based on ground surface temperatures. Climate vulnerability based on this VI was generally highest in the southern, more urbanized areas of the watershed and lowest in the rural, more natural areas of the watershed (Figure 10a). This distribution in temperature demonstrates the important function of natural cover in thermal regulation, which affects the functioning and persistence of flora and fauna species in the landscape. With expected increases in temperature and extreme heat events due to climate change, it is important to consider natural cover as an important adaptation measure as it provides the critical ecosystem service of thermal regulation and buffers against urban heat island effects.

5.5.1.2 Climate sensitive vegetation

Approximately 64% of the natural areas surveyed in the Carruthers Creek watershed were categorized as low vulnerability, 11% as medium vulnerability and less than 1% as high vulnerability (Figure 10b). Given that the vegetation community surveys are conducted only within the natural areas, these percentages are based on information only within natural cover and do not include areas outside natural cover (no data). As indicated in Figure 10b, most of the highly vulnerable areas for climate sensitive vegetation are in the middle sections of the watershed. These are mostly fens and Treed Sand Barren communities (White Cedar Low Treed Mineral Fen FET2-A, White Cedar – Scots Pine Low Treed Mineral Fen FET2-B, Treed Sand Barren SBT1). Communities with medium vulnerability are more widely distributed, primarily in the middle and lower areas of the watershed. These include several shallow and meadow marsh communities (e.g. Pondweed Submerged Shallow Aquatic SAS1-1, Broad-leaved Sedge Mineral Meadow Marsh MAM2-6), open sand barrens, deciduous thickets, treed beaches, open sand beaches, treed bluffs, shrub beaches and fens. These medium and high vulnerability vegetation communities represent those most at risk from climate change impacts based on expected changes in hydrology, soil fertility and natural dynamics that are required for community persistence, thus should be prioritized for climate adaptation.

5.5.1.3 Habitat patch quality

Approximately 8% of the natural areas surveyed in the Carruthers Creek watershed were categorized as low vulnerability, 61% as medium vulnerability and 31% as high vulnerability (Figure 10c). Given that the habitat patches are defined only within the natural areas there are no data on patch quality outside in the urban matrix, thus these areas are designated as no data for this analysis. As indicated in the Figure 10c, most of the areas of high vulnerability based on patch quality are located in the lower middle sections of the watershed, where patches are thinner and more linear. These patches are subject to high adverse matrix influences from surrounding urban areas. Most areas with medium and low vulnerability are in areas with larger habitat patches, less linear patches and less severe matrix influences such as the wide riparian corridor and provincially significant wetland (Ajax Warbler Swamp) in the south and areas along the Lake Iroqouis shoreline in the middle-north of the watershed. To adapt to climate change impacts, it is important to focus efforts on enhancing the high vulnerability areas through patch enhancements as well as matrix influence management. In addition, for medium vulnerability areas, especially those that are in the north outside of greenbelt areas, future urbanization may exacerbate the vulnerabilities, thus focus should be on managing the urban matrix impacts.

5.5.1.4 Soil drainage

Approximately 59% of the Carruthers Creek watershed was categorized as low vulnerability, 16% as medium vulnerability and 26% as high vulnerability based on soil drainage as the VI (Figure 10d). It is important to note that the soil data used in this analysis are from 1929-2003, thus the amount of urban land is underestimated, especially in south-central portions of the watershed. This may underestimate the vulnerabilities in these areas. Regardless, the general spatial pattern shows that most of the high vulnerability areas are in the southern, more urbanized areas of the watershed and along the riparian corridors. Given that the streams/riparian corridors were classified as bottomlands leading to poor soil drainage, it is expected that these areas will come up as high vulnerability areas that will be impacted by climate change impacts. Likewise, most of the urban built sections are also highly vulnerable. Medium vulnerability areas are distributed across the watershed due to presence of imperfectly drained soils such as Milliken loam in the northwest, Tecumseth sandy loam, Smithfield clay loam and muck along the middle-eastern borders of the watershed and Guerin loam and Smithfield clay loam in the south. Other than these most of the rural areas with an agricultural land base is classified as low vulnerability to climate change impacts. This, however, may change if future urbanization converts these permeable areas to built surfaces.

5.5.1.5 Wetlands

Approximately 73% of wetlands in the Carruthers Creek watershed were categorized as low vulnerability, 17% as medium vulnerability and 11% as high vulnerability (Figure 10e). Wetlands classified as low vulnerability are those along stream corridors and with groundwater sources (water table within 1 m of ground surface) thereby ensuring that the hydrology inputs are more secure from multiple sources. Several wetlands are classified as medium vulnerability including the Rossland Road wetland that has groundwater sources but more limited surface water contributions. High vulnerability wetlands are scattered throughout the watershed and generally consist of mineral/deciduous organic/thicket swamps receiving limited to no groundwater and surface water contributions. The hydrology of these highly vulnerable wetlands is not moderated by supplemental sources of water beyond precipitation that might stabilize the hydroperiod during drought conditions. These wetlands are likely to be impacted heavily under climate change conditions, unless specific measures are taken to protect them.

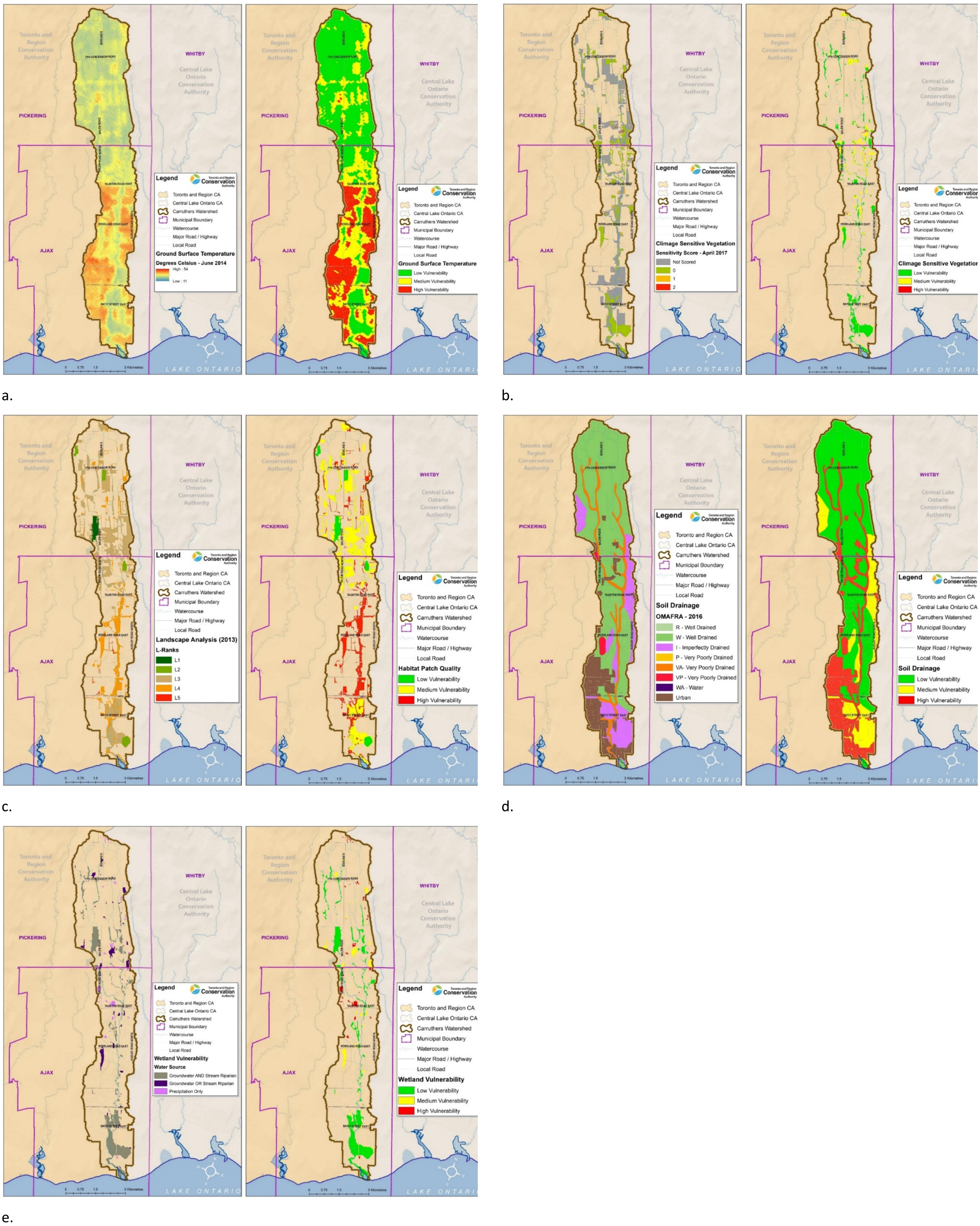

Figure 10. Five vulnerability indicators representing the gradient of vulnerability characterization (high, medium and low) of the terrestrial system in Carruthers Creek watershed (a) Ground surface temperature, (b) Climate sensitive vegetation communities, (c) Habitat patch quality, (d) Soil drainage, (e) Wetlands. Figures show raw data in the left panel and vulnerability in the right panel for each VI.

5.5.2 Land use scenario comparison

For this TIA, each of the five VI reflecting terrestrial system vulnerability to climate change and the additive vulnerability map were compared with the Current and the three future land use scenarios (Figures 11 to 15). This provides understanding of the extent of impacts on the high vulnerability areas and the extent of protection provided by the NHS under each land use scenario.

Table 12 quantifies the extent of high and medium vulnerability areas that are contained within the NHS under each land use scenario. This provides insights into the benefits of the NHS for climate adaptation as well as reveals where future land use changes can exacerbate climate vulnerabilities. This information integrates climate adaptation planning and land use planning to move towards a resilient watershed.

Table 12. High and medium climate vulnerability areas (terrestrial) overlap with the NHS areas in the Carruthers Creek watershed under the Current, +OP, +NHS, and +Potential Urban land use scenarios

Vulnerability Indicator	Total area (ha) of "high" vulnerability *in the watershed*	Total area (ha) of "high" vulnerability *overlapping with the NHS*				Percent (%) of "high" vulnerability *overlapping with the NHS*			
		Current	+OP	+NHS	+Potential Urban	Current	+OP	+NHS	+Potential Urban
Ground surface temperature	740	9	9	11	11	1	1	1	1
Climate sensitive community	3	3	3	3	3	84	84	88	88
Habitat patch quality	305	238	238	263	263	78	78	86	86
Soil drainage	943	235	235	285	285	25	25	30	30
Wetlands	41	27	27	29	29	65	65	70	70
	Total area (ha) of "medium" vulnerability *in the watershed*	Total area (ha) of "medium" vulnerability *overlapping with the NHS*				Percent (%) of "medium" vulnerability *overlapping with the NHS*			
		Current	+OP	+NHS	+Potential Urban	Current	+OP	+NHS	+Potential Urban
Ground surface temperature	1163	171	171	250	250	15	15	21	21
Climate sensitive communities	109	89	89	92	92	81	81	84	84
Habitat patch quality	599	489	489	562	562	82	82	94	94
Soil drainage	586	190	190	207	207	32	32	35	35
Wetlands	65	47	47	50	50	72	72	76	76

Table 12 and Figures 11 to 15 show that under the Current land use scenario most of the high vulnerability areas related to natural features indicators (climate sensitive vegetation, habitat patch quality, and wetlands) are within the NHS (84%, 78%, and 65%). However, the vulnerable areas driven by indicators that are general landscape parameters (ground temperature and soil drainage) are very limited in the NHS (1% and 25%). This trend continues even under the +NHS and +Potential Urban scenarios that has the enhanced NHS. When medium vulnerability areas are considered a similar trend continues across all indicators.

Some of the high vulnerability areas that are not included in the NHS represent areas that historically contained these communities, wetlands, or natural cover patches but have since been developed. For example, a Treed Sand Barren was identified in 2002 at a site that has now been developed and as such, is not part of the NHS. The ELC layer used for the CCVA includes the most current information, but also includes data that could be up to 15 years old.

These results illustrate that the NHS is beneficial for protecting the existing natural features such as vulnerable vegetation communities, lower quality habitat patches, and vulnerable wetlands, however to reduce the vulnerability outside the natural features in the urban matrix, the NHS has a smaller influence. This highlights an important challenge for reducing climate vulnerabilities of the terrestrial system, especially under the +Potential Urban scenario where the urban matrix will potentially increase significantly (approximately 190 ha), as permeable agricultural lands are converted to built surfaces. This will increase ground surface temperatures, alter soil drainage patterns, and decrease habitat patch quality thereby increasing vulnerability. Some specific areas where these impacts may be more pronounced are shown in Figures 11 to 15. The potential solution to this requires management and implementation of climate adaptation measures outside of the traditionally defined NHS, which may include less built up areas and implementing more living green infrastructure (e.g. urban canopy, green roofs, Low Impact Development (LID; e.g. permeable pavements, bioswales)).

5.5.3 Climate vulnerability improvement opportunities

5.5.3.1 South of Taunton Rd. (Urban context)

Specific areas for climate vulnerability improvements are provided for the more urbanized region of the Carruthers Creek watershed (south of Taunton Road) in Figures 11 to 15 and discussed in this section. Changes between the Current and +OP scenarios south of Taunton Road could affect ground surface temperatures, soil drainage, climate sensitive vegetation and wetland function. Industrialization and residential development in areas that are currently agricultural or open space could increase ground surface temperatures and decrease soil drainage, both of which will increase the vulnerability of these areas. If these changes proceed, ways to mitigate these impacts include maintaining as much of the existing open/agricultural areas as possible and restoring to natural cover and urban forest, and using green infrastructure.

Changes under the current OPs could also lead to the loss of climate sensitive vegetation and wetland function. Two Treed Sand Barren ELC communities are located adjacent to an area currently delineated as open space (with some development already) on the east side of Salem Road just south of the railway line. Under the +OP scenario, more of the open space areas are converted to commercial development and this could negatively affect these communities. Treed Sand Barrens are areas of exposed sands formed by extant or historical shorelines or aeolian processes with less than 25% vegetation cover (MNR 2014). These communities are considered highly vulnerable based on the CCVA scoring system suggesting that these communities will be negatively impacted by increasing seasonal temperatures and increasing variability in precipitation (TRCA 2018a). Proximate factors in the surrounding landscape could also affect the persistence of these communities and these should be limited since these communities are already especially vulnerable to changes in climate. For example, Treed Sand Barrens could be negatively affected by soil compaction in the surrounding areas, changes in nutrients or chemicals from runoff and invasive species. The most of important of these impacts would be to control runoff and the associated additions of excess water and nutrients. These impacts could be mitigated by planting a buffer of native vegetation between the commercial development and these areas and utilizing LID techniques to minimize nutrient and road salt runoff. Some additional planting is already proposed in the ROP assessment and further focus should be on its protection.

The Rossland Road wetland could be affected by industrial development surrounding the wetland. This wetland has a medium vulnerability to the impacts of climate change based on the CCVA because its hydrology is controlled by groundwater and is not closely linked to a permanent watercourse from which its hydrology could also be controlled. This wetland may be more vulnerable during periods of drought or extended high temperatures compared to wetlands that have additional water sources that can provide hydrological stability (TRCA 2018a). This vulnerability, in addition to changes that could occur with industrial development surrounding the wetland (and other development in the watershed that could affect the water table), suggests that best practices should be used for development that minimizes impacts on the hydrology of the landscape (limiting development, using recommended buffer sizes, water balance guidelines, LID, green infrastructure).

5.5.3.2 North of Taunton Rd. (Rural context)

Specific areas for climate vulnerability improvements are provided for the more rural region of the Carruthers Creek watershed (North of Taunton Road) in Figures 11 to 15 and discussed in this section. Changes between the Current and +OP scenarios north of Taunton Road could affect ground surface temperatures, soil drainage and highly vulnerable climate sensitive vegetation communities. Conversion from open space to industrial has already occurred under the OP for an area immediately to the east of Salem Road and south of the Highway 407 extension. While changes to the landscape here were minimal and would only likely minimally increase ground surface temperatures and minimally affect natural soil drainage patterns, as these “minimal” changes occur over more of the landscape over time (as in the +Potential Urban scenario) the effects are cumulative.

In addition to this area in the north end of the watershed, a portion of the Deer Creek Golf Club and several areas just to the north of the golf course (off of Sideline 4) change from open space to estate residential under the +OP scenario. Areas adjacent to these proposed developments contain one of the densest clusters of highly vulnerable climate sensitive vegetation communities including several Treed Sand Barrens and a White Cedar – Scots Pine Low Treed Mineral Fen. Again, efforts should be made to control soil compaction in the surrounding areas, nutrient runoff and changes in hydrology. This could be achieved through the incorporation of green infrastructure, LID techniques and Restoration Opportunity Plans into the development.

Under the +NHS scenario, ground surface temperatures remain low, patch quality improves, areas with climate sensitive communities and wetlands are preserved and these efforts would generally decrease the overall vulnerability of the watershed or maintain the vulnerability under the +OP scenario. Under the +Potential Urban scenario, there are both positive and negative changes related to the vulnerability indicators. With the conservation of the enhanced NHS, several of the highly vulnerable feature-based VIs are expected to be conserved (wetlands, sensitive ELC communities) and several of the more physical VIs (ground surface temperature, soil drainage) are expected to either be maintained at their current vulnerability or decrease in vulnerability. Overall, the creation and conservation of the NHS improves the resiliency of the CCW, but the potential urban development is expected to negate some of these gains through increased ground surface temperatures, soil drainage patterns and matrix influences along with other indirect impacts (altered hydrology, runoff). Again, some of these effects are mitigated through the maintenance of the NHS, but could also be mitigated within the proposed urban areas by implementing more living green infrastructure and using ROPs in land use planning.

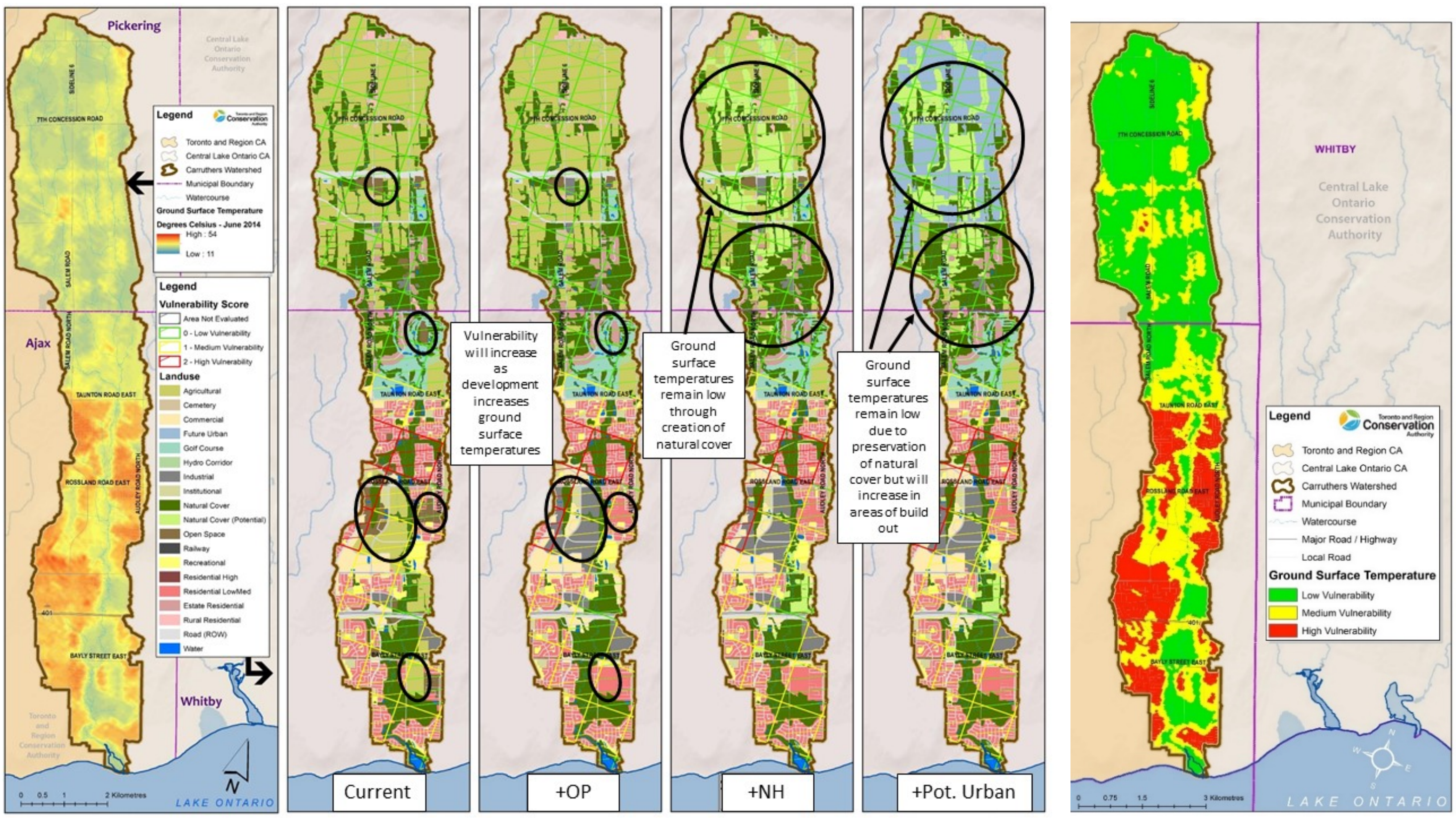

Figure 11. Predicted changes in natural system vulnerability to climate change based on ground surface temperature in the Carruthers Creek watershed

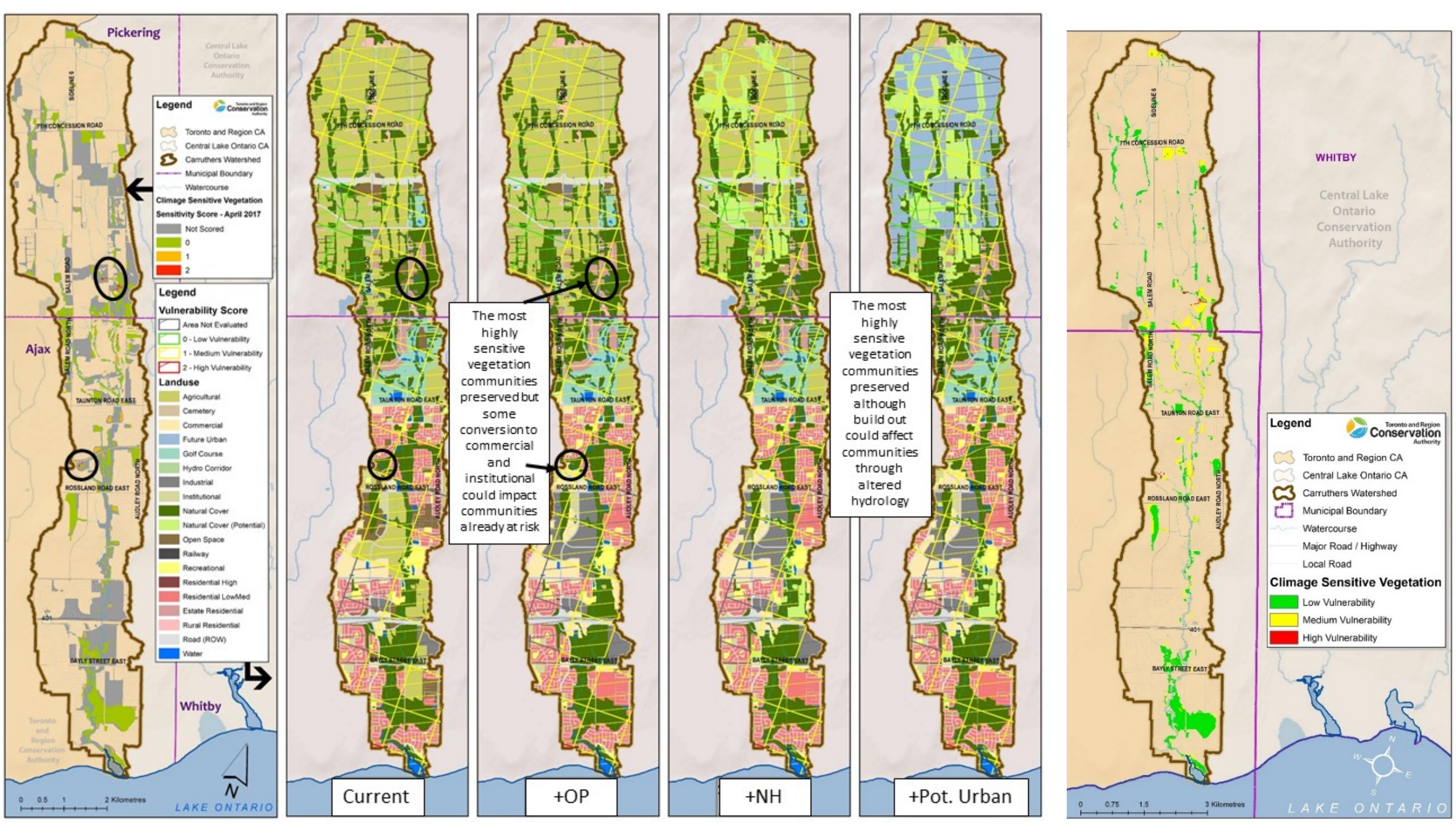

Figure 12. Predicted changes in natural system vulnerability to climate change based on climate sensitive vegetation in the Carruthers Creek watershed

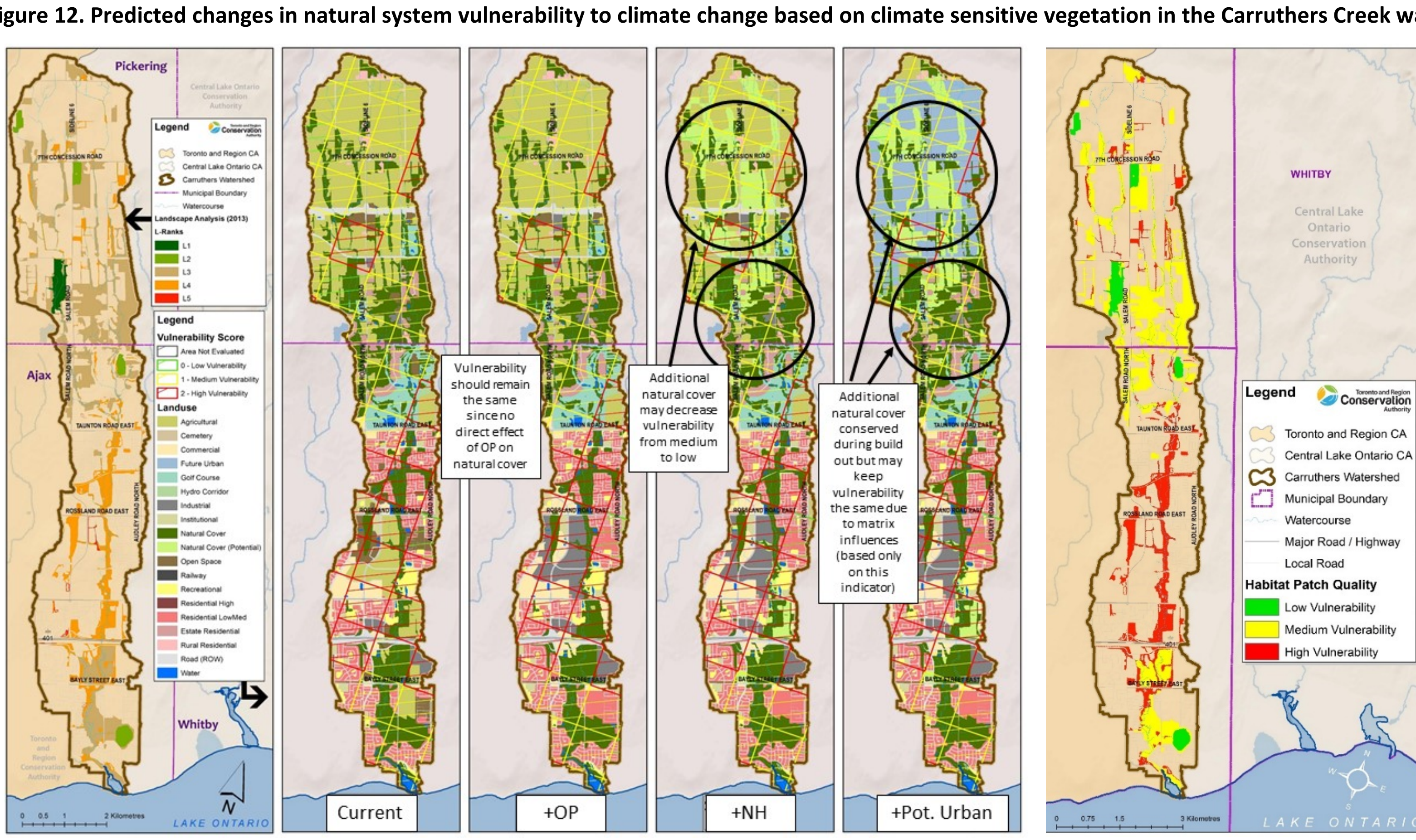

Figure 13. Predicted changes in natural system vulnerability to climate change based on patch quality in the Carruthers Creek watershed

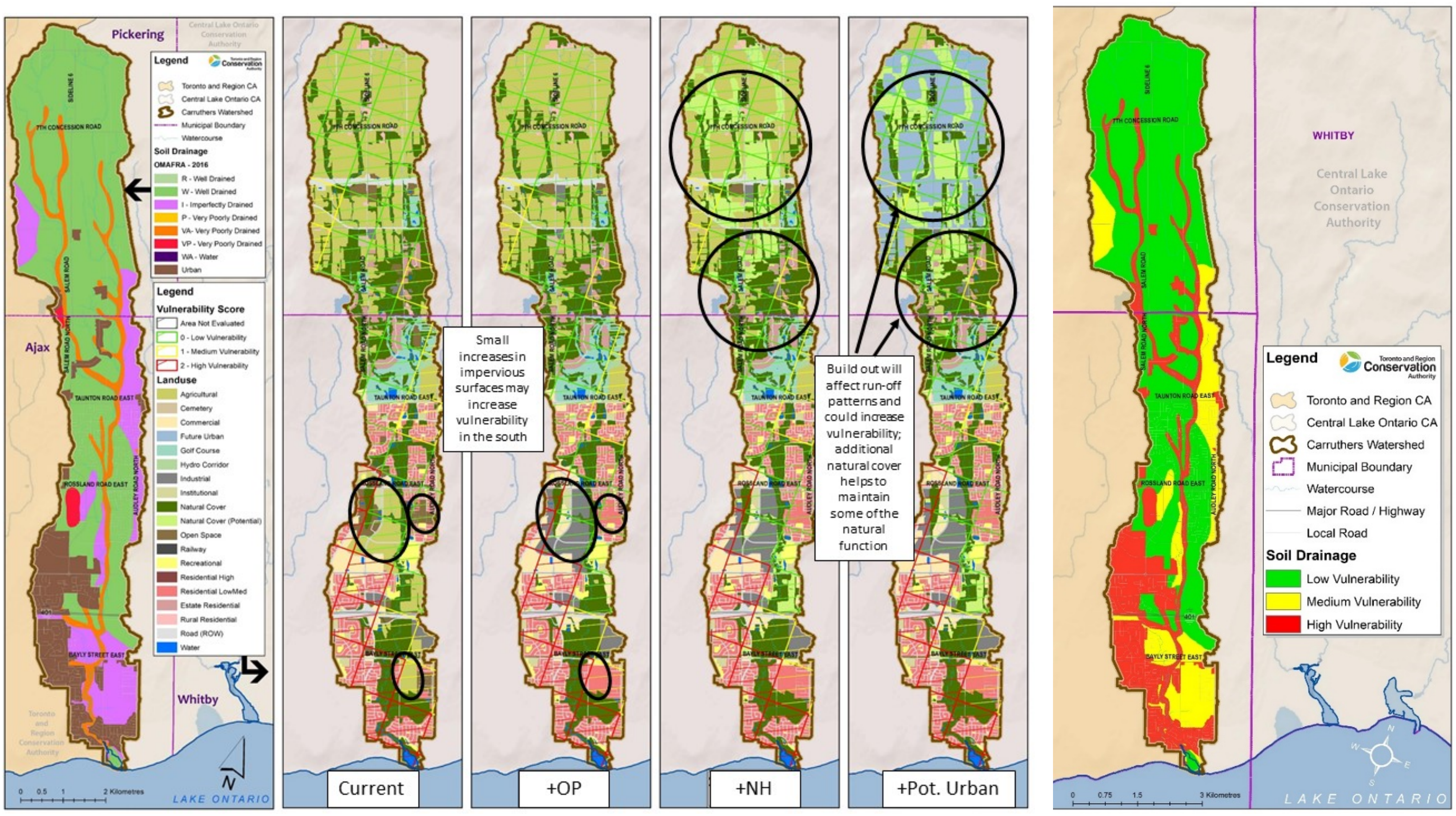

Figure 14. Predicted changes in natural system vulnerability to climate change based on soil drainage in the Carruthers Creek watershed

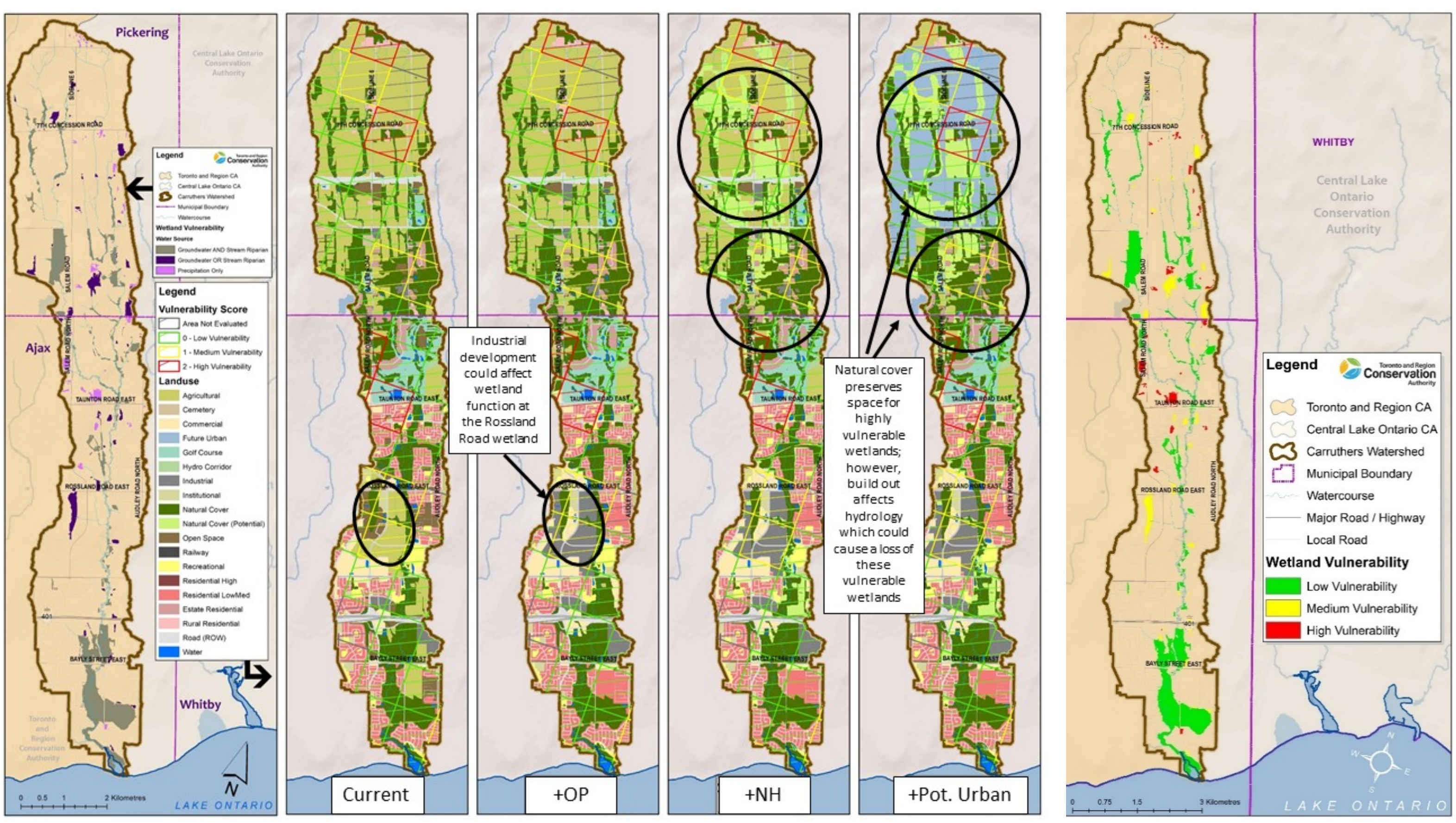

Figure 15. Predicted changes in terrestrial system vulnerability to climate change based on wetland vulnerability in the Carruthers Creek watershed

6 Conclusions and Recommendations

6.1 Summary

The CCWP (in progress) continues to strive for protecting and enhancing terrestrial habitat and species as outlined in the CCWP (2003). To achieve this the CCWP continues its commitment to achieve the three main objectives identified in CCWP (2003), in addition to one more proposed fourth objective as listed below.

1. Objective 14: Increase the amount of natural cover to a quantity that will protect long-term terrestrial biodiversity
2. Objective 15: Protect natural system quality and function from the influence of surrounding land uses
3. Objective 16: Protect and restore all native terrestrial community types and species
4. Objective 17: Manage climate vulnerabilities of the terrestrial system

The overall purpose of this TIA was to assess the implications of different land use scenarios, including the Current and three potential future scenarios on the objectives for the terrestrial system in the Carruthers Creek watershed. For this assessment, five specific indicators were used as listed below.

a. natural cover quantity (Objective 14)
b. natural cover quality (Objective 15)
c. landscape connectivity (Objective 15)
d. vegetation communities and fauna (Objective 16)
e. climate change vulnerabilities (Objective 17)

A comparison of potential impacts of each scenario would (i) update overall objectives and targets for the watershed, (ii) provide a better understanding of the implications of each land use scenario on each objective, and (iii) identify strategic actions that will assist Durham Region in its objective to achieve greater sustainability and resiliency.

This analysis compared the historical and current watershed conditions to predicted watershed conditions under three future land use scenarios. Historical conditions represent the historical landscape used to characterize the watershed in the 2003 Carruthers Creek Watershed Plan (CCWP). Current conditions represent existing land use based on 2015 imagery. Scenario 1 (+OP) reflects current conditions (with some additional development occurring south of the Greenbelt) based on OP data. Scenario 2 (+NHS) reflects changes in land use occurring when the Natural Heritage System (NHS) is protected and enhanced. Scenario 3 (+Potential Urban) reflects changes in land use occurring when the NHS is protected and enhanced and development (beyond what is proposed in the OP) occurs outside the NHS.

This TIA was a comparative assessment between the historical and Current scenarios and identified that there is a substantial increase in the urban land use class at the expense of agricultural lands and, to a lesser extent, natural cover. Though the agricultural lands were converted in the northern parts of the watershed, in the southern portions the conversion included natural cover in some areas. This reflects that as urbanization continues mostly permeable cover is converted to built areas dominated by impervious cover. The comparison between the Current scenario and three future land use scenarios allowed inferences to be made in terms of their impacts on the terrestrial system objectives and thereby the trend towards or away from achieving the stated objective.

Overall, the results of the TIA suggest that the CCWP goal of protecting and enhancing terrestrial habitat and species in the Carruthers Creek watershed can be achieved at various levels under the Current and the three future land use scenarios examined in this study. The differences are mostly driven by the varied level of success expected for the four objectives focussed on improving habitat quantity, quality, species and community composition, and addressing climate vulnerabilities. These are summarized below in Appendix 5 to showcase the estimates of each metrics under different land use scenarios in one place. This information will be used for target setting for the watershed, which will be completed in the next phase.

In terms of the first and second objectives of the CCWP that aim to increase **natural cover quantity and quality**, there is not much difference between the Current and +OP scenarios. However, when compared to the +NHS scenario, there is a substantial positive influence with an increase in natural cover (from 25% to 36%). This is driven by the additional areas delineated for the enhanced NHS, primarily in the north portion of the watershed. The potential increase in quantity also seems to enhance the quality of natural cover as there are more good and excellent patches in the watershed under the enhanced NHS condition. This is attributed to the larger patches with lesser edge effects and a more conducive matrix around these habitat patches under +NHS scenario. However, when the +NHS scenario is compared to the +Potential Urban scenario even though natural cover remained constant as both scenarios use the same enhanced NHS, there was a substantial decrease in habitat quality, which is attributed to the increased negative matrix influence. This is expected since under the +Potential Urban scenario the urban areas are assumed to be dominated by built cover which increases from 0% to 19% and agricultural cover decreases from 19% to 4%. It will be critical to manage the urban matrix impacts to maintain the gains achieved by investing in the enhancements to the NHS, if the +Potential Urban land use scenario (or variation thereof) is to be considered for the future of the Carruthers Creek watershed.

A comparison of the habitat connectivity priorities coverage within the NHS under each land use scenario indicates that under the +NHS scenario there is a substantial increase in areal coverage of local and regional habitat connectivity priority areas. The coverage of regional connectivity priorities at both the TRCA scale and watershed scale improves substantially under the +NHS scenario. This is an important functional ecological gain beyond adding quantity as it facilitates the long-term dispersal movements between habitats that allows wildlife to adapt to negative impacts posed by land use and climate change. Dispersal movements may be infrequent but critical for wildlife to persist in the landscape and deal with uncertainties. However, it is worth noting that as the built portions of the watershed increases (such as in the +Potential Urban scenario) there will be more inhospitable areas for wildlife (e.g. roads, buildings) that will have additional adverse impacts, and partially compromises the estimated gains in connectivity through the enhanced NHS. These will have to be mitigated with special targeted efforts in addition to NHS enhancement such as with wildlife crossings, maintaining some agricultural features through the environmental assessment and development planning process. Some specific examples are provided in this report on potential locations for such targeted initiatives under each scenario.

The third objective of **protecting and restoring species and vegetation communities** is challenging for the Carruthers Creek watershed, especially in the urban portions of the watershed. The conversion of open space areas to industrial or residential land uses (from the Current to +OP scenarios) could lead to the loss of habitat for at least six species currently using these areas: bobolink, common raven, horned lark, willow flycatcher, savannah sparrow, northern flicker, eastern kingbird and gray catbird. An urban matrix often has more negative consequences for wildlife using natural cover patches compared to an agricultural matrix because the predator community and density are different with areas of higher housing densities containing a higher predator abundance (Haskell et al. 2001). An increase in nest predators is an important consideration for breeding songbirds because nest predation is the leading cause of nest failure in birds and this affects recruitment to the population (Martin 1995). In addition, urban noise can interfere with avian communication methods and lead to lower densities of breeding birds near roads. Enhancement to the NHS under the +NHS scenario can buffer some of these impacts and should be considered strongly for these areas. In terms of vegetation communities there were direct community losses and additional matrix influences under the +OP scenario that could contribute to community loss or degradation.

Many fauna species inhabit the forest patches within the rural portion of the Carruthers Creek watershed including small numbers of wood thrush, white-breasted nuthatch, red-eyed vireo, rose-breasted grosbeak, mourning warbler, least flycatcher, indigo bunting, gray catbird, brown thrasher and American redstart among many others. Under the +OP scenario, most of the current fauna species are likely not directly impacted since only minimal changes are proposed. However, a small portion of the land that may change from open space to industrial may have increased matrix influences that may affect the surrounding habitat patches. Maintenance of agricultural lands under the +NHS scenario in the north will continue to provide habitat for numerous species such as those dependent on open and/or agricultural landscapes such as vesper sparrow, savannah sparrow, wild turkey, eastern meadowlark, bobolink, northern harrier, horned lark and field sparrow. Restoring some of the agricultural areas to forested natural cover under the +NHS scenario will change the species communities from grassland-associated species to more forest-associated species. Under the +Potential Urban scenario, if agricultural lands are converted into built surfaces then it will cause a direct loss of habitat for numerous species mentioned earlier that currently use these areas. This includes several threatened or endangered species under Ontario's Endangered Species Act such as bobolink, eastern meadowlark and barn swallow. While the addition of natural cover through the enhanced NHS provides benefits, negative matrix influences associated with urban areas may negate some of the gains achieved from the enhanced NHS.

Lastly, the fourth objective of **incorporating climate change vulnerabilities** in natural systems planning is accomplished through the NHS, especially for those areas where vulnerabilities are driven by natural features (climate sensitive vegetation, habitat patch quality, and wetlands). Under all land use scenarios, a substantial portion of the high vulnerability areas defined by these vulnerability indicators are within the NHS, but highest under +NHS scenario (88%, 86%, and 70%). However, the vulnerable areas driven by indicators that are general landscape parameters (ground temperature and soil drainage) are very limited in the NHS (1% and 25%). When medium vulnerability areas are considered a similar trend continues across all indicators. These results illustrate that the NHS is beneficial for protecting the existing natural features such as vulnerable vegetation community patches, lower quality habitat patches, and vulnerable wetlands. However, to reduce the vulnerability outside the natural features in the urban matrix, the NHS has a smaller influence. This highlights an important challenge for reducing climate vulnerabilities of the terrestrial system, especially under the +Potential Urban scenario where the urban matrix will potentially increase significantly (approximately 190 ha), as permeable agricultural lands are converted to built surfaces. This will increase ground surface temperature, alter soil drainage patterns, and decrease habitat patch quality thereby increasing the vulnerable areas. The potential solution to this requires management and implementation of climate adaptation measures outside of the traditionally defined NHS, which may include less built up areas and implementing more green infrastructure (e.g. urban canopy, green roofs, and other LID tools).

6.2 Recommendations

The Terrestrial Impact Assessment indicated that to achieve the terrestrial goal and objectives for CCWP there are a number of key recommendations that needs to be addressed, which include protection, restoration, as well as improved management both within the natural areas as well as in the surrounding landscape accounting for the changes and uncertainties associated with land use and climate. The following sections lists the key recommendations and associated actions as well as considerations that are important for terrestrial systems within Carruthers Creek watershed. Furthermore, Section 6.3. provides an illustration and a brief discussion of some specific actions that could be undertaken in the watershed. In addition there were a number of recommendations provided in the Phase I of the CCWP, which are presented in Appendix 6.

6.2.1 Protect and enhance natural cover quantity

1. **Identify habitat opportunities** (forest, wetland, meadow) for future enhancement and restoration in the watershed using the Restoration Opportunity Planning (ROP) polygons that are grounded on the existing fauna, flora and vegetation communities data to improve habitat suitability and biodiversity.
2. **Further screening of wetlands for further study should take place as soon as more information on the nature of the land use and/or built form is available** (e.g. subwatershed plans, Master Environmental Servicing Plans, Plans of Subdivision). This screening can help to determine the need for and scope of FBWB studies to inform the development of these areas such that the wetland functions are not affected.
3. **Identify the locations of habitat for terrestrial Species-at-Risk in Ontario** that are protected under Ontario's Endangered Species Act and proactively protect habitat and contributing areas as designated regulated habitat to increase the amount of habitat for all other associated species.
4. **Collaborate with public and private partners to protect and enhance habitat** for species of regional concern as well as species at risk. For example continue to work with Deer Creek Golf Course to restore areas to meadow in support of Redside Dace and open country bird species at risk.
5. **Be Involved in innovative multi-objective projects such as the The Meadoway (themeadoway.ca) to extend habitat opportunities** to the Carruthers Creek watershed (beyond Petticoat and Duffins watersheds) to create larger meadow patches, if possible to support open country species.

6.2.2 Protect and enhance natural cover quality

6. **Improve management of public use in the habitat patches** including restricted access to the sensitive species habitat areas, limited permitted use during breeding season, and allowing only the appropriate forms of public use in the functioning habitat areas for biodiversity.
7. **Improve management of existing and new invasive species** in the strategic habitat patches within the watershed to protect the quality of habitat patch. This includes deploying an early detection and rapid response system for new invasive species as well as a well-planned strategic invasive control and contain program for existing invasive species.

8. **Account for the cumulative effects of the land use changes on habitat in planning processes** even when the amount of habitat is not directly lost. While the majority of land use change may not result on loss of cover, they may result in producing inhospitable landscape for biodiversity (e.g. paved areas, vehicular traffic). When these indirect effects are accumulated over time and across larger area, the habitat function may be lost and may cause major impacts (Theobald et al. 1997).
9. **Incorporate different forms of green infrastructure in planning processes and design** (e.g. street and backyard trees, green roofs, pollinator gardens, and other recommendations made in the CCWP Urban Forest Assessment report (in progress)) across entire landscape to prevent and minimize negative urban matrix influence to maintain habitat quality. This is especially critical in areas that contribute directly to the targeted enhanced natural heritage systems (e.g. near Greenwood and center of headwaters areas).
10. **Improve connectivity among habitat patches to allow for wildlife movement and long term gene flow** that can help biodiversity adapt to any changes in their existing habitat, may it be due to changes in land use or climate. Specific areas for connectivity enhancements are listed below.
    - Near Salem Road North immediately south of the railway line (just north of Rossland Road), where significant commercial development is expected under the +OP scenario. There is a wetland in this area with good connectivity to other natural cover patches to the east; however, connections to the west and to areas outside of the watershed should be maintained (and likely will be along the railway line).
    - Between the Rossland Road wetland and the central riparian corridor along with the riparian corridor south of Kingston Road to Carruthers Marsh. These areas are important to consider for restoration planting or urban forest enhancement to contribute to wildlife movement opportunities (CCWP Urban Forest Assessment, in progress).
    - Along Shoal Point Road between the Ajax Warbler Swamp and the main Carruthers Creek. If not already present, a wildlife passage should be created at this location.
    - Between the Rossland Road wetland and Carruthers Creek. The small strip of natural cover that is currently maintained is important to maintain connectivity of the wetland, which is otherwise isolated. There is an existing culvert under Salem road along this corridor which should allow for wildlife passage but this should be confirmed.
11. **Integrate habitat restoration opportunity planning with habitat connectivity enhancement needs**, including installation of wildlife crossing structures, as appropriate. This is to mitigate the adverse impacts of land use change on habitat connectivity and wildlife movement. For example a portion of the Deer Creek Golf Club and several areas just to the north of the golf course (off of Sideline 4) change from open space to estate residential under the +OP scenario, where this could be applied.
12. **Incorporate measures to protect and enhance habitat connectivity and prevent wildlife mortality on the road in enhanced NHS** during future land use and infrastructure planning processes. The enhancement areas in the enhanced NHS do not currently have roads, however if that changes then these areas need to be explicitly looked at for habitat connectivity impairments. For example the intersection of the 8th Concession and Sideline 6, crossing the 7th Concession west of Balsam Road and east of Sideline 6, and across Salem Road just north and south of the 6th Concession.

13. **Undertake habitat connectivity and wildlife movement studies (including road mortality surveys) to identify strategic areas for mitigation** and connectivity improvement under each land use scenario. This should be critical study to be undertaken prior to any future linear infrastructure planning as well as development planning.

6.2.3 Protect vegetation communities, flora, and fauna species of regional concern

14. **Emphasize actions to protect sensitive species and their habitat, which may require finer level management interventions at site level.** For example the Rossland Road wetland could respond negatively to +OP scenario due to an increase in industrial areas adjacent to the wetland if more surfaces become impervious. This wetland contains numerous sensitive species such as twig-rush (*Cladium mariscoides*; L2), a seepage fen specialist (TRCA 2017a, Pennsylvania Natural Heritage Program 2018). Conserving habitat for this species and other fen specialists would involve enhancing buffers, controlling invasive species and protecting the natural hydrology of the wetland (Pennsylvania Natural Heritage Program 2018).

15. **Minimize different kinds of direct and indirect anthropogenic disturbances such as recreational uses and noise disturbance for sensitive species.** For example noise disturbance to the heronry at the Ajax Warbler swamp during planned/ongoing residential development and plant areas within the buffers around Ajax Warbler Swamp with native thorny species to discourage human disturbance in this sensitive area.

16. **Create larger habitat patches in the rural parts of the watershed through the enhanced NHS,** which would create future forested natural cover that would subsequently provide habitat for more interior forest-dependent and area-sensitive species. Many of these lands are located in the northern, more agricultural, portion of the watershed and as such, a strategy should be put in place outlining a process for engaging and seeking the support of affected parties.

17. **Maintain agricultural areas in north Carruthers for meadow-dependent species** including several Species-at-Risk (bobolink and eastern meadowlark).

18. **Account for sensitive vegetation communities in the areas where the land is targeted for land use conversion**. For example conversion to estate residential areas just west of Sideline 4 between the 5th and 6th concessions under the +OP scenario should consider nearby sensitive vegetation communities such as forests, fens and sand barrens.

19. **Incorporate existing sensitive flora and fauna species and adjacent vegetation communities into site-level restoration plans** to facilitate restoration success.

20. **Proactively account for the Species at Risk Ontario (SARO) with regulated habitat in land use and infrastructure planning processes**. For example at least two locations of bank swallow colonies and four barn swallow nests (SARO with regulated habitat) have been identified in Carruthers Creek since 2015. Bobolink and eastern meadowlark (SARO with regulated habitat) have been confirmed breeding or recorded as probable breeders throughout the watershed but primarily (but not exclusively) north of the 6th concession.

6.2.4 Building climate resilience of the habitat, communities, and species

21. **Include the high and medium vulnerability natural features and areas in the targeted enhanced natural heritage system to protect further loss of habitat and their functions due to climate change drivers**. This includes vulnerable habitat patches, climate sensitive vegetation communities, and wetlands. The protection warranted through the target enhanced NHS will improve resilience and adaptive capacity of these features and areas.
22. **Manage and adapt urban matrix to address the high and medium vulnerability areas for ground surface temperatures** (by reducing urban heat island effects) and soil drainage (by maintaining permeability). These areas are mostly in the built portions of the watershed and affects the structure and function of the terrestrial system, both inside and outside the natural heritage system.
23. **Adapt restoration and land management measures in the high and medium vulnerability areas for climate sensitive vegetation** such that it accounts for the possibility that climate drivers may pose challenging conditions for these vegetation communities to thrive in the watershed. Relatively new adaptation and management approaches such as assisted migration and facilitating native seed banks should be explored as standard management practice, as appropriate.
24. **Manage urban matrix influences outside the targeted enhanced NHS through innovative approaches** to prevent further exacerbation of climate impacts on terrestrial features and areas**.** This includes maintaining permeable areas dominated by different forms of living green infrastructure (e.g. natural areas, urban canopy, green roofs, bioswales).
25. **Mitigate cumulative impacts of urbanization that may further compromise the resilience of the climate sensitive vegetation, if appropriate, through targeted protection and management**. For example
    - Two Treed Sand Barren ELC communities (highly vulnerable) are located adjacent to an area currently delineated as open space (with some development already) on the east side of Salem Road just south of the railway line. Under the +OP scenario, more of the open space areas are converted to commercial development. Treed Sand Barrens could be negatively affected by soil compaction in the surrounding areas, changes in nutrients or chemicals from runoff and invasive species. These impacts could be mitigated by planting a buffer of native vegetation and utilizing LID techniques to minimize nutrient and road salt runoff. Some additional planting is already proposed in the ROP assessment.
    - A portion of the Deer Creek Golf Club and several areas just to the north of the golf course (off of Sideline 4) change from open space to estate residential under the +OP scenario. Areas adjacent to these proposed developments contain one of the densest clusters of highly vulnerable climate sensitive vegetation communities including several Treed Sand Barrens and a White Cedar – Scots Pine Low Treed Mineral Fen. Again, efforts should be made to control soil compaction in the surrounding areas, nutrient runoff and changes in hydrology. This could be achieved through the incorporation of green infrastructure, LID techniques and Restoration Opportunity Plans into the development.

6.2.5 Identifying critical questions and establishing a long term monitoring network

26. **Develop a list of long-term strategic questions that are important to be answered to assess the state of the terrestrial system and target setting and achievements in the Carruthers Creek watershed in future**.

This should be informed by this study and the indicators and metrics used in the process as well as the gaps identified through this study.

27. **Establish a long term monitoring network to allow for the strategic research questions to be answered to help achieve the terrestrial goal and objectives of the CCWP.**

6.3 Illustration of Specific Recommended Actions

Figure 16 provides an illustration of the spatially explicit actions that was revealed through the TIA, which builds upon the targeted enhancements in the +NHS scenario to help achieve the terrestrial goal and objectives of CCWP. This includes identification of additional areas for targeted enhanced NHS, specific actions for improving connectivity, maintaining agricultural lands for its potential to contribute to habitat function, and protecting and enhancing habitat for SARO as well as species of regional concern. Additionally, the figure illustrates examples of areas where natural features could be integrated with potential urban land uses and minimizing urban matrix influences.

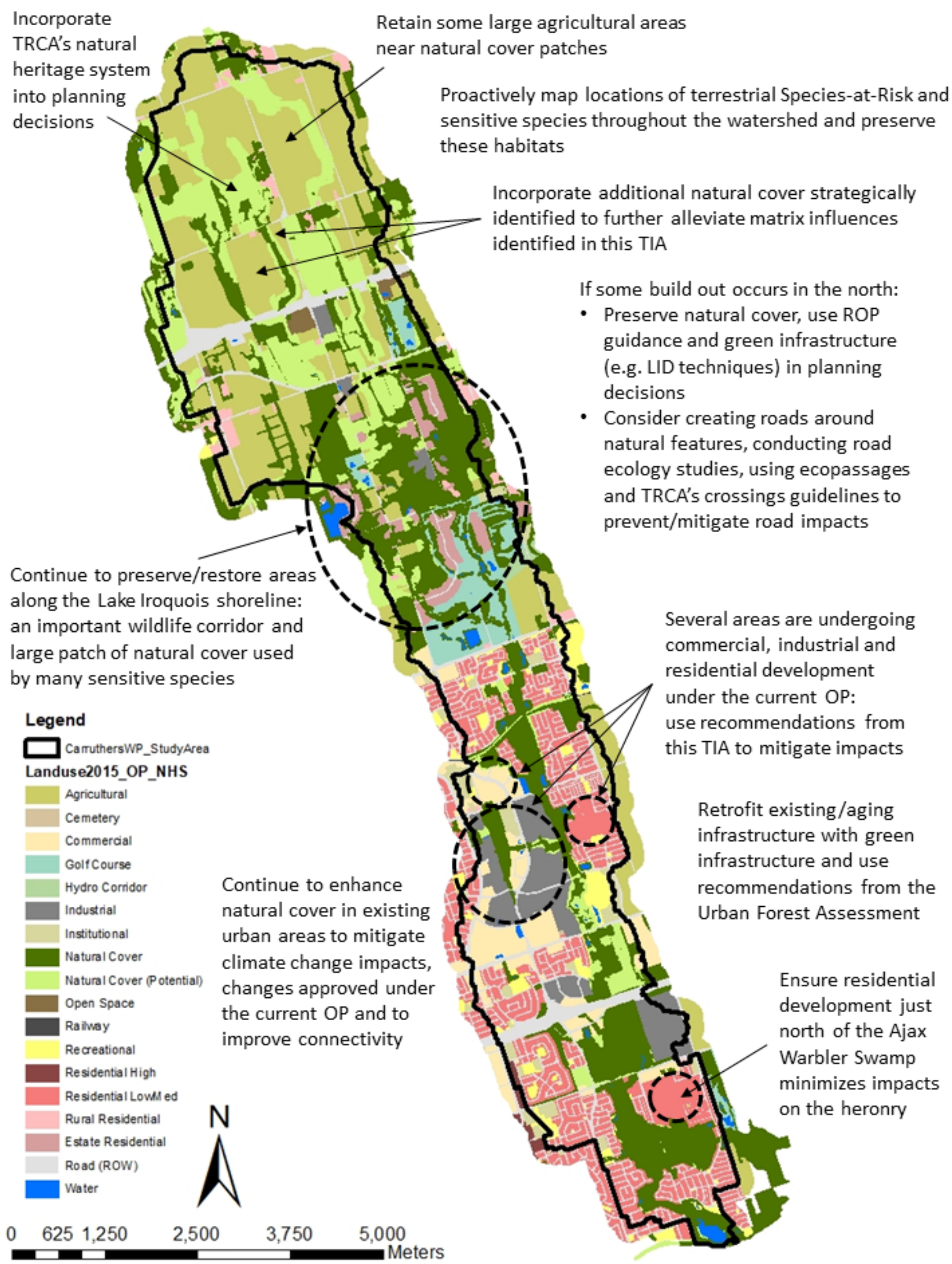

Figure 16. Additional land use recommendations for the terrestrial NHS based on the results of the TIA.

Figure 16 emphasizes protection of some key strategic areas of the existing agricultural lands and adds more natural cover to the +NHS scenario to address some key terrestrial issues revealed through the TIA.

Agricultural lands in southern Ontario produce over $1 billion in ecosystem services such as pollination, soil retention, atmospheric regulation and wildlife habitat and conserving some agricultural lands in the Carruthers Creek watershed will help maintain these functions and services (Troy and Bagstad 2009). Conservation of strategic areas for agricultural lands helps to achieve certain specific terrestrial system objectives, namely providing habitat for open country species (including SARO), allowing safer passage for wildlife amidst future built out areas, and offsetting some of the future urban matrix influences. Breeding SARO were detected in these areas in 2015/2016 surveys and the habitat is currently considered regulated by the Ministry of Natural Resources and Forestry (MNRF) now under the Ministry of the Environment, Conservation and Parks (MECP). If non-compatible land use changes (e.g. urban development) are proposed in these areas in the future, the MNRF may request a re-survey of areas where SARO have been historically found and subsequently make decisions about land use.

The data from TRCA's terrestrial long-term monitoring plots collected between 2008 and 2014 across the jurisdiction show that there are strong, negative effects of urbanization on almost all aspects of flora and fauna communities (TRCA 2015b). In urban areas of the TRCA's jurisdiction, flora and fauna communities on average consist of more generalist species, more non-native species, fewer area-sensitive species and fewer species of frogs (TRCA 2015b). Maintaining some agricultural land will help to preserve a more rural landscape and are expected to continue to provide flora and fauna communities with a landscape characteristic of the rural, less impacted areas of the jurisdiction (TRCA 2015b).

The additional natural cover in the north central parts of the watershed is aimed at improving the targeted enhanced NHS delineated in the +NHS scenario to specifically increase the area of the largest habitat patch in the watershed. The additional areas of natural cover are strategically placed in locations that fill in the gaps between existing natural cover such that they maximize larger habitat patches in the system. The presence of large habitat patches in the landscape not only improves the habitat quality of the particular patch that can support more sensitive species but also allows for the smaller habitat patches in the landscape to function better by providing a robust source population and other habitat needs. This large patch further alleviates future matrix influences and create habitat for area-sensitive species and species of conservation concern.

The type of urban land use affects terrestrial ecosystem function and the amount of habitat for flora and fauna. Implementation of different forms of green infrastructure and LID features can help mitigate some of these impacts. For example, LID techniques and soil conservation practices can reduce development impacts on local streams and hydrology by lowering runoff volumes and pollutant export (Dietz and Clausen 2008). This can help to maintain pre-development hydrology and the natural features that rely of specific hydrologic regimes (e.g. wetlands, streams). In areas where build out is necessary, incorporating tree conservation and planting, restoration using the ROP database, green roofs, green walls, bioswales, and other green infrastructure is an important consideration for mitigating future climate impacts (e.g. reducing temperatures and runoff; NRC 2003).

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8 Appendices

Appendix 1.: GIS notes on the five land use scenarios

Land Use – Current conditions

1. The base layers for the Land Use – Current Conditions (Existing – 2015) was compiled using various datasets
    a. Land Use TRCA (landuse_trca) – 2013 data layer updated in 2015 using orthophoto-
    b. ELC (elc_trca) – 2015
    c. Habitat (habitat_trca) – 2013
2. 'Habitat' was the base layer used as it provided coverage throughout all of the Carruthers
3. 'ELC' was then erased out of 'Habitat' as the 'ELC' had been compiled recently and was the most up-to- date. The erased Habitat layer was then merged with the ELC (Habitat + ELC)
4. The 'Land Use TRCA' layer was then erased using the new layer 'Habitat + ELC'. This was then merged (Land Use + Habitat + ELC) to create a new layer to be used as the base for 'Land Use – Current Conditions'
5. 'Land Use – Current Conditions' was <u>verified using 2015 aerial imagery</u> to confirm the land use classifications were accurate or needed to be updated.
6. Agricultural category was updated using maps that had been ground verified on what crop was growing there or that in fact was an agricultural field.
7. The following categories were decided to be used as the Land Use – Current Conditions categories:
    a. Agricultural
    b. Cemetery
    c. Commercial
    d. Estate Residential
    e. Golf Course
    f. Hydro Corridor
    g. Industrial
    h. Institutional
    i. Natural Areas
    j. Open Space
    k. Open Space Construction
    l. Railway
    m. Recreational
    n. Residential High
    o. Residential LowMed
    p. Road (ROW)
    q. Rural Residential
    r. Water

8. There were many consultations that occurred with internal staff and external partners to verify that the dataset was true to what was shown on the 2015 imagery. Once this layer was approved, it was used as the base for Scenarios 1-3

Land Use – Scenario 1

1. Current Conditions was the basis for Scenario 1 – Existing Land Use + OP.
2. The most recent OP data was downloaded from Ajax, Pickering and Durham. The data was then used for comparison of what was documented on the ground 2015.
3. A separate field was created in the attribute table of the layer in order to capture the change from 2015 to whatever year the OP was established as long the OP was more recent than 2015
4. This layer was also reviewed by internal staff that were working on the Carruthers WP
5. 'Open Space Construction' category was now replaced with what was built in that space

Land Use – Scenario 2

1. Scenario 1 was used as the basis for Scenario 2 – Existing Land Use + OP + NHS
2. This layer used the existing Natural Heritage System and through various exercises with internal staff was updated to include areas that:

    a. where not captured in the previous heritage system
    b. encompassed all the recommendations: floodplain, greenbelt, wetlands, etc.
3. Once the final Natural Cover and Enhanced Natural Cover were agreed upon, this layer was erased out of Scenario 1 and then merged together
4. 'Enhanced Natural Area' was now added to the legend

Land Use – Scenario 3

1. Scenario 1 was used as the basis for Scenario 3 – Existing Land Use + OP + NHS + Potential Urban. Area for build out was all area outside of the NHS from Scenario 2.

Appendix 2: Carruthers Creek Wetland Catchment Analysis

1. Introduction and Objectives

The objective of this work is to identify areas within the Carruthers Creek watershed where future urban development has the potential to significantly alter the water balance of wetlands. Changes to the proportion of impervious cover and size of a wetland's catchment can alter the timing and magnitude of water level conditions throughout the year, which in turn can lead to degradation or loss of wetland plant and animal species if conditions are too dry or wet at particular times of year. In general, the potential for disruption of a wetland's ecological functions and services as a result of hydrological changes (and secondary effects, e.g. sedimentation) increases as the proportion of urban cover within its catchment increases (Taylor *et al.* 1995, Hicks and Larson 1997, Reinelt and Taylor 2001).

Studies suggest that the potential loss of amphibians and other more sensitive species increases significantly past 10% catchment impervious cover, while only certain tolerant and/or exotic flora and fauna species will be found above 25% impervious cover (Taylor 1993, Taylor *et al.* 1995, Chin 1996, Boward *et al.* 1999, Hicks and Larson 1997, Reinelt and Taylor 2001). However, these studies focused on urban development situations in which there was little to no consideration of the impact of altered urban drainage on natural features in the design of new urban areas. In many situations, it will be possible to identify opportunities to mitigate the impacts of urban development on wetland hydrology through a feature-based water balance analysis (FBWB). TRCA may require a FBWB to be completed in certain situations in order to satisfy its stormwater management criteria for water balance, as outlined in the Stormwater Management Criteria document (TRCA 2012).

This analysis identifies wetland catchments in the Carruthers Creek watershed in which feature-based water balance may need to be considered in future development plans. The intent of this analysis is to provide information that can be used as a screening tool, to identify areas of the watershed where FBWB will likely need to be considered in the design of future urban areas, rather than definitively identifying which wetlands will require a FBWB. The decision to require a FBWB will necessitate collection of more detailed information about both the specific wetland(s) in question, as well as the precise nature and extent of the proposed development. By ensuring that feature-based water balance is considered early on in the planning and development process, this analysis will help to maintain the current proportion of wetland cover in the Carruthers Creek watershed, as well as the plant and animal communities using these habitats.

Other types of natural features, including woodlands and streams or headwater drainage features, may also benefit from consideration of feature-based water balance, and are included in the water balance component of TRCA's Stormwater Management Criteria (2012). Delineation of contributing drainage areas for woodlands may not always be possible, depending on how the woodland feature boundaries align with patterns of topography. While consideration of woodlands was initially determined to be within scope for this analysis, ultimately it was determined that screening for FBWB for woodlands would be more appropriate at the site scale, once more information is available about the proposed development to inform how hydrology may be altered.

2. Methodology

2.1 Wetland mapping

The wetlands in the TRCA 2018 generic regulatory layer were combined with those wetlands from the TRCA 2014 natural cover layer which were identified from interpretation of aerial orthophotographs to create a comprehensive wetlands layer for Carruthers Creek watershed. A number of smaller wetlands, mostly <1 ha, did not appear in the generic regulatory layer. Wetlands from the natural cover layer that overlapped with those from the generic regulatory layer were eliminated, as these were assumed to represent the same underlying natural feature except with reduced accuracy in the delineation of feature limits. The additional wetlands derived from the natural cover layer underwent further visual QA/QC using the most recent orthophotographs available to ensure that the data represented wetlands that were still on the landscape and that were natural wetlands as opposed to stormwater ponds, golf course features, or other non-wetland features.

2.2 Wetland selection

To facilitate catchment analysis, certain wetlands were eliminated from the scope of the analysis. Firstly, and most significantly, those wetlands that were in the more urbanized part of the Carruthers Creek watershed, defined as south of Taunton Road, were eliminated from the analysis. This was justified because substantial alteration of land use has already taken place and the opportunity to inform urban design through FBWB is therefore more limited. The hydroperiod of these urban wetlands may also have been substantially altered from the pre-development baseline already. Additionally, delineation of wetland catchments based on LiDAR-derived topography, as described below, is prone to large errors in urban areas due to presence of sewers, storm drains, and other sub-surface drainage infrastructure, and therefore application of topographical methods to derive wetland catchments provides less useful information. Eliminating the wetlands south of Taunton Road reduced the number of wetlands considered for analysis from 219 to 107.

From this reduced pool of wetlands, an arbitrary minimum size criterion of 0.25 ha was applied in order to make the scope of analysis more manageable, as catchments delineation involved many manual spatial analysis steps. Little additional data was available about the majority of these small wetlands, the presence of which was inferred from aerial orthophotography, to support evaluation of sensitivity. TRCA does not normally apply a minimum size criterion to define wetland features; rather, this minimum size criterion relates to the feasibility of analysis within a high-level screening exercise. Application of the size criterion resulted in the number of wetlands included in the analysis being reduced to 73.

2.3 Catchment delineation

To delineate the area draining to each of the wetlands considered to be within the scope of the analysis, the following process was used:

- Wetland catchment delineation was attempted for each individual wetland feature by applying the ArcHydro module in ESRI ArcGIS 10.3 to a LiDAR-derived digital elevation model for the Carruthers Creek watershed.
- The flow path tracing tool, which traces the line that a hypothetical water droplet would follow across the saturated landscape, was used to determine the number of locations at which water outlets from the boundaries of each wetland feature (i.e. the number of outlets).

- For wetlands with more than one outlet, a catchment was defined for those wetlands which had flow path convergence within 50 m down-gradient of the feature boundary by delineating the catchment to the convergence point. This meant that some down-gradient (or downstream) area was included in the catchment boundary, but is justified because this down-gradient area may be seasonally inundated and the wetland boundaries may occasionally extend to this point.
- Catchments for wetlands with more than 5 outlets were said to be undefinable using this approach, and therefore catchments could not be determined for these wetlands. Catchments for wetlands with fewer than 5 outlets but which had drainage flowing to multiple different downstream catchments could not always be defined, but in some circumstances catchment delineation was possible. These issues were most commonly encountered in forested swamps, where the limits of seasonal inundation are often more challenging to define, and where similar forest community composition is often used to define the feature boundary.
- Wetlands were aggregated together if they were separated by a distance of less than 100 m and shared a common drainage point; most commonly this occurred along watercourses. In these cases, a single catchment was derived to represent multiple wetlands.
- Of the 73 wetlands included in the scope of the analysis, it was possible to derive catchments for 59 of them, or approximately 81% of the total wetlands assessed, using the approach outlined here. Several of the wetlands on the main branch of Carruthers Creek immediately north of Taunton Road were found to have catchments coincident with the entire northern half of the watershed; these wetlands were also eliminated from consideration in the analysis, bringing the final number of wetlands in the analysis to 55. After aggregating several of these wetlands by proximity, these 55 wetlands corresponded to 50 wetland catchments.

2.4 Comparison with Carruthers Creek land use scenarios

Each of the 50 catchments were assigned values based on the proportion of additional future urban land use within the catchments under scenario 1 (+OP) and scenario 3 (+Potential Urban), as the extent of new (i.e. not presently existing) urban area only differed for these two of the five land use scenarios.

A value of 10% new urban area within the wetland catchment was set as the minimum threshold to screen catchments for which a FBWB may be required. The 10% threshold for impervious cover is one that TRCA staff would commonly use in determining whether a monitoring program may be required to inform a modeling analysis (TRCA 2017), and is derived from the scientific literature (Taylor 1993, Taylor *et al.* 1995, Chin 1996, Boward *et al.* 1999, Hicks and Larson 1997, Reinelt and Taylor 2001). Although a value of 10% new urban area may not equate to 10% impervious cover (i.e. not all new urban area is impervious), this value serves as a good starting point for a screening exercise. In general, as the proportion of new urban area within a wetland catchment increases, the likelihood that FBWB will be an important consideration in development design also increases.

2.5 Evaluation of wetland sensitivity to hydrological change

The sensitivity of the wetlands in this analysis to hydrological change was evaluated using the framework outlined in the *Wetland Water Balance Risk Evaluation* (TRCA 2017). Briefly, this method considers the ecology of the wetland, including known fauna and flora records and classification according to southern Ontario Ecological Land Classification code (Lee *et al.* 1998). The hydrology of the wetland is also considered, with wetlands receiving water inputs from a permanently flowing watercourse understood as being less vulnerable to hydrological change than wetlands relying solely on runoff generated from a small localized catchment (e.g. isolated kettle wetlands). See TRCA (2017) for further details on methodology.

3. Results

3.1 Wetland catchments

Figure 1 shows all of the 50 wetland catchments for which overlap with new urban areas was evaluated. The area of each catchment is shown in Table 1.

3.2 Extent of future urban area within wetland catchments

Under the +OP scenario, only one wetland catchment exceeded the 10% new urban area threshold, while under the +Potential Urban scenario, 30 catchments (60%) exceeded this threshold (Figure 2, Figure 3, Table 13).

3.3 Wetland sensitivity to hydrological change

Sufficient data was available to classify the sensitivity to hydrological change of 44 of the 50 wetland catchments. Of the 44 classified wetlands, 12 (27%) were classified as highly sensitive, 13 (30%) as medium sensitivity, and the remaining 19 (43%) as low sensitivity. The results for each individual wetland catchment are shown in Table 13.

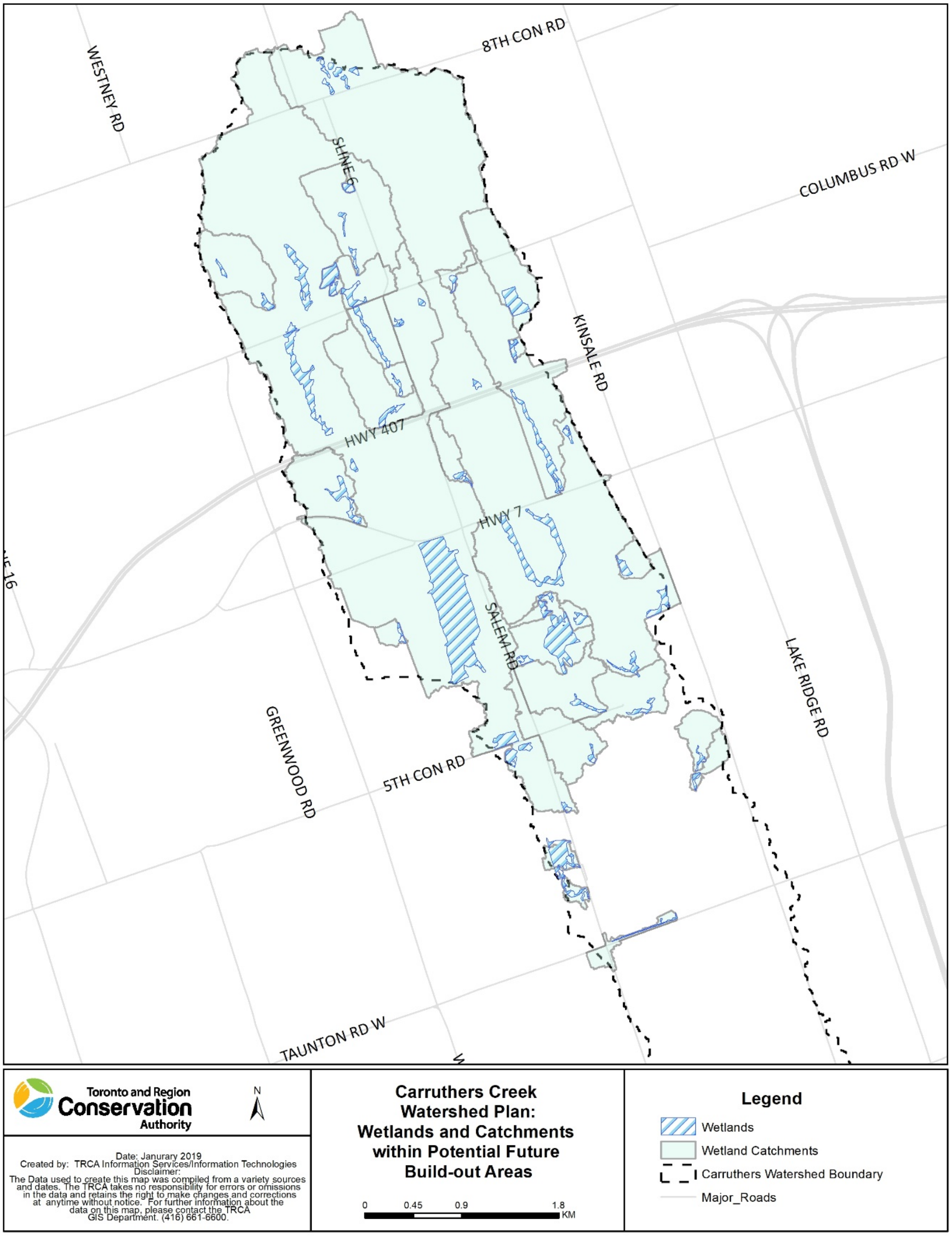

Figure 17: Map showing the wetlands considered in the analysis and their catchment areas. Due to issues of boundary overlap, not all catchments can be clearly distinguished on the map.

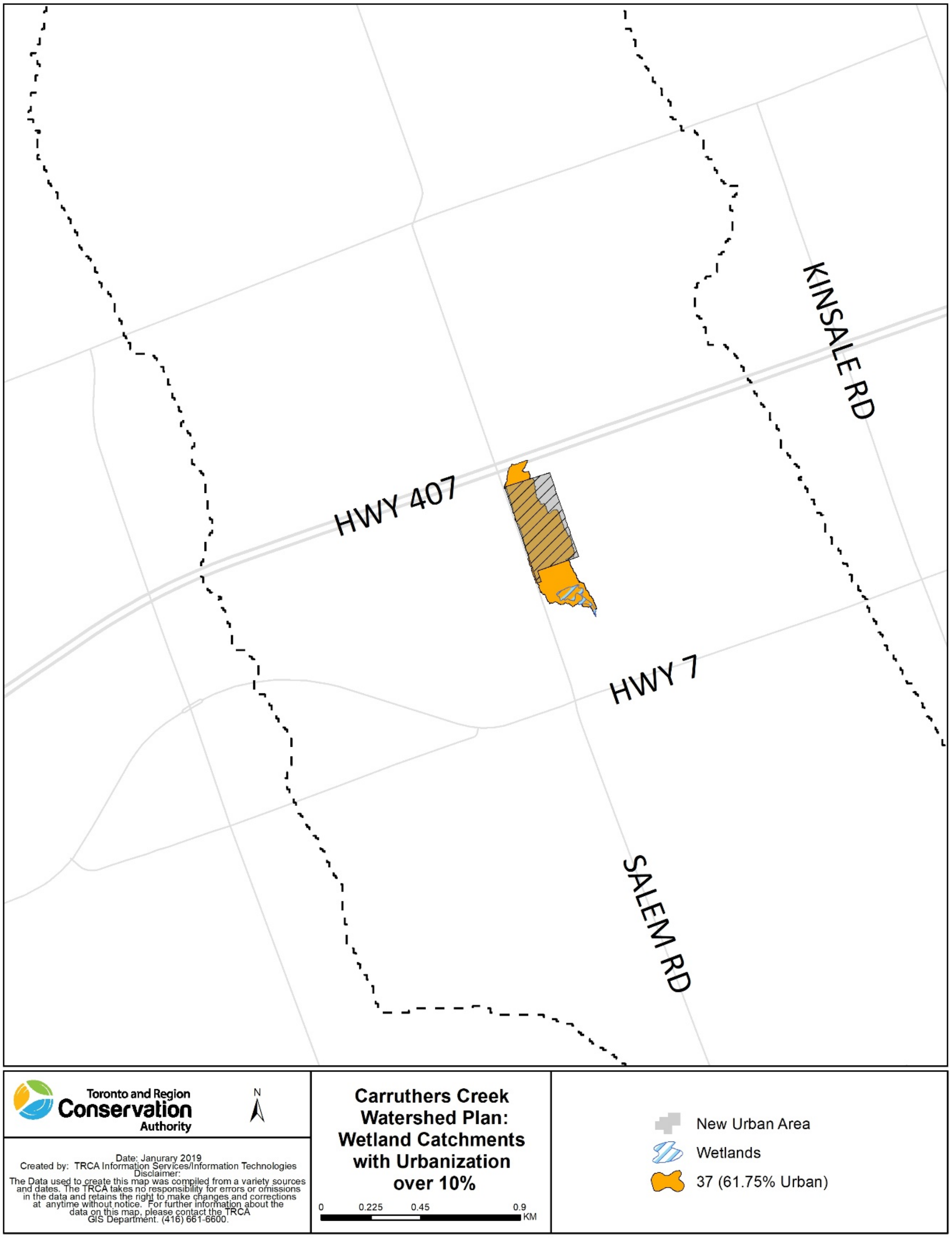

Figure 18: Results of wetland catchment analysis for +OP scenario. Future urban areas for this scenario are shown as transparent grey overlay.

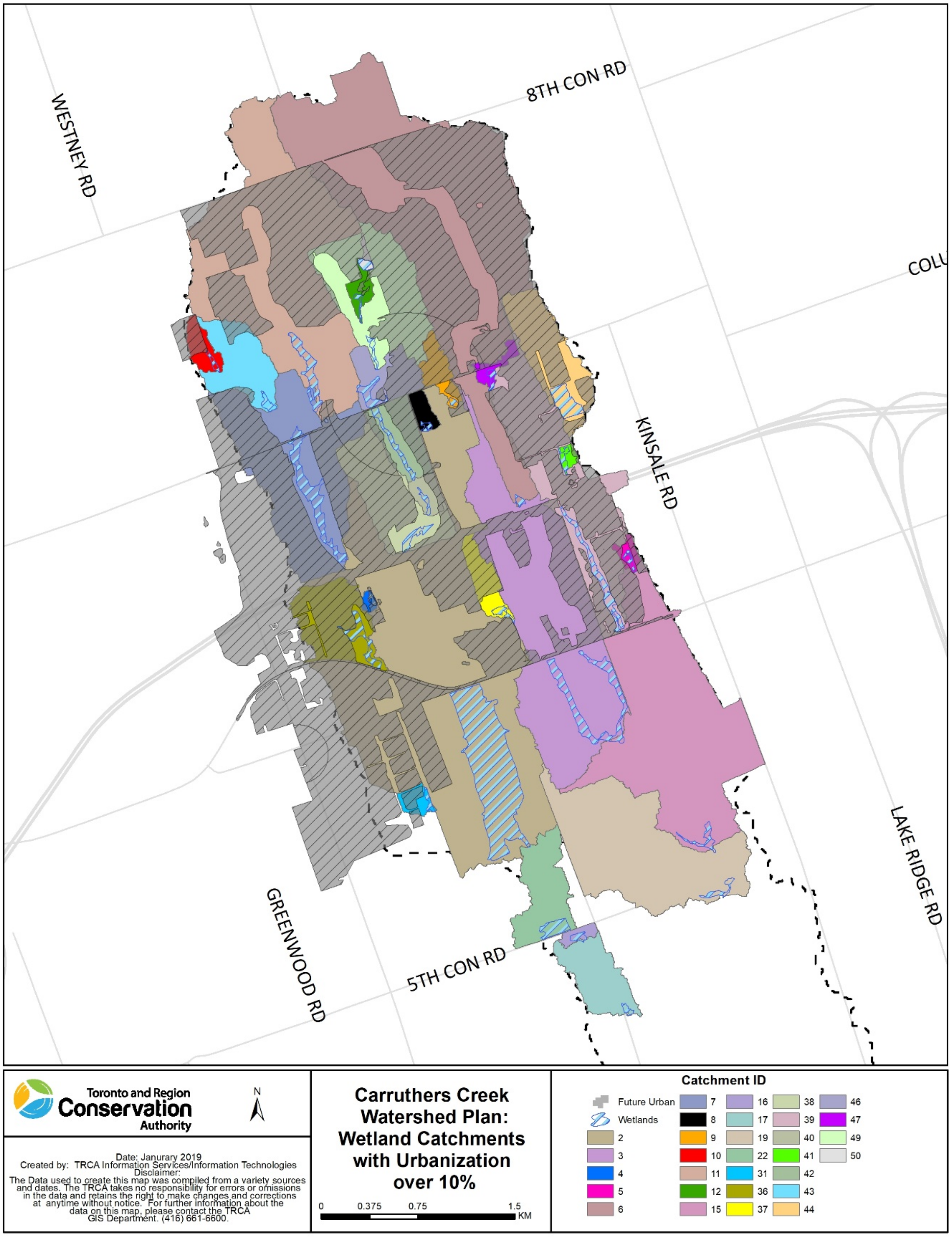

Figure 19: Results of wetland catchment analysis for + Potential Urban scenario. Potential future urban areas for this scenario are shown as transparent grey overlay with hatching. Wetland catchments with >10% potential future urban area are shown as solid colours. Due to issues of boundary overlap, not all catchments can be clearly distinguished on the map.

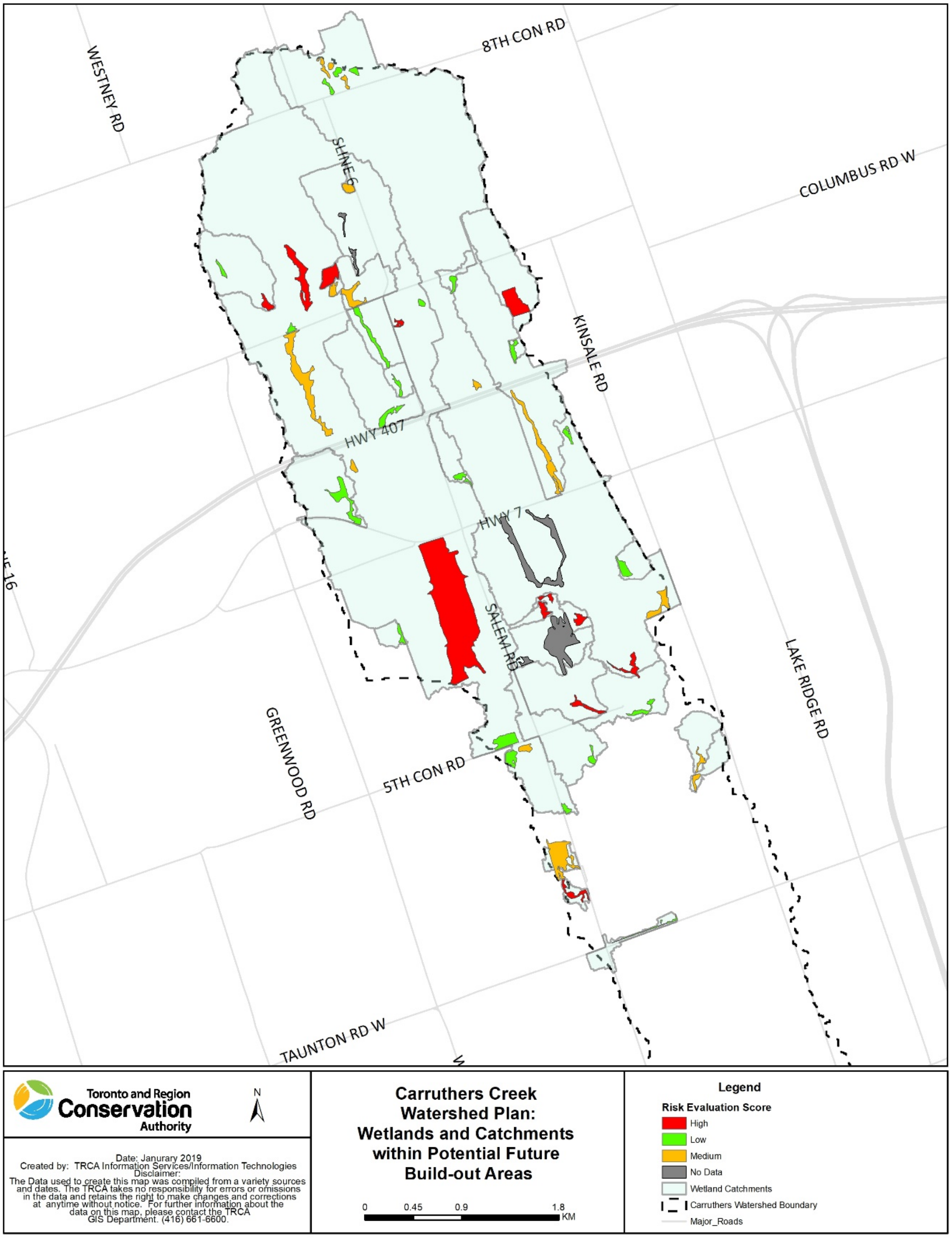

Figure 20: Results of evaluating wetland sensitivity to hydrological change using the Wetland Water Balance Risk Evaluation (TRCA, 2017) framework. Wetland colour indicates sensitivity (red=high, yellow=medium, green=low, grey=insufficient data).

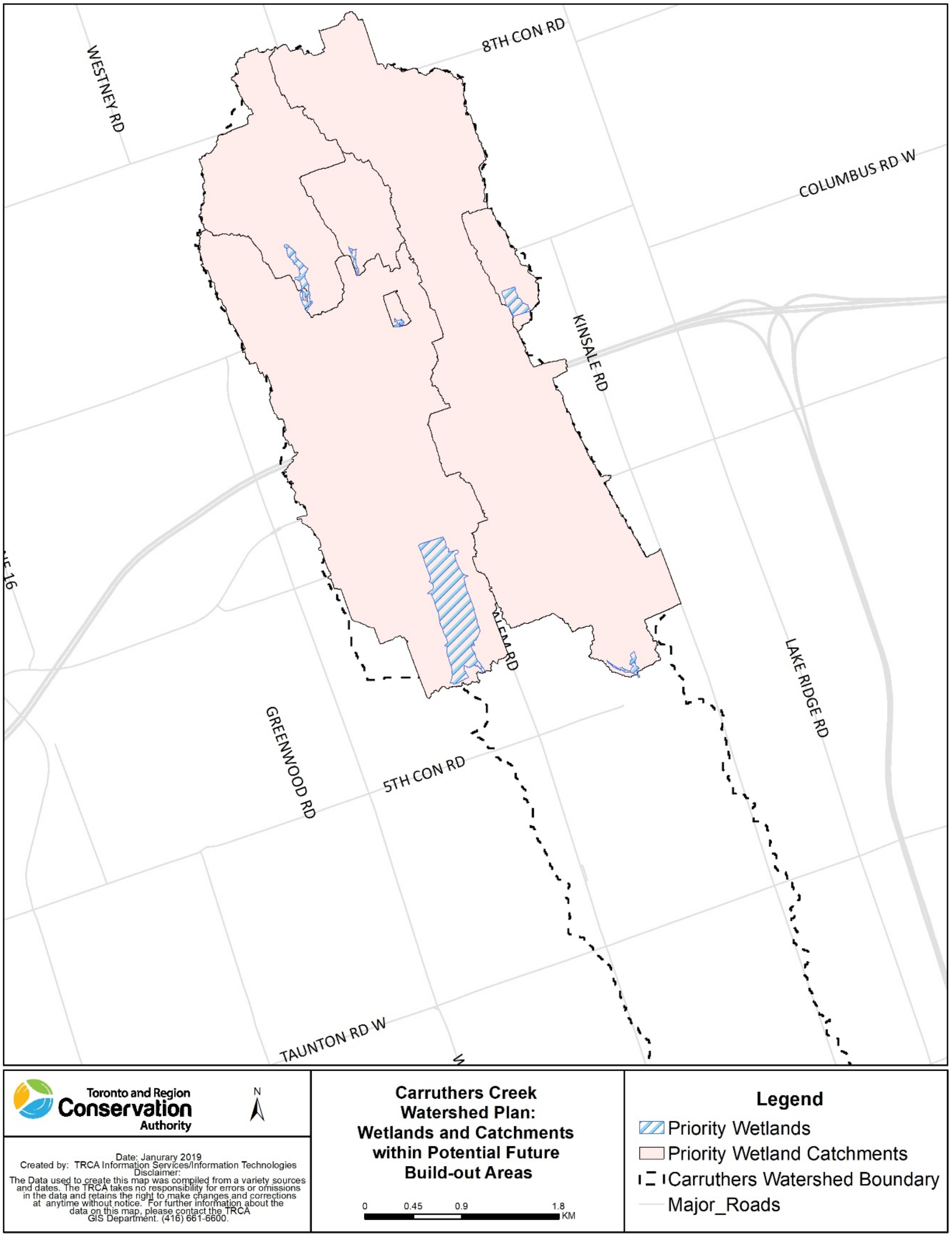

Figure 21: Wetlands identified as a priority for proactive hydrological monitoring under +Potential Urban scenario. These priority wetlands were identified as being both highly sensitive and as having a high likelihood of hydrological disturbance under the +Potential Urban scenario.

Table 13: Results of wetland catchment analysis for scenario 1 (+OP) and scenario 3 (+Potential Urban). Cells in the "catchment ID" column are coloured according to the evaluated sensitivity of the wetlands as per the Wetland Water Balance Risk Evaluation (TRCA, 2017) (red=high, yellow=medium, green=low, grey=insufficient data). Cells in "% urban" columns are highlighted in grey where the proportion of new urban area for a given scenario within the wetland catchment exceeded 10% of the catchment area. Rows that are bolded and italicized indicate that the catchment has been identified as a monitoring priority under scenario 3 (+Potential Urban).

Catchment ID	Catchment Area (ha)	Scenario 1 % Urban	Scenario 3 % Urban	Catchment ID	Catchment Area (ha)	Scenario 1 % Urban	Scenario 3 % Urban
1	12.3	0.0	0.0	26	4.1	0.0	0.0
2	***822.0***	***0.0***	***49.6***	27	20.3	0.0	0.0
3	418.6	0.0	42.9	28	12.7	0.0	0.0
4	1.5	0.0	53.8	29	33.8	0.0	0.0
5	3.3	0.0	54.7	30	2.0	0.0	0.0
6	253.3	0.0	54.7	31	4.7	0.0	45.0
7	310.0	0.0	52.1	32	11.5	0.0	0.0
8	***4.7***	***0.0***	***10.3***	33	34.6	0.0	0.0
9	9.2	0.0	85.5	34	3.3	0.0	0.0
10	7.2	0.0	45.5	35	8.2	0.0	0.0
11	***176.0***	***0.0***	***52.4***	36	32.8	0.0	75.3
12	6.0	0.0	24.4	37	11.2	61.8	69.8
13	6.3	0.0	0.0	38	144.1	0.0	64.2
14	1.8	0.0	0.0	39	126.2	0.0	71.7
15	***698.1***	***0.0***	***39.9***	40	104.9	0.0	58.2
16	852.9	0.0	47.8	41	2.2	0.0	14.6
17	875.8	0.0	46.5	42	98.9	0.0	59.9
18	6.6	0.0	0.0	43	33.6	0.0	19.2
19	795.0	0.0	35.0	***44***	***36.0***	***0.0***	***71.4***
20	1.5	0.0	0.0	45	1.6	0.0	0.0
21	67.5	0.0	0.0	46	79.8	0.0	61.6
22	849.9	0.0	47.9	47	4.5	0.0	50.1
23	1.9	0.0	0.0	48	2.5	0.0	0.0
24	6.6	0.0	0.0	***49***	***61.9***	***0.0***	***64.9***
25	8.1	0.0	0.0	50	1.5	0.0	48.5

4. Discussion

This analysis is meant to be a screening exercise to identify the areas of Carruthers Creek watershed that are most likely require further investigation at the site or sub-watershed scale to set FBWB study terms. The 10% threshold for new urban area within a catchment does not imply that a FBWB will be required for each catchment; rather, urban development within catchments identified as having 10-20% new urban area will need to show in draft designs that it does not exceed the 10% impervious cover threshold. The 10% impervious cover threshold is used in the TRCA *Wetland Water Balance Risk Evaluation* (2017) to determine whether monitoring and modeling may be required to inform a FBWB. The same numerical threshold (10%) is used to evaluate changes to the size of a wetland's contributing drainage area. The proportion of new urban cover within each catchment for the +OP and +Potential Urban scenarios should therefore be interpreted as reflecting the likelihood that a FBWB study will be required to inform development in the area of Carruthers Creek watershed north of Taunton Road. Wetland catchments with a very high proportion of new urban area (e.g. >50%) would be very likely to require a FBWB to maintain the form and function of that particular wetland.

In the +OP scenario, only one of the wetlands north of Taunton Road was projected to be impacted by new urban development beyond the new urban area threshold of 10%. The single impacted wetland, located immediately south of the Highway 407 corridor, was however projected to be heavily impacted, with 61.8% of the catchment slated for new urban development. Impacts to this wetland via altered water balance would be very likely without consideration of feature-based water balance in the design of this small block of urban development. The large majority of new urban development in the +OP scenario is to the south of Taunton Road. There may still be opportunities to improve urban design in these infill development areas through consideration of FBWB, however these wetlands and their associated catchments were beyond the scope of this analysis.

By contrast, in the +Potential Urban scenario, over 60% of the wetland catchments were projected to have >10% overlap with new urban areas. Furthermore, more than 30% of the wetland catchments analyzed (16 catchments) are projected to have >50% new urban area, meaning that extensive alteration of the wetland hydrology would be likely in the absence of design measures to help mitigate the impacts to wetland water balance. The most heavily impacted wetland catchments are generally in the areas along Westney Road, both north and south of Highway 7, and in the northernmost part of the watershed between Concession Road 7 and Concession Road 8. More data on the ecology and hydrological sensitivity of wetlands in this area, as well as on the form of urban development that might be proposed, would be needed to scope FBWB studies appropriately, should this part of the watershed be deemed appropriate for development. Development of this area of Carruthers Creek watershed, which contains many wetlands and headwater drainage features, may require municipal investment in proactive monitoring and subwatershed studies to avoid degradation of wetlands and adjacent natural heritage features via altered hydrology.

This analysis excluded consideration of wetlands in the more urbanized areas of the watershed south of Taunton Road. However, there may still be some benefit to considering FBWB in the design of infill developments and infrastructure retrofits within the area draining to these wetlands, where opportunities to restore hydrology or improve ecological function may exist.

5. Recommendations

The following recommendations emerge from this analysis:

- The most sensitive wetlands with the highest degree of new urban area projected within their catchments should be prioritized for further study, as more detailed information on Settlement Area Boundary Expansions and proposed municipal zoning within these areas becomes available. The *Wetland Water Balance Risk Evaluation* (2017) provides further background on what attributes characterize wetland sensitivity to hydrological disturbance. Prioritization of wetlands for further screening should also consider existing information on wetland ecology, species at risk (as per the Ontario Endangered Species Act and Canada Species at Risk Act), surficial geology, and groundwater conditions.
- Further screening of wetlands for further study should take place as soon as more information on the nature of the land use and/or built form is available (e.g. subwatershed plans, Master Environmental Servicing Plans, Plans of Subdivision). This screening can help to determine the need for and scope of FBWB studies to inform the development of these areas.
- Update the mapping of the natural heritage system to incorporate the findings of this report, considering in particular areas of the catchments of more sensitive wetlands where additional natural heritage system objectives (e.g. wildlife connectivity, natural cover targets) can be met.
- Proactive hydrological monitoring of highly sensitive features may be warranted where the feature has high natural heritage value (e.g. presence of species of conservation concern) and where significant expansion of the urban boundary within the wetland catchment is being considered or has been determined. Ensure that data are collected according to the TRCA *Wetland Water Balance Monitoring Protocol* (2016) and that at least three years of continuous baseline data are captured where possible. This data can then be used to calibrate a hydrology model to determine appropriate design alternatives in a FBWB study. The municipality may wish to undertake this monitoring itself, or to contract another entity to carry out this monitoring, in order to have it available at the earliest possible stage in the development process and thereby ensure that development is expedited.
- The information provided through this analysis provides a good starting point from which to scope further studies to protect wetlands in Carruthers Creek from adverse impacts of development. This will assist the municipalities to achieve the objectives for wetland conservation set out by the Provincial Policy Statement, the Province’s Wetland Conservation Strategy, and in other provincial policy and legislation.

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Appendix 3. Vulnerability indicators, related ecosystem services and relationship to climate drivers and impacts.

The indicators, ecosystem services and relationships to climate drivers are from Tu et al. (2017) but have been modified based on indicators used for the jurisdiction-wide analysis

Vulnerability indicator	Ecosystem service (function) represented	Relationship to climate drivers and impacts
Ground surface temperature (mid-afternoon) **Layer:** A **Scale:** Regional; 30 m resolution **Source:** LANDSAT satellite imagery assessed in ArcGIS for ground surface temperature June 18, 2014	1) Thermal Regulation (shading/thermal refuge for species; cooling of flow-through water and terrestrial system) 2) Regulation of Urban Heat Island Effect (areas with high ground surface temperatures indicate increased Urban Heat Island (UHI) influences and thus could be considered higher priority to mitigate using natural cover) 3) Energy Use and Conservation (indirectly implies which areas may require more cooling or higher energy amounts in the summer season)	**Increasing Temperatures**: Direct. Increasing (air) temperatures may increase ground surface temperatures depending upon local conditions in an area, such as the amount of natural cover present, the amount of urban forest canopy and its location in relation to the Lake Ontario shoreline. This in turn could reduce thermal regulation and refuge for species, impact the UHI regulation service and increase the amount of energy required for humans to stay cool. **Increasing Precipitation**: Indirect. Higher amounts of precipitation, if present/available during days with high temperatures or during extreme heat events, may reduce ground surface temperatures to an extent, although it is expected that the degree to which temperatures and extreme heat events could increase will be much larger and therefore ground surface temperatures will become higher and more pronounced in areas with insufficient natural cover, little urban forest and urban cover. **Drought**: Indirect. It is not anticipated that a lack of precipitation or a period of prolonged drought would significantly alter ground surface temperatures, although depending on the timing of occurrence, ground surface temperatures may remain elevated in urban areas with insufficient tree canopy and/or natural cover if weather systems bringing precipitation provide thermal cooling in the atmosphere do not occur for extended periods of time (although this would be limited). **Extreme Precipitation**: Indirect. Higher amounts and potentially more frequent extreme precipitation events, if present/available during days with high temperatures or during extreme heat events, may reduce ground surface temperatures to an extent, although it is expected that the degree to which temperatures and extreme heat events could increase will be much larger and therefore ground surface temperatures will become higher and more pronounced in areas with insufficient natural cover, little urban forest and urban cover. **Extreme Heat**: Direct. Extreme heat events with very high (air) temperatures may increase ground surface temperatures depending upon local conditions in an area, such as the amount of natural cover present, the amount of urban forest canopy and its location in relation to the Lake Ontario shoreline. This in turn could reduce thermal regulation and refuge for species, impact the UHI regulation service and increase the amount of energy required for humans to stay cool. **Growing Season Length**: Indirect. A longer growing season may increase ground surface temperatures on average and under extreme events, if it brings higher temperatures more frequently thereby exacerbating the urban heat island effect on areas with impervious cover.

Climate-sensitive vegetation (ELC community type) **Layer:** B **Scale:** Regional **Source:** TRCA terrestrial inventory ELC data; April 2017 ELC layer	1) Habitat Diversity (species-specific wildlife/bird breeding habitat, food resource, over wintering habitat, general cover 2) Moderation of invasives (competition)	**Increasing Temperatures**: Direct. Warmer temperatures likely to decrease the number and diversity of flora due to sensitivity of ELC community to heat stress/soil dryness; in turn this may disrupt ecological functions (as defined). NOTE: a decrease may not be measured but rather a shift from native to non-native composition might occur, in turn impacting species-specific habitat provision & moderation of invasive species. **Increasing Precipitation**: Direct. More precipitation may decrease the number and diversity of flora due to sensitivity of ELC community to wetter soils; impacts to ecological function (as defined) likely only if the shift is towards a substantial decrease in richness. NOTE: a decrease may not be measured but rather a shift from native to non- native composition might occur, in turn impacting species-specific habitat provision & moderation of invasive species. **Drought**: Direct. Long-term drought may decrease the number of climate sensitive vegetation species due to sensitivities to inadequate moisture; in turn this may disrupt ecological functions (as defined). NOTE: likelihood for greatest decrease in richness would be if drought is also coincident with extreme heat. **Extreme Precipitation**: Direct. Extreme (and frequent) amounts of precipitation may decrease the number and extent of climate sensitive native vegetation through physical damage/uprooting or drowning of ELC communities sensitive to frequent inundation; these impacts may be spatially limited to flood prone areas and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Extreme Heat:** Direct. Extreme heat events may decrease the number and extent of climate sensitive native vegetation due to acute heat stress (leading to mortality) in sensitive ELC communities; these impacts may be spatially limited to areas where vegetation is currently "highly" vulnerable (e.g. urban forest) and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Ice Storms**: Direct. Ice storms may decrease the number and extent of climate sensitive native vegetation due to physical damage (leading to mortality) in sensitive ELC communities; these impacts may be spatially limited to areas where vegetation is currently "highly" vulnerable (e.g. urban forest, EAB infested/decrease, other?) and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Growing Season Length**: Direct. A longer growing season may increase the number and extent of climate sensitive native vegetation, if there is sufficient precipitation to support this longer frost-free period, late-seasonal frosts are not experienced and phenology is not disrupted; impacts to ecological functions (as defined) are not anticipated under the scenario described above.
Habitat patch quality **Layer:** C **Scale:** Watershed **Source:** Habitat patches assessed by TRCA; 2013 layer	1) Habitat Diversity (physical habitat connectivity through valley-corridors and across table lands) 2) Hydrological Cycle Regulation (attenuation, infiltration, ET and E) 3) Erosion Regulation (top soil stability/structure, valley and stream bank stability) 4) Thermal Regulation (shading/ thermal refuge in streams, through valley- stream corridor, and on table lands) 5) Air Quality Regulation (transpiration processes) 6) Water Quality Regulation (contaminant uptake)	**Increasing Temperatures**: Direct. Warmer temperatures may decrease amount and size of habitat patches and/or shift distribution due to sensitivity of ELC community to heat stress/soil dryness; in turn this may disrupt ecological functions (as defined), particularly connectivity functions leading to constrained gene flow and reductions in genetic diversity in the natural terrestrial species. **Increasing Precipitation:** Direct. More precipitation may shift amount and size of habitat patches and/or distribution due to sensitivity of ELC community to wetter soils; impacts to ecological function (as defined) likely only if the shift is towards a substantial loss of natural cover. **Drought:** Direct. Long-term drought may decrease amount and size of habitat patches and/or shift their distribution due to sensitivities of ELC communities to inadequate moisture; such a loss would exacerbate the problems of habitat connectivity, cause loss of habitat, etc. **Extreme Precipitation:** Direct. Extreme (and frequent) amounts of precipitation may decrease habitat patch cover and distribution through physical damage/uprooting or drowning of ELC communities sensitive to frequent inundation; these impacts may be spatially limited to flood prone areas and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Extreme Heat:** Direct. Extreme heat events may decrease habitat patch and distribution due to acute heat stress (leading to mortality) in sensitive ELC communities; these impacts may be spatially limited to areas

		where vegetation is currently "highly" vulnerable (e.g. urban forest) and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Ice Storms:** Direct. Ice storms may decrease habitat patch cover and distribution due to physical damage (leading to mortality) in sensitive ELC communities; these impacts may be spatially limited to areas where vegetation is currently "highly" vulnerable (e.g. urban forest, EAB infested/disease) and thus not expected to have measurable disruption to ecological function (as defined) at the system level. **Growing Season Length:** Direct. A longer growing season may increase the amount of habitat patches and their distribution, if there is sufficient precipitation to support this longer frost-free period, late- seasonal frosts are not experienced and phenology is not disrupted; impacts to ecological functions (as defined) are not anticipated under the scenario described above.
Soil drainage **Layer:** D **Scale:** Region **Source:** 2016 Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) Soils layer (Land Information Ontario (LIO)) based on data collected between 1929 and 2002	1) Soil Quality Regulation (moisture absorption / retention, microbial activity, nutrient cycling, pH balance, texture) 2) Hydrological Cycle Regulation (infiltration and runoff potential) 3) Erosion regulation (topography based)	**Increasing Temperatures**: Indirect. Warmer temperatures will increase evaporative losses of moisture from the soil surface (higher in low- organic soils with good drainage); in turn overlying vegetation may become stressed and areas of high drainage rating may experience very rapid infiltration, limiting the recovery of dry soils during rain events. **Increasing Precipitation**: Direct. Higher amounts of precipitation will potentially increase average soil moisture content (higher in high- organic soils with poor drainage); in turn overlying vegetation may become stressed, areas of poor drainage rating may collect water at surface more frequently while areas of good drainage may have increasing runoff /soil erosion (depends on slope). **Drought**: Direct. Drought conditions will directly dry soils (more severe effect in low-organic soils with good drainage); in turn overlying vegetation may become stressed and areas of high drainage rating may experience complete drying with low potential for recovery. **Extreme Precipitation**: Direct. Increases in extreme precipitation events will saturate soils at various rates (less water absorbed by low - organic soil with poor drainage); in turn overlying vegetation may become stressed, areas of low drainage rating are more likely to experience flooding while areas of high drainage more likely to experience runoff and erosion. **Extreme Heat**: Direct. Short-term extremely high temperatures may cause drying of soils (higher in low-organic soils with good drainage) but direct heat stress to vegetation likely primary issue. **Growing Season Length**: Indirect. A longer frost-free period may allow for longer infiltration into groundwater and long vegetative growth thus changing soil conditions.

Wetlands **Layer:** E **Scale:** Watershed **Source:** 2013 Natural Cover layer wetlands; 2016 ELC layer; Spring 2017 MNR classified wetland layer ELC wetland communities: BOS, BOT FEO, FES, FET MAM, MAS SAF, SAM, SAS SWC, SWD, SWM, SWT 2007 riparian layer 2017 interpolated regional water table surface layer (Oak Ridges Moraine Groundwater Program)	1) Hydrological Cycle Regulation (attenuation, infiltration/recharge, flow variation, ET and E) 2) Habitat Diversity (different wetland types, habitat connectivity, spawning/breeding) 3) Thermal Regulation (shading/thermal refuge for wetland-dependent species; cooling of flow- through water if groundwater fed wetland) 4) Water Quality Regulation (nutrient and contaminant uptake/storage)	**Increasing Temperatures**: Indirect. Warmer temperatures may increase evaporative losses (ET, E) and thus reduce wetland areal extent; surface water dependent and/or isolated wetlands may be more severely affected; in turn, most ecological functions (as defined) are likely to sustain losses, with less certainty around hydrologic function of attenuation, infiltration/recharge (these may remain intact if footprint of wetland remains?). **Increasing Precipitation**: Direct. Increases in precipitation, depending on its distribution, may increase wetland areal extent as standing water levels increase/expand and are generally sustained at a new baseline. Depending on surrounding land use, expansion would have limits as would hydrologic functions. Some vegetation types may respond to longer periods of standing water (depends on wetland type) and result in community shifts, which could have food chain implications. **Drought**: Direct. A lack of precipitation is likely to reduce areal extent of a wetland, particularly if surface water dependent and/or isolated. Impacts as described above and would be more severe if drought is coincident with extreme heat. **Extreme Precipitation**: Direct. Extreme storm events may temporarily increase wetland areal extent as standing water levels increase through attenuation processes and gradually recede (infiltration/flow through). Depending on surrounding land use, expansion would have limits as would hydrologic functions. Some vegetation types may respond to more frequent/intense inundation and result in community shifts, which could have food chain implications. **Extreme Heat**: Indirect. Extreme high temperatures may temporarily increase evaporative losses and thus reduce wetland areal extent for a period of time. The severity of impacts and potential for recovery likely dependent on condition of wetland prior to extreme heat days. **Growing Season Length**: Indirect. A longer frost-free period would allow for increased runoff to enter a wetland thereby increasing water levels and the areal extent.

Appendix 4. Climate vulnerability indicators scores

Indicator	Scoring
A) Ground surface temperature	Scored based on percentile rankings into three equal abundance classes (low 13-28°C; med 29-36°C; high 37-47°C) after removing cells falling outside the land area (i.e. Lake Ontario).
B) Climate-sensitive vegetation	Scored based on ecology ranking table considering factors of hydrology, fertility, and dynamics (interaction between terms). For the jurisdiction analysis, the hydrology column was removed to account for the fact that it was considered 'double counting' of the hydrological vulnerability of wetlands, which was considered to be captured in layer E. Wetland ELC communities were scored only using fertility and dynamics: 0-low, 1-med, 2-high. Non-wetland ELC communities were scored using hydrology, fertility and dynamics: 0-low, 1-med, 2 or 3-high.
C) Habitat patch quality	Scored low, medium or high based on habitat patch L-rank (low=L1,L2; med=L3; high=L4,L5) deriving from TNHS landscape assessment model.
D) Soil drainage	Scored based on combined soil drainage classification (from OMAFRA soil county survey); well-drained=low, imperfectly drained=med, very poorly drained=high; areas within the Urban Cover also considered 'high'.
E) Wetlands	Scored based on number of potential water sources; only precipitation = high; precipitation plus one of two additional sources = med; all three potential sources (groundwater + surface water supported) = least vulnerable.

Appendix 5: Summary of the Carruthers Creek Watershed Plan objectives, indicators, metric, and the assessed values under four land use scenarios

Objective	Indicator	Measure	Current	+OP	+NHS	+PU
Objective 14	**Natural cover**					
Increase percent natural cover to a quantity that provides targeted biodiversity		% natural cover	23.3%	24.0%	35.5%	35.5%
		% forest	9.2%	9.3%	15.8%	15.8%
		% wetland	6.5%	6.5%	7.0%	7.0%
		% meadow	2.8%	2.9%	3.3%	3.3%
		% successional	4.4%	4.5%	8.9%	8.9%
Objective 15	**Habitat Patch Landscape Analysis Model (LAM)**					
Protect natural system quality and function from the influence of surrounding land uses		Average patch size (ha) Median patch size (ha) range of patch size (ha)	1.3 0.2 <0.01-74.6	1.3 0.2 <0.01-74.6	2.7 0.2 <0.01-136	2.6 0.2 <0.01-136
		Average patch shape Median patch shape range of patch shape	244 201 103-882	244 203 103-882	246 201 102-846	247 202 102-846
		Average matrix influence Median matrix influence range of matrix influence	7.7 15 (-61)-56	4.4 14 (-72)-55	13.4 30 (-66)-56	5 6.6 (-66)-56
		Average patch LAM total score Median patch LAM total score range of LAM total score L-rank class	7.6 8 4-12.8 Poor	7.5 8 4-12.8 Poor	7.9 8 4-12.8 Poor	7.6 8 4-12.8 Poor
	Habitat connectivity	**Maintain current or improve**				
		Regional connectivity - R (100% overlap between priority area and NHS)	28	28	46	46
		Regional connectivity - W (100% overlap between priority area and NHS)	28	28	45	45
		Local connectivity F-F (100% overlap between priority area and NHS)	43	45	59	59
		Local connectivity F-W (100% overlap between priority area and NHS)	60	60	66	66
Objective 16	**Vegetation communities**	**Maintain current or improve**				
Protect and restore all native vegetation community types and species to targeted levels		# of L1-L3 ELC community types (2015/2016 inventory surveys only)	39	-	-	-
		# hectares of L1-L3 ELC community types (2015-2016 inventory surveys only)	42 ha	-	-	-
		Specific variables of interest - TBD	-	-	-	-
	Fauna	**Maintain current or improve**				
		# of L1-L3 species (frogs, birds; 2015/2016 inventory surveys only)	43	-	-	-
		# of species and individuals (set-up long-term monitoring plots to determine baselines)	-	-	-	-
		Long-term monitoring plots - TBD	-	-	-	-
Objective 17	**Climate vulnerability**	**Decrease individual vulnerabilities**				
Manage for the climate vulnerabilities of the terrestrial system		Ground surface temperature (TBD – mostly outside of TNHS so not estimated for scenarios)	-	-	-	-
		Climate sensitive vegetation communities (100% coverage of high vulnerable areas in NHS)	84	84	88	88
		Patch quality (100% coverage of high vulnerable areas in NHS)	78	78	86	86
		Soil drainage (TBD – mostly outside of TNHS so not estimated for scenarios)	-	-	-	-
		Wetland cover (100% coverage of high vulnerable areas in NHS)	65	65	70	70

Appendix 6: Terrestrial system recommendations based on Phase I: current conditions report (extracted from TRCA 2017a)

The most meaningful indication of the current state of the watershed natural system is provided by assessing the distribution of sensitive flora and fauna species (especially habitat dependent forest birds). This suite of species is largely restricted to the forest habitat between 5th Concession Road and Highway 7. The quality of even the larger forest blocks to the south of the 5th Concession Road is highly compromised, due primarily to the impacts of negative matrix influence associated with the extensive urban and suburban development that has occurred over the past two decades.

Given the current situation, protecting what still remains within the watershed should be the main priority of watershed management. Once this has been achieved, consideration should be given to creating opportunities for some of the less degraded features in the lower reaches to re-establish L1 to L3 fauna species communities. Such communities are only likely to have a chance of establishing if the habitat features maintain or even increase their area. Beyond the sheer size of the habitat features, it will be important to ensure that the negative matrix influences associated with current and future neighbouring urban and suburban developments be mitigated.

At the watershed level, there is an obvious need to protect and maximize the remaining natural habitat patches. In turn, this will improve the watershed's contribution to the wider regional natural system, particularly in maintaining connectivity across TRCA's eastern border. It is important to recognize that cumulative impacts on the watershed's natural system stem from even relatively small losses in any section of this small watershed. Thus, the loss of several L3 species (e.g. wood thrush, veery, northern waterthrush (*Parkesia noveboracensis*)) from the lower urbanized reaches of the watershed, confer even more significance on the remaining refuges for these same species in the northern half of the watershed. To have, for several species of regional concern, their entire watershed population increasingly restricted to just one forest block, creates a situation where failure of that one isolated population will result in watershed-wide extirpation and a decline in biodiversity.

Habitat quality in the southern half of the watershed is currently limited by public use and trail density (and thereby the absence of any extensive undisturbed areas); by the presence of invasive non-native species (including free-roaming domestic cats); and by high population densities of subsidized nest predators, brood parasites, and herbivores and omnivores (e.g. deer). Minimizing the negative matrix influences system (e.g. predation from domestic/feral animals and storm water quantity and quality issues) is essential for achieving a higher quality natural system.

The following recommendations address the decline in biodiversity as well as the landscape ecology indicators of habitat quality, matrix influence, patch size/shape, and the degree of connectivity to the larger system. From a terrestrial natural heritage point of view, the natural system of the Carruthers Creek watershed would benefit most from 1) reinforcing the protection of the natural heritage system within the Carruthers Creek watershed; 2) expansion of any patches of natural cover; 3) improved management of public use of any natural features on public land; 4) improvements in connectivity; 5) management of non-native and invasive species; and 6) a better understanding of the changing status of the fauna and flora of the watershed by implementing further monitoring. Acting on these management options would afford the natural system of the watershed more protection in the face of declining biodiversity.

8.1.1.1 Reinforcement of Protection of Natural Heritage System

The Carruthers Creek watershed has a mix of urban and rural land uses; of public parklands (mostly in the urban zone) and privately-held lands. There are therefore broader land use issues that can directly affect the quantity and integrity of natural cover (e.g. direct loss of natural cover due to development). The area south of Taunton Road is largely developed with some undeveloped lands also near Bayly Street. The area north of Taunton Road to Highway 7 lies within the greenbelt, along with lands just outside the watershed east of Audley Road. And large areas of land north of Highway 7 in the headwaters are currently rural but open to development changes (“white belt” or “vanilla lands”). Land use planning and other policies need to address the protection of natural heritage more comprehensively.

a. Refine the regional target natural heritage system within the undeveloped areas, at the watershed level, based on the most recent field work.

b. If opportunities are available, the ANSI and especially the evaluated wetland boundaries based on the most recent field data could be updated. Consider merging the Rossland and Salem wetland complexes into one complex if feasible.

c. Address the issue of “clean” fill deposition, particularly within the topographically- and botanically-diverse Iroquois Shoreline area. Ensure that the area’s sandy soils, hydrology, and flora are not compromised by the importation of heavy clay fill laden with invasive species propagules. This will benefit not only natural areas but overall urban forest.

d. Consider strategic acquisition of natural heritage lands where they are unprotected and where they make strong contributions to the natural heritage system (e.g. part of a large patch of natural cover, or contain flora or fauna species of concern).

8.1.1.2 Expansion of Natural Cover Patches

Opportunities for the expansion of natural cover patches in the Carruthers Creek watershed are rather restricted, especially in the southern half of the watershed, where residential developments are pushing right up against many of the remaining forest patches. Nevertheless, opportunities should be fully explored, seeking to restore adjacent open areas and thereby increasing the overall area of each forest patch, ensuring an effective buffer against the drying influence of edge effects. The large forest patch east of Salem Rd., just south of Hwy 401, would be an excellent candidate for such expansion, there being opportunities for restoration work in openings both within the forest patch and on agricultural land at the south-east corner. The same is true for the patch just north of Hwy 401 and the riparian forest cover between Kingston and Rossland Roads.

Even if, as is possibly the case within the southern half of the watershed, these adjacent lands are already marked for development, extensive set-backs, buffering the riparian habitat, should be sought, and these buffer areas should be restored to forest cover. In the northern half of the watershed, much of the land adjacent to the remnant riparian forest cover is active agricultural land. Such lands potentially already have significant natural heritage value, providing nesting and foraging opportunities for declining open country species. Through landowner stewardship there may be opportunities to restore forest cover adjacent to existing riparian forest; if such opportunities arise it is important to consider the relative benefits to the watershed and regional natural heritage of either actively restoring forest cover or simply setting aside the area as meadow habitat.

The following should be considered in any plans to restore and expand current natural habitat within the watershed.

a. Where invasive species are not an issue, the preference is for passive restoration based on natural regeneration. Site conditions, such as topography and drainage, should dictate restoration work and vegetation selection. For example, moist forest with vernal pools for flatter, poorly-drained tableland.

b. Collect and propagate local seed; there should be careful attention to seed sourcing and site conditions in all restoration projects.

c. Plant fruit-bearing shrub cover at the edges of forested areas, creating important foraging opportunities for local and migrating songbirds.

d. Maintain and retain sufficient open habitat to enhance fauna and flora biodiversity. Any management work conducted needs to occur during times when there will be the least impact on the vegetation, breeding birds and dispersing and migrating amphibians.

e. Consider and investigate rehabilitating wetland habitats at the mouth of the Carruthers Creek by controlling marsh water levels independent of the lake levels. By doing this, a more structurally diverse wetland habitat would result, bringing with it the potential to recruit and restore a more diverse avifauna.

8.1.1.3 Improved Management of Public Use

No matter how much forest habitat is restored throughout the watershed, if this habitat is subject to extensive negative matrix influences there will be no real improvement in the status of fauna species of conservation concern. Landscape metrics indicate that the matrix influence across much of the southern half of the watershed is largely negative, scoring as “poor” for much of the area south of Taunton Road. North of Taunton Road the matrix influence swings to the positive side.

Visitor pressure on many of the natural habitat features throughout the southern half of the watershed is likely to increase in the future as the local population grows, and an expectation to formalize access to these features arises. Several species are teetering on the brink of local extirpation south of Taunton Road. Thus, regardless of potential improvements in habitat quality, the detrimental effects of public use on the existing and restored natural habitats will continue to result in further losses in the populations of sensitive fauna and flora species.

The following are recommendations for managing public use:

a. Where property ownership allows, arrange to designate the larger natural features as Nature Reserves. Monitor each reserve to ensure informal trails are not being created.

   Five candidate locations for Nature Reserves are:

   1) the extensive forest habitat located between Audley Road North and Salem Road, north of the 5th Concession Road,

   2) the forested riparian habitat extending from the top of Carruthers Marsh to Hwy 401,

3) the forested riparian habitat extending north and south from Rossland Road East,

4) the heronry in Ajax Warbler Swamp, and

5) Carruthers Marsh itself (which is already largely fenced and with highly limited access).

b. Organize stewardship, particularly in designated Nature Reserves, to help maintain habitat quality and biodiversity. Landowners and the public can be involved

c. Use expertise of terrestrial biologists with local experience to help plan and place trails and other recreational projects in order to minimize the damage to existing natural cover. Incorporate issues of trail density and/or trail type into trail planning.

d. Whenever the opportunity arises (for example, when upgrades to existing road networks are anticipated) at locations where road-kill hotspots have been identified, appropriate wildlife crossing structures (e.g. culverts) should be incorporated.

e. If trails on publicly owned and managed properties are to be installed or restored, management should investigate the option of installing board walks. Boardwalks, even running through non-wetland habitats, can potentially reduce many impacts on the habitat and do not constitute a barrier to the seasonal and foraging movements of terrestrial fauna. Users are also far less likely to step off of a well-maintained boardwalk, even in relatively dry forest and meadow habitats.

f. Set-up clear signage along trails that describes the importance of staying on trails, leaving wildlife untouched, keeping pets leashed, etc. Consider a watershed user education/awareness campaign or volunteer stewardship program focusing on watershed wildlife and landforms that includes, as an example, signage to inform visitors of the importance of the riparian habitat as a migrant songbird corridor.

g. Work with landowners along the Carruthers Creek to avoid and eliminate encroachment.

8.1.1.4 Improvements in Connectivity

Connectivity along the north-south axis of the Carruthers Creek watershed is of considerable importance at both the local level (ensuring genetic health throughout local populations of flora and terrestrial fauna) and the broader regional and provincial levels (facilitating the safe passage of migrating songbirds from the lakeshore to northern nesting habitats). Currently, connections along the east-west axis are largely obstructed by extensive housing developments in the southern half of the watershed. There appears to be just one major east-west connection – through the greenbelt lands north of Taunton Road; this is an extremely significant corridor, connecting the extensive natural cover of the lower Duffins Creek watershed (Duffins Creek Marsh through Duffins Heights and the Seaton Lands) to the middle reaches of Lynde Creek watershed to the east of the TRCA jurisdiction. There are also several somewhat constricted east-west connections: along the railway line running north of Rossland Road; through the Ajax Warbler Swamp to the Lynde Shores Conservation Area (CLOCA); and along the waterfront itself.

The following are recommendations for improving connectivity:

a. In the long-term, major wildlife passages over and under roads such as Bayly Street East, Taunton Road, Highway 7 and Highway 407 should be considered to form a strong corridor along the watershed's north-south axis between the Oak Ridges Moraine and Lake Ontario. Similarly, Salem and Audley Roads and other potential east-west barriers should be monitored for the potential to facilitate and improve the limited east-west connectivity across the watershed.

b. Conduct a detailed search for road-kill hotspots and herp crossing points throughout the watershed. In the light of any findings, mechanisms to allow safe passage of herps at such hotspots should be considered (e.g. amphibian tunnels).

c. Work with industry and commercial developers to retain as much tree canopy as possible and implement green infrastructure and increased tree cover within the identified forest-forest connections.

8.1.1.5 Management of Non-native and Invasive Species

The following recommendations focus on non-native invasive species management and reducing predation and herbivory. The most recent scientific literature available should be consulted to create specific invasive species management plans.

a. Develop a non-native invasive species management plan for the Carruthers Creek watershed.

b. Investigate the feasibility and benefits of prescribed burns in order to maintain the small oak forest and woodland remnants and sand barrens with their associated species of concern. This will help control many non-native invasive species (though not dog-strangling vine (*Cynanchum rossicum*)).

c. Identify and control non-native invasive species populations where feasible; e.g. Asiatic bittersweet (*Celastrus orbiculatus*), shrub honeysuckle (*Lonicera* x *bella*), lily-of-the-valley (*Convallaria majalis*), periwinkle (*Vinca minor*), Norway maple (*Acer platanoides*), multiflora rose (*Rosa multiflora*), eulalia (*Miscanthus sacchariflorus*), and common reed (*Phragmites australis* ssp. *australis*) where found in smaller, isolated patches.

d. Address more abundant non-native invasive species such as common reed, buckthorn, dog-strangling vine and garlic mustard (*Alliaria petiolate*) through controlling sources of disturbance such as encroachment or dumping; erosion (in forest environments), nutrient input, and trampling. Competitive native plantings may play a role in containing non-native invasions.

e. Target invasive control around populations of species of concern, for example by wick application of herbicide to remove dog-strangling vine from near remnant woodland species.

f. Where possible, implement biological control for the most widespread and dominant invasives, especially dog-strangling vine, for which further trials and release of the moth *Hypena opulenta* is recommended. Biological control is the most promising option also for common reed.

g. Investigate methods for reducing predation and herbivory, e.g. the damage inflicted by deer on native plant populations.

8.1.1.6 Implementation of further monitoring

It is important to monitor the changes throughout the watershed in order to verify that current management strategies are doing what they intend to do and that ecological changes are at acceptable levels. Although the existing protected areas (ANSIs, PSWs, ESAs) shown on Map 3 protect some of the highest quality habitat, our monitoring and assessment results already indicate that more nature reserves are needed.

a. Establish a long-term monitoring program within the Carruthers Creek watershed to assess possible changes over time.

b. Greater attention should be given to the non-forested habitat associated with the largely agricultural northern section of the watershed. It is here that the largest numbers of federally and provincially listed Species at Risk have been recorded, namely bobolink and eastern meadowlark, together with a whole suite of sensitive meadow species.

c. The Ajax Warbler Swamp area is also a priority for monitoring.

The condition of the natural system within the Carruthers Creek watershed is of considerable significance across the local landscape and to the neighbouring watersheds, providing areas of existing and potential natural cover and supporting many species of birds and other animals that depend on large areas of undisturbed forest or diverse habitats. Following the recommendations listed here will help to ensure that the watershed:

a. continues to provide enough higher quality habitat for existing species (and perhaps one day even for returning species) and

b. becomes protected in a way that mitigates the anticipated increase in negative matrix influence resulting from the growing population of local residents.

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