Headwaters Subwatershed Study

Subwatershed 19

Phase 2:
Impact Assessment and Evaluation of Alternative Management Strategies

DRAFT

July 2009

CVC
CREDIT VALLEY CONSERVATION

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This document is the third in a series of reports that outlines the results of the Headwaters Subwatershed Study. This study was initiated in 2005 to update an earlier study which was completed in 1997.

This Report provides the results of Phase II of the Headwaters Subwatershed Study. It describes the potential effects of changes in land use, evaluates five alternative scenarios and recommends various management strategies based on the goals and objectives for environmental protection and enhancement that were developed during Phase I of the study. The contents of this report have been organized as follows:

Chapter 1 provides a brief **Overview** of the Headwaters Subwatershed Study.

Chapter 2 provides an **Introduction** to Phase II of the Headwaters Subwatershed Study and describes five alternative scenarios.

Chapter 3 outlines the **Methodology** used to evaluate the five alternative scenarios described in Chapter 2 and defines the Objectives, Indicators and Targets used in the evaluation.

Chapter 4 outlines the **Results** of the evaluation of the five alternative scenarios and briefly discusses the key findings.

Chapter 5 provides the **Conclusions and Recommendations** of Phase II based on the evaluation results described in Chapter 4.

Executive Summary

Subwatershed management is the process of creating and implementing plans and programs to sustain and enhance the natural heritage features and functions of a subwatershed. The process has become a generally accepted means of addressing environmental concerns over broad areas of land and contributes to the development of an overall land use management strategy.

The Headwaters Subwatershed (also referred to by CVC as Subwatershed 19) drains the approximately 62 km^2 of lands that comprise the headwaters of the Credit River watershed. The Subwatershed can be divided into five catchment zones: Monora Creek Tributaries, Eastern Tributaries, Mill Creek, Caledon Tributaries and the Credit River. Within each zone, surface water flow characteristics are generally consistent.

Approximately 37% of the overall subwatershed is comprised of natural areas, including terrestrial (e.g. forest), wetland (e.g. swamp) and aquatic (e.g. lake) communities. Approximately 33% consists of lands under cultivation, while 27% consists of areas committed to urban land uses. Urban land uses strongly affect the movement of water between the atmosphere, the earth's surface and the ground because the earth's surface is typically covered by impervious materials such as concrete and asphalt. Increased imperviousness results in greater surface runoff and reduced infiltration

CVC and its member municipalities completed the first Subwatershed Study of the Headwaters Subwatershed in 1997. Since that time, advances in science, changes in policy/legislation, and changes in land use have triggered an update of the original study. CVC initiated the new Headwaters Subwatershed Study in 2005.

The Headwaters Subwatershed Study is being conducted in four phases. The Background phase was completed in 2006 and Phase I of the study proper was completed in 2009. This report provides the results of Phase II of the Study.

The primary objective of Phase II is to evaluate the potential effects of different alternative scenarios on the existing conditions of the Headwaters Subwatershed. The Study's Technical Committee selected five alternative scenarios for evaluation. These alternative scenarios vary based on different approaches to land use, storm water management and the establishment of a Natural Heritage System (NHS).

The five alternative scenarios include two alternative patterns of land use. The first is defined by existing conditions. The second is defined by future development in conformance with the Provincial Growth Plan for the Greater Golden Horseshoe (Places to Grow).

The five alternative scenarios include three different approaches to storm water management, including the following:

- Business as Usual (BAU) - the application of the existing approach to stormwater management to new development;

- Low Impact Development (LID) - the application of the LID approach to stormwater management to new development; and

- Retrofitting - the application of the LID approach to stormwater management to existing development through retrofitting.

Low Impact Development is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution. LID comprises a set of site design approaches and small scale stormwater practices that promote the use of natural systems for infiltration, evapotranspiration and the reuse of stormwater. These practices can effectively remove nutrients, pathogens and metals from stormwater, and they reduce the volume and intensity of stormwater flows (EPA 2007).

The five alternative scenarios include two different approaches to the establishment of a Natural Heritage System (NHS). The first approach is based on existing policies and practices. Under this approach, elements of the NHS are defined by and protected from development under existing legislation, regulations and policies. The second, enhanced approach incorporates the NHS defined under existing policies and practices, but also includes additional lands based on generally accepted ecological concepts. Development within these additional lands is not currently prohibited under existing legislation, regulation and policies. As such, the long-term preservation of these additional lands would be achieved through stewardship-based measures.

Once the alternative scenarios were defined, the Technical Committee used a step-wise approach to evaluate their potential effects on the existing conditions of the Headwaters Subwatershed. This approach included the following steps:

- Identified 18 environmental objectives for the Headwaters Subwatershed.

- Established for each environmental objective various indicators, measurable parameters and targets.

- Conducted hydrologic modelling and other quantitative/semi-quantitative analyses to determine the environmental response of the Headwaters Subwatershed to each of the five alternative scenarios.

- Determined whether the five alternative scenarios degrade, maintain or enhance existing conditions by scoring the environmental response of each against the targets associated with the environmental objectives for the Headwaters Subwatershed.

Eight of the 18 Objectives developed during Phase I of the Headwaters Subwatershed Study were utilized in the Phase II evaluation of the alternative scenarios. The eight Objectives used in the evaluation (Objectives 4, 5, 6, 7, 8, 9, 15 and 16) relate to hydrology, stream processes (erosion), flooding, groundwater, water quality and aquatic and terrestrial ecology.

A comprehensive evaluation of the alternative scenarios based on all 18 Objectives for the Headwaters Subwatershed is beyond the scope of this study. The evaluation presented here provides a “big picture” comparison to illustrate the relative merits of the different approaches to land use, storm water management and the establishment of a Natural Heritage System. Based on the evaluation results, the following general conclusions can be made:

1. The application of the Business as Usual approach to stormwater management to new development will **degrade** existing environmental conditions.

2. The application of LID measures to new development will generally **maintain** existing environmental conditions.

3. The application of LID measures to new development and the retrofitting of existing developed areas will **maintain or improve** existing environmental conditions.

4. The benefits of LID vary between catchment zones. Generally, the greater the extent of existing development, the greater the benefits of implementing LID measures through retrofitting. The implementation of LID measures through retrofitting would particularly benefit the Monora Creek Tributaries, Mill Creek and Credit River catchment zones.

5. The application of LID measures will help to maintain baseflow in watercourses in the vicinity of water wells. However, because existing development in these areas is located downgradient of the water wells, their retrofit with LID measures may not benefit water supply.

6. The application of LID measures may be important to maintaining/enhancing baseflow in the Credit River to support future discharge rates from the Sewage Treatment Plant.

7. Relative to existing policies and practices, the enhanced approach to the establishment of a NHS best meets Subwatershed targets to create an integrated network of natural heritage features. This approach has limited ability to mitigate the effects of urbanization on the hydrologic cycle and water quality, but would provide a number of other environmental and social benefits not addressed by this study.

8. Scenario 3a is preferred. This scenario incorporates the following approaches:

   - future development in conformance with the Provincial Growth Plan for the Greater Golden Horseshoe (Places to Grow);

   - the application of the LID approach to stormwater management to new development and to existing developed areas through retrofitting; and

   - the establishment of an enhanced NHS that includes elements defined under existing policies and practices as well as additional lands based on stewardship.

Phase III of the Headwaters Subwatershed Study is recommended to proceed to implement the management strategies recommended in this report. Phase IIII will describe what is required to achieve the goals and objectives established for the Headwaters Subwatershed; will identify roles and responsibilities of the various stakeholders for implementing the various recommendations and will identify long-term monitoring goals.

1 Introduction

1.1 Overview Subwatershed Management

Subwatershed management is the process of creating and implementing plans and programs to sustain and enhance the natural heritage features and functions of a subwatershed. The process has become a generally accepted means of addressing environmental concerns over broad areas of land and contributes to the development of an overall land use management strategy.

Credit Valley Conservation (CVC) uses the Adaptive Environmental Management (AEM) approach to subwatershed management. The AEM approach utilizes iterative science-based subwatershed studies to identify and refine management strategies that are intended to protect the health of human communities and the natural environment.

AEM-based subwatershed management typically involves four phases (Figure 1). During Phase 1 (Subwatershed Characterization) background information and fieldwork are used to develop a comprehensive understanding of the subwatershed's natural resources. During Phase 2 (Impact Assessment) knowledge of existing conditions is used to predict the subwatershed's response to various stressors and to evaluate alternative management strategies. In Phase 3 (Implementation) the most appropriate management strategies are identified and collectively implemented as a Subwatershed Plan, while during Phase 4 (Monitoring), data from follow-up monitoring are used to test the assumptions made during earlier studies to evaluate the performance of the selected management strategies.

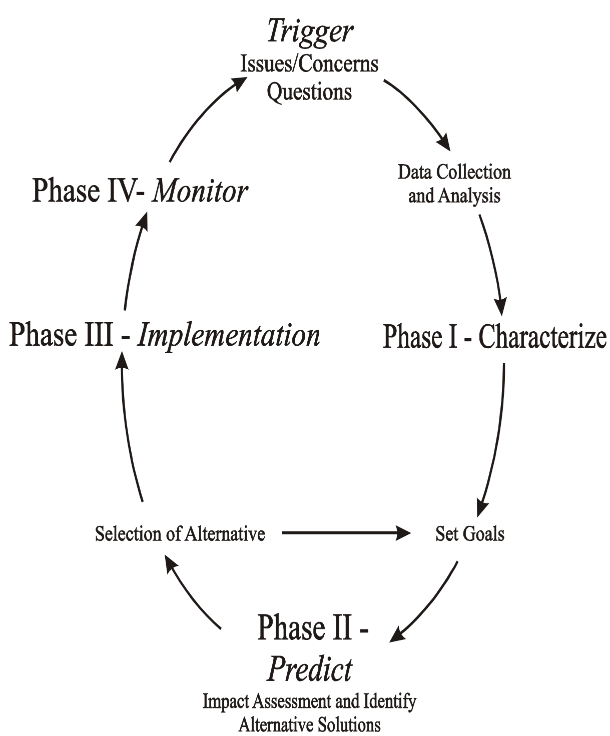


Figure 1: AEM-based approach to Subwatershed Management.

1.2 Overview of the Headwaters Subwatershed

The Headwaters Subwatershed (also referred to by CVC as Subwatershed 19) is aptly named because it drains the approximately 62 km^2 of lands that comprise the headwaters of the Credit River watershed. Figure 2 illustrates the location of the Headwaters Subwatershed in relation to the entire Credit River watershed.

The Headwaters Subwatershed encompasses portions of two upper tier municipalities (the Region of Peel and the County of Dufferin) as well as portions of five local municipalities, including the Town of Caledon, the Town of Mono, the Town of Orangeville, the Township of Amaranth and the Township of East Garafraxa (Figure 2).

The Headwaters Subwatershed features several watercourses and a large reservoir (Island Lake) that forms the largest body of open water in the entire Credit River watershed. The upper portion of the subwatershed includes Upper Monora Creek, Middle Monora Creek and Lower Monora Creek, all of which drain into Island Lake Reservoir from the west. Two unnamed tributaries also drain into Island Lake Reservoir from the east. Outflow from the Island Lake Reservoir at the south dam marks the start of the Credit River. As the Credit River flows south, it is joined by Mill Creek from the west, and at the southern end of the subwatershed, by three unnamed tributaries that flow east through the Town of Caledon. The Melville dam forms the downstream limit of the Headwaters Subwatershed. Figure 3 illustrates the urban areas, roads and watercourses of the Headwaters Subwatershed.

1.2.1 Catchment Zones

For the purposes of discussion, the Headwaters Subwatershed can be divided into five catchment zones based on their geology, topography and land cover. Within each zone, surface water flow characteristics are generally consistent. These five catchment zones include the following:

Monora Creek Tributaries

This catchment zone drains the entire area upstream of Highway 10 and 24, north of Broadway (Highway 9) up to the watershed divide and encompasses the three tributaries of Monora Creek, including Upper Monora Creek, Middle Monora Creek and Lower Monora Creek (Figure 4).

Eastern Tributaries

This catchment zone drains the area between Highway 9 and Fifth Sideroad, east of Island Lake, up to the watershed divide. The zone encompasses two unnamed tributaries that drain directly into Island Lake. Island Lake is also considered part of this zone (Figure 4).

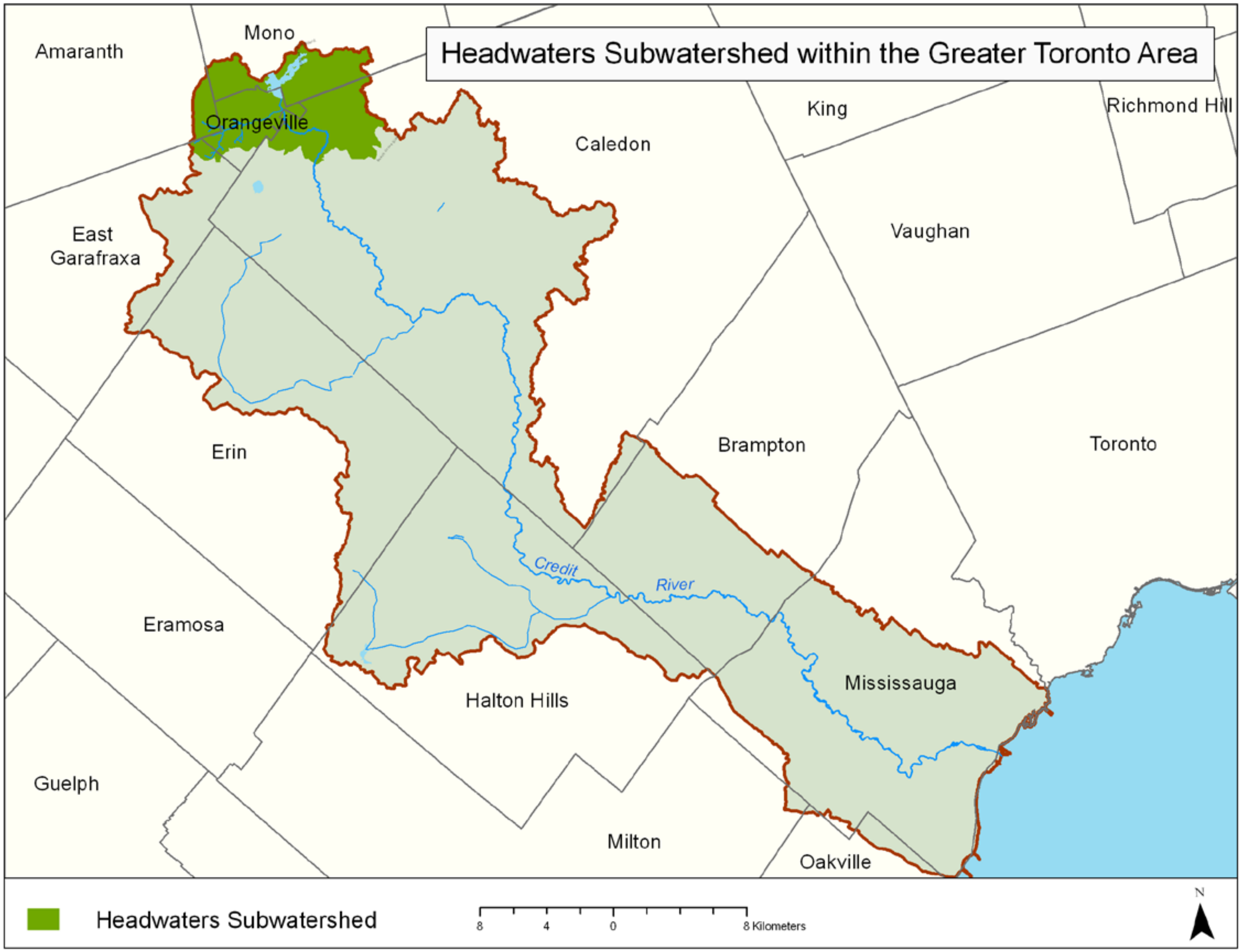


Figure 2: The location of the Headwaters Subwatershed within the Credit River Watershed.

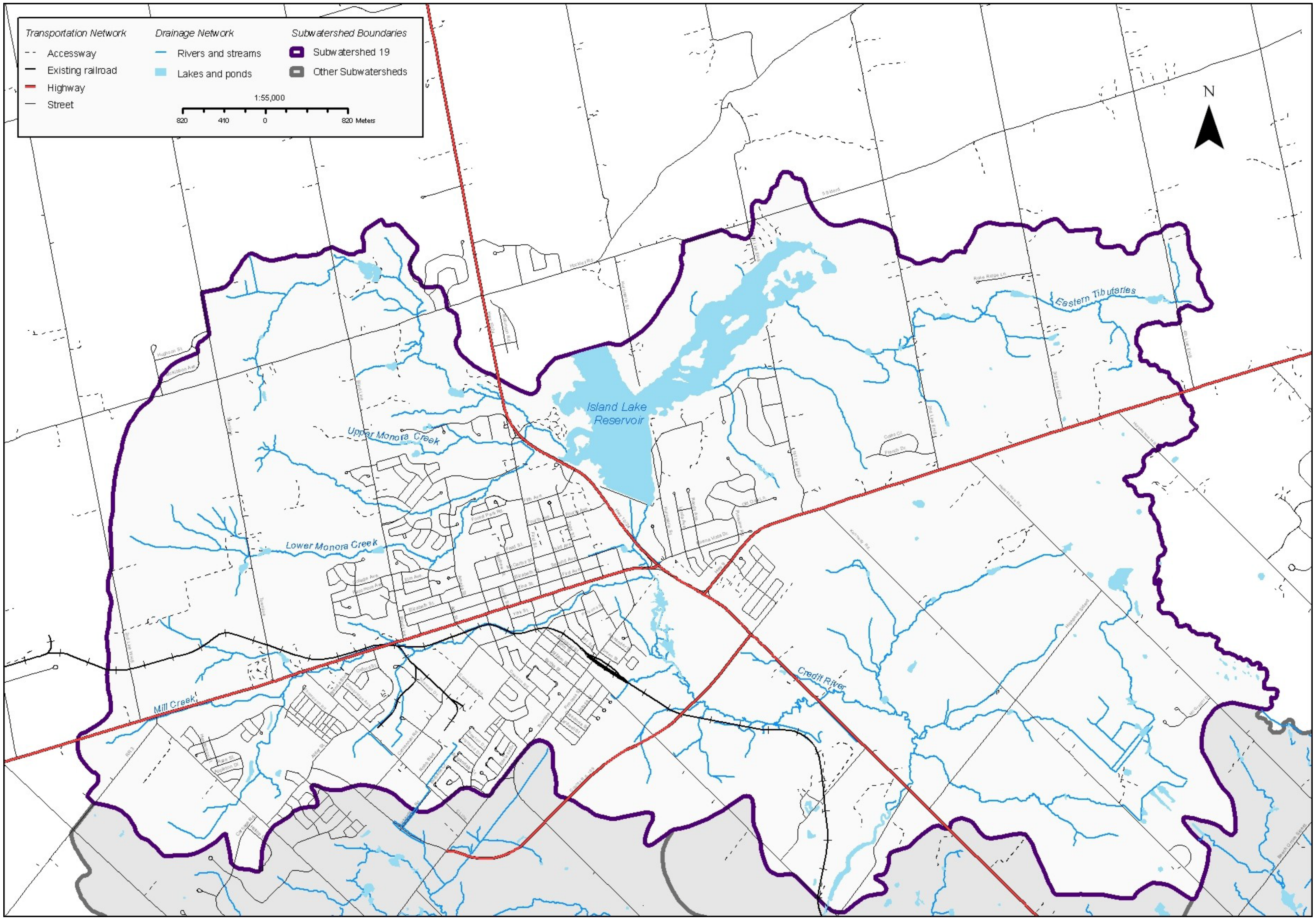


Figure 3: Urban areas, roads and watercourses of the Headwaters Subwatershed.

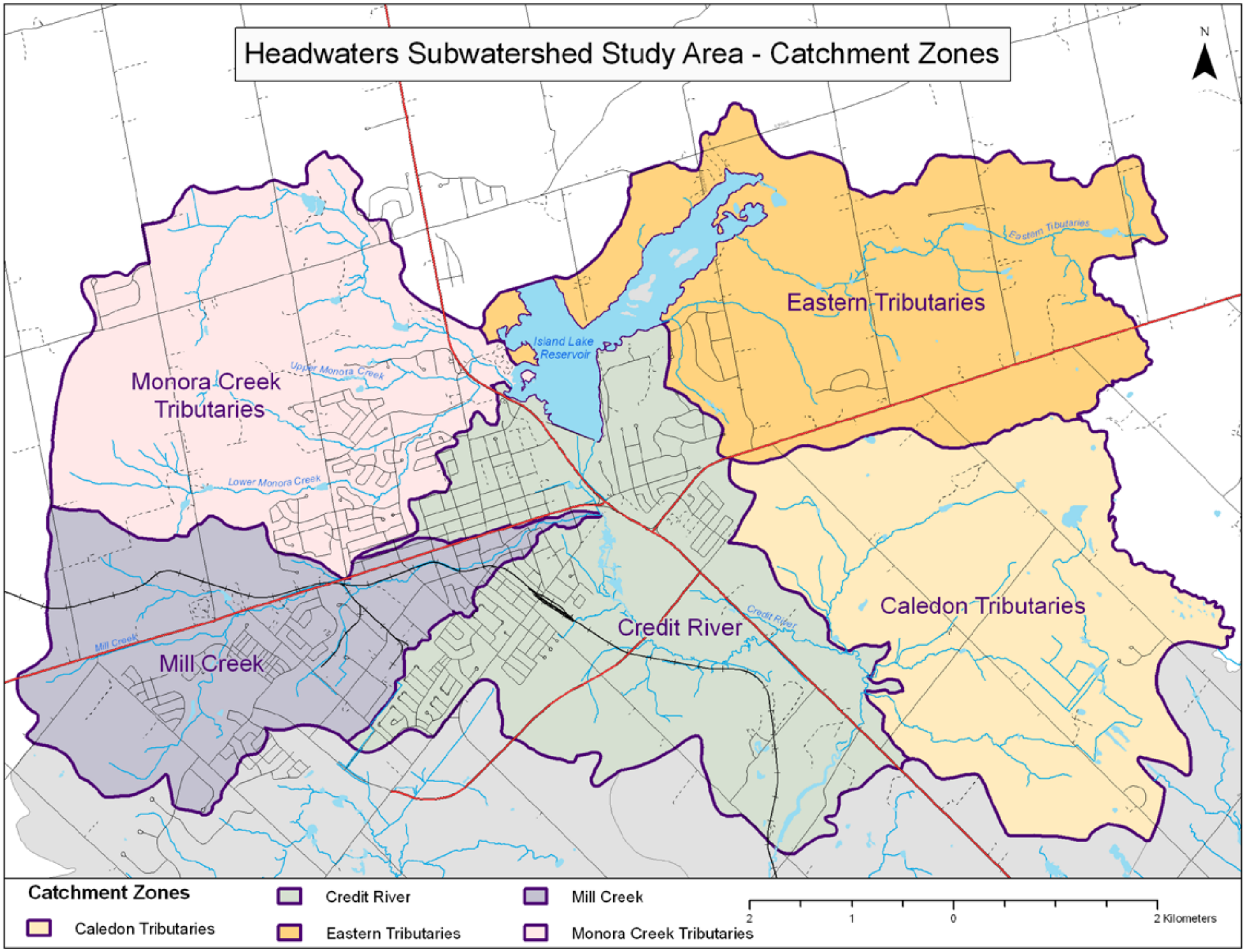


Figure 4: The five catchment zones of the Headwaters Subwatershed.

Mill Creek

This catchment zone encompasses Mill Creek, which drains the area from its confluence with the Credit River upstream to the watershed divide (Figure 4).

Caledon Tributaries

This catchment zone drains the lands between Highway 10, Highway 24 and 2nd Line East, South of Highway 9 to the watershed divide. The zone encompasses three separate watercourses that drain directly into the main branch of the Credit River (Figure 4).

Credit River

This catchment zone encompasses the main branch of the Credit River, which extends from Island Lake South Dam to Melville village at Willoughby Road (Figure 4).

1.2.2 Land Use

Land use within the Headwaters Subwatershed was categorized during Phase I of the Headwaters Subwatershed Study (see Section 1.3).

Approximately 37% of the overall subwatershed is comprised of natural areas, including terrestrial (e.g. forest), wetland (e.g. swamp) and aquatic (e.g. lake) communities. These communities have been classified and mapped using the Ecological Land Classification (ELC) system (Figure 5). ELC is a standardized, hierarchal system that provides a consistent means of identifying, describing, naming, and mapping ecological communities (Lee et al. 1998).

Developed areas within the subwatershed have been classified and mapped based on dominant land use. Approximately 33% of the overall subwatershed consists of lands under cultivation, either as intensive agriculture (e.g. cultivation of row crops) or non-intensive agriculture (e.g. pasture). Approximately 27% of the overall subwatershed consists of areas committed to urban land uses, including residential, commercial/industrial and manicured open space.

Patterns of land use strongly affect the movement of water between the atmosphere, the earth's surface and the ground. In natural areas and lands in agricultural production, the earth's surface remains permeable, which permits rainwater and snowmelt to soak into the ground. In contrast, in urban areas, the earth's surface is typically covered by impervious materials such as concrete and asphalt. Increased imperviousness results in greater surface runoff and reduced infiltration (Figure 6).

Different urban land uses vary in their degree of imperviousness. Table 1 lists the estimated imperviousness associated with different categories of urban land use in the Headwaters Subwatershed. As shown by Table 2 and Figure 7, the degree of imperviousness varies widely between catchment zones due to differences in land use.

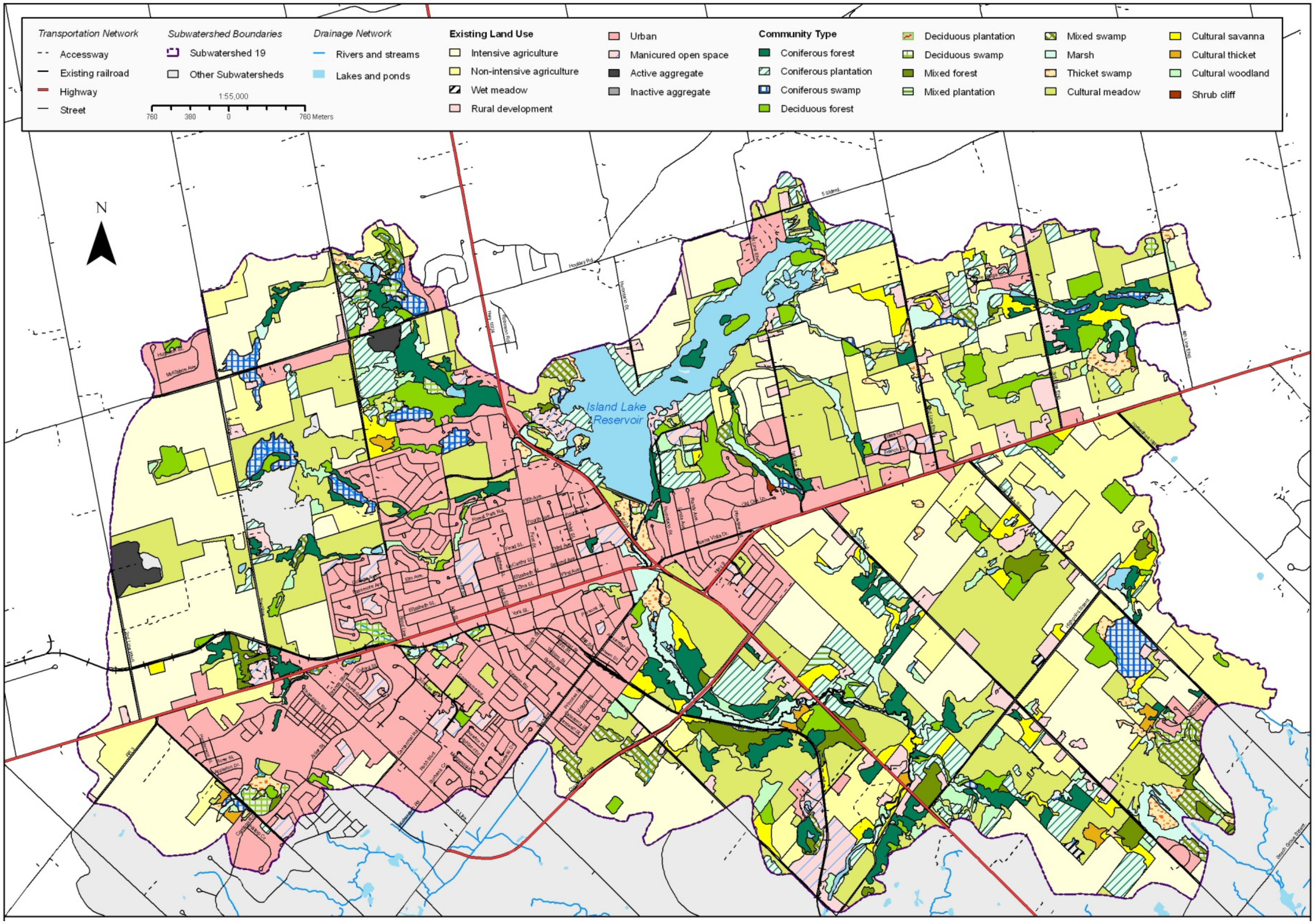


Figure 5: Land use within the Headwaters Subwatershed based on Ecological Land Classification.

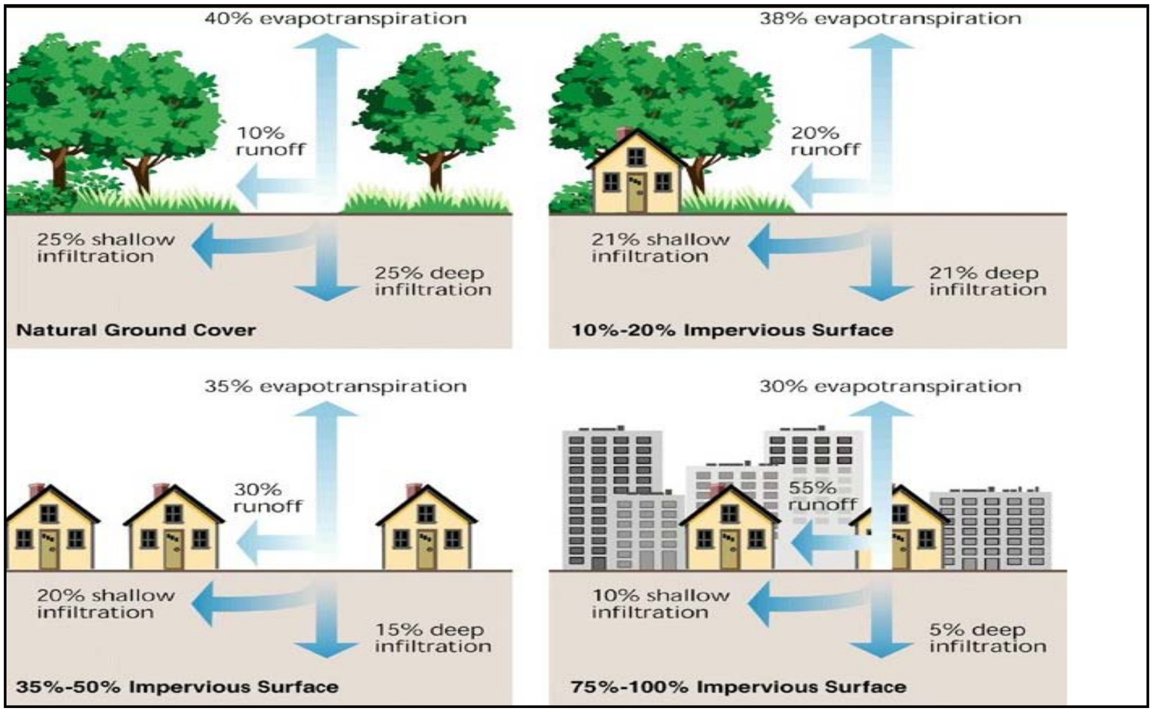


Figure 6: The impact of conventional urbanization on the hydrologic cycle.

Table 1: Estimated imperviousness associated with urban land use categories.

Urban Land Use Category	Imperviousness (%)
Manicured Open Space	0
Residential 1 (< 1 dwelling unit/ha)	10
Residential 1 (< 1 dwelling unit/ha)	20
Residential 1 (< 1 dwelling unit/ha)	30
Residential 1 (< 1 dwelling unit/ha)	50
Residential 1 (< 1 dwelling unit/ha)	65
Commercial/Industrial	85
Railroads	85
Roads	99

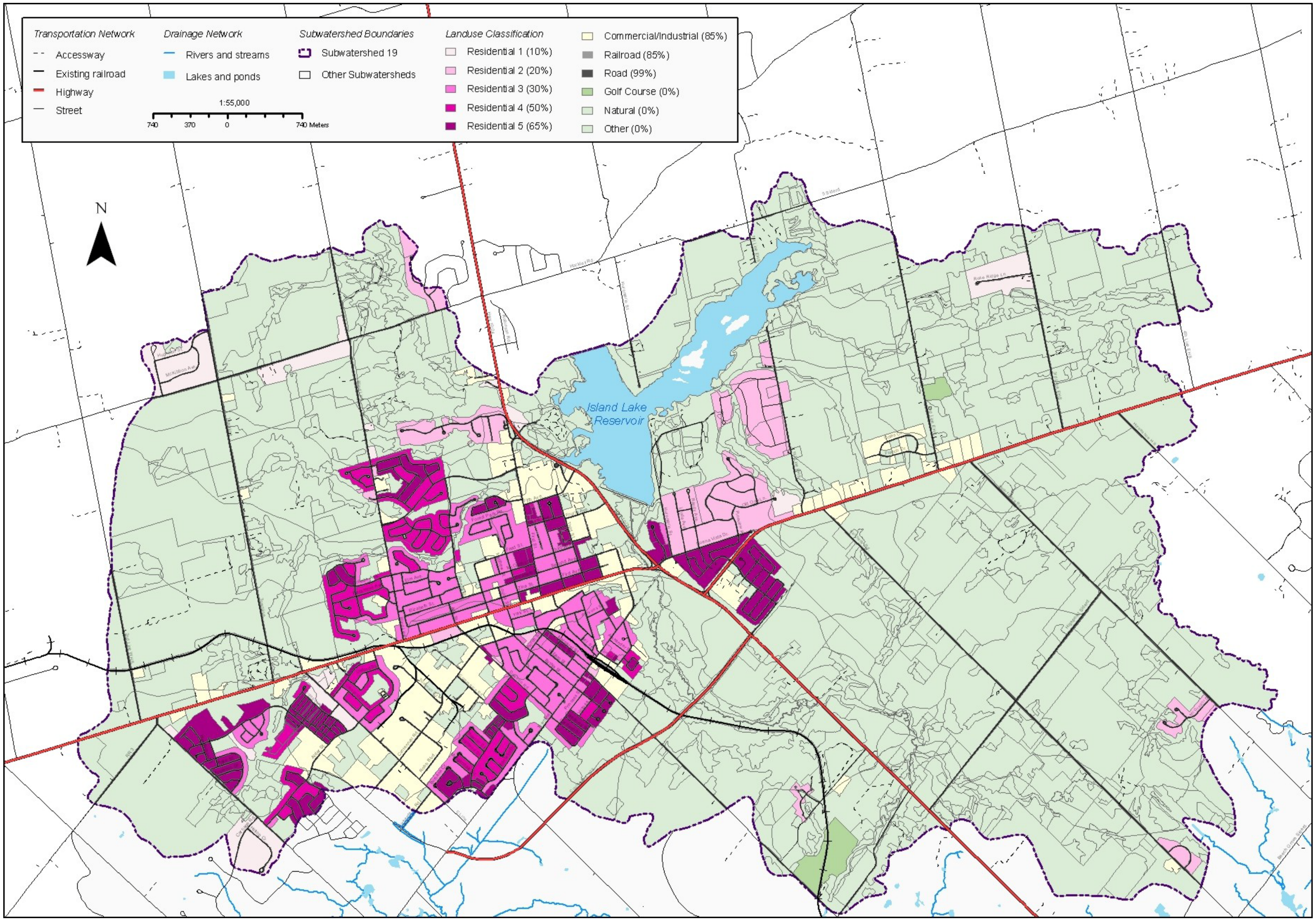


Figure 7: Estimated impervious associated with different land use categories within the Headwaters Subwatershed.

Table 2: Patterns of land use in the five catchment zones of the Headwaters Subwatershed under existing conditions.

	Catchment Zones				
	Monora Creek Tributaries	Eastern Tributaries	Mill Creek	Caledon Tributaries	Credit River
Total Area (ha)	1196.96	1257.95	867.31	1201.59	1317.62
Residential (%)	17.5	5.6	20.4	1.3	23.7
Commercial/Industrial (%)	3.2	3.4	17.2	0.2	5.8
Agricultural (%)	30.3	42.6	35.8	45.3	14.2
Natural Areas (%)	36.3	39.3	12.7	48.3	42.6
Other (%)	12.7	9.1	13.9	4.9	13.7
Total Impervious Area (ha)	145.19	72.89	253.01	24.98	279.16
Total Impervious Area (%)	12.1	5.8	29.2	2.1	21.2
Comments	• Dominant land use categories (in descending order) include natural areas, agricultural and residential	• Dominant land use categories (in descending order) include agricultural and natural areas. • Commercial/industrial land use is most prevalent within the southern portion of the zone.	• Most of the zone is located within the urban boundary of the Town of Orangeville. • Agriculture is the dominant land use, but residential and commercial/industrial land uses are prevalent. • This zone has the lowest proportion of Natural Areas and the highest % imperviousness in the Headwaters Subwatershed	• Natural Areas is the dominant land use category; residential and commercial/industrial land uses are limited. • This zone has the lowest % imperviousness in the Headwaters Subwatershed	• Natural Areas is the dominant land use category; residential and commercial/industrial land uses are generally located within the urban boundary of the Town of Orangeville. • This zone has the second highest % imperviousness in the Headwaters Subwatershed

1.3 Overview of Headwaters Subwatershed Study

CVC and its member municipalities completed the first Subwatershed Study of the Headwaters Subwatershed in 1997. Since that time, advances in science, changes in policy/legislation, and changes in land use have triggered an update of the original study. CVC initiated the new Headwaters Subwatershed Study (hereafter, simply the Headwaters Subwatershed Study) in 2005. This is the first update of the original study since it was completed in 1997, and the first update of a CVC subwatershed study since the CVC initiated subwatershed management in the Credit River watershed.

The aim of the Headwaters Subwatershed Study is to:

- consider relevant new legislation;
- consider the results of more recent and concurrent studies;
- consider advances in scientific assessments and tools since the original study;
- assess and test the management recommendations of the original study;
- assess impacts from current and future land use changes; and
- assess the implications of climatic extremes.

The Headwaters Subwatershed study will update our understanding of current environmental conditions in the Subwatershed, reassess the recommendations of the original study from 1997, determine the lessons learned, update the original Subwatershed Plan and develop an implementation program for the updated Plan. The results of the updated study are intended to be used as one component of an overall land use management strategy that may be developed by the municipal partners in an effort to balance economic, social and environmental needs within their communities.

1.3.1 Study Team

The Headwaters Subwatershed Study is being completed by a team that includes CVC staff, representatives of local municipalities and interested agencies, technical experts from a number of consulting firms and members of the general public. Study participants are organized into four groups, including a Project Management Team, a Steering Committee, a Technical Committee and a Focus Group.

The Project Management Team oversees the overall study process to ensure that the Headwaters Subwatershed Study is completed in a timely and technically sound manner. Since CVC is the lead agency for the study team, the Project Management Team consists of three CVC staff members.

The Steering Committee includes representatives from municipalities and agencies that have an interest in the Headwaters Subwatershed Study, including the Town of Orangeville, the Town of Caledon, the Town of Mono, the Township of Amaranth, the Township of East Garafraxa, the Ontario Ministry of Natural Resources (MNR), the Ontario Ministry of the Environment (MOE), and the Region of Peel. The Steering Committee guides the overall study process.

The Technical Committee is comprised of representatives from consulting firms and CVC staff who have expertise in the technical components of the study hydrology, hydraulics, hydrogeology, water quality, fluvial geomorphology, terrestrial, planning and aquatics. The purpose of the Technical Committee is to complete the Subwatershed Study as guided by the Project Management Team and the Steering Committee.

The Focus Group consists of landowners, members of the general public and representatives of community groups with an interest in the Headwaters Subwatershed. The purpose of the Focus Group is to review the study results as they became available and to assist in the development of policies and priorities for the study area. The Focus Group also assists in the development of strategies to communicate study results.

1.3.2 Study Organization and Report Structure

The Headwaters Subwatershed Study is being conducted in four phases. During the initial background phase, the study team summarized existing information on the environmental features of the Headwaters Subwatershed, identified data gaps and developed a field program to fill in those data gaps. The results of the background phase are provided in a report titled *Headwaters Subwatershed Study: Background Report* (CVC et al. 2006).

Phase I of the Headwaters Subwatershed Study proper began in 2006. During Phase I, the study team characterized the existing conditions of the Headwaters Subwatershed using both historical information and data collected from field work conducted in 2006 and 2007. The results are provided in a report titled *Headwaters Subwatershed Study: Phase 1 Characterization Report* (CVC et al. 2009). The Phase I report provides an up-to-date and comprehensive understanding of the natural heritage features and functions of the Headwaters Subwatershed, identifies issues of concern, and outlines Goals and Objectives for environmental protection and enhancement.

Phase II of the Headwaters Subwatershed Study was initiated in 2008. During Phase II, the study team evaluated the potential effects of land use changes associated with different alternative scenarios on the existing conditions as identified during Phase I. This phase of the study addressed questions such as: What are the potential stressors? What are the potential impacts from these stressors? What are the alternate solutions? This Report provides the results of Phase II of the Headwaters Subwatershed Study. As such, it describes potential impacts, evaluates alternative scenarios and recommends appropriate management strategies based on the goals and objectives for environmental protection and enhancement developed during Phase I of the study.

Phase III of the Headwaters Subwatershed Study will focus on the implementation of the recommended management strategies, collectively referred to as the Subwatershed Plan. It will describe what is required to achieve the established goals, will identify roles and responsibilities of the various stakeholders for implementing the various recommendations and will identify long-term monitoring goals. Phase III of the study is expected to be initiated in 2010.

1.4 Overview of Concurrent Studies

A number of other studies currently under way have informed the results of Phase II of the Headwaters Subwatershed Study. These include the following:

- Tier 3 Water Budget Case Study;
- Orangeville WPCP Expansion Enhanced Class EA; and
- Orangeville/Mono Tier 1 Water Quality Risk Assessment.

The following sections provide a brief overview of these concurrent studies.

1.4.1 Tier 3 Water Budget Case Study

This study of the Town of Orangeville's water is being undertaken in accordance with the Province's Source Water Protection (SWP) program as mandated by the *Clean Water Act* (2006). It is being managed by the MNR and executed through a contract with the consulting firms AquaResources Incorporated and R.J. Burnside and Associates.

A Tier 3 Water Quantity Risk Assessment is required for all communities that obtain municipal water supplies from subwatersheds previously identified as being under moderate or significant levels of hydrological stress due to developmental demands placed upon the resource. The aim of the study is to estimate the quantity of water flowing through the area, understand the processes that affect availability, and provide baseline information for future planning and development. The objectives of the study are to:

- develop and calibrate a local area groundwater flow model with sufficient detail to simulate groundwater flow near wells and streams;
- review and comment on the ability of the existing surface water model for the area to simulate variable streamflow under a variety of current and future development options;
- use the calibrated models to complete the Tier 3 Risk Assessment as defined in the current guidance documentation; and
- consider the appropriateness of proposed risk management initiatives.

The study commenced in April 2007 and is scheduled for completion in September 2009.

1.4.2 Orangeville Water Pollution Control Plant Expansion Enhanced Class EA

The Town of Orangeville completed its Long Term Servicing Strategy (LTSS) in November, 2004. The LTSS was undertaken to identify the preferred approach to providing both water supply and sewage treatment for the remaining undeveloped lands within the Town's existing municipal boundary. The preferred alternative for sewage treatment servicing selected as a result of the LTSS included the following elements:

- ccontinued implementation of water use efficiency;
- continued reduction of extraneous flows entering into the collection system;
- expansion and upgrading of the existing Orangeville Water Pollution Control Plant (WPCP) to provide treatment capacity of 17,500 m^3/d to service the Town at build-out; and
- continued anaerobic digestion followed by dewatering of biosolids and further development of options for final utilization/disposal.

The LTSS fulfilled the requirements of Phases 1 and 2 of the Municipal Class Environmental Assessment (Class EA). To complete the remaining phases of the EA, the Town has now entered into an Enhanced Class EA, which will follow the general process outlined in the Municipal Class EA (MEA, June 2000) but will involve measures that go beyond the standard requirements for the Municipal Class EA project, including an enhanced level of technical studies aimed at addressing the issues that were raised during the LTSS.

Specific technical work to be undertaken as part of the Enhanced Class EA includes:

- confirmation of effluent limits for an expanded and upgraded water pollution control plant;
- continued monitoring of the Orangeville Marsh (aka Melville Marshes);
- undertaking a cumulative impact assessment to identify the cumulative environmental impacts arising from the proposed Orangeville WPCP upgrade and expansion; and
- identification of the preferred design approach to provide treatment capacity of 17,500 m^3/d to service the Town at build-out.

The Town of Orangeville retained XCG Consultants Limited to complete the Enhanced Class EA. Work commenced in 2007 and was completed in 2009.

1.4.3 Orangeville / Mono Tier 1 Water Quality Risk Assessment

Residents of the Towns of Orangeville and Mono rely on groundwater for their drinking water supplies. Both Towns recognize the need to protect this resource and have agreed to work together to complete a Tier 1 Water Quality Risk Assessment in accordance with the technical guidance modules prepared by the MOE as part of the Province's Source Water Protection Program.

Both municipalities have defined Wellhead Protection Areas (WHPAs) through previously completed Groundwater Management Studies. These studies did not, however, include a vulnerability assessment, an inventory of potential threats or an evaluation of issues. The Tier 1 Water Quality Risk Assessment, which has been funded by the MOE, is being undertaken to fill these gaps. The two municipalities are working together since the wellfields in question are proximate to each other.

The objectives of the project are to:

- update the Intrinsic Susceptibility Index (ISI) mapping and develop Aquifer Vulnerability Index (AVI) ratings for the WHPAs and areas identified for future groundwater development;
- complete a threats inventory and issues evaluation;
- apply uncertainty factors to vulnerability mapping in the WHPAs;
- carry out field verification of the preferential pathways within the WHPAs;
- refine the threats and issues inventory;
- develop contaminant hazard ratings; and
- complete a Water Quality Risk Assessment.

The project commenced in the spring of 2007 and was completed in 2008.

2 Phase II of the Headwaters Subwatershed Study

2.1 Description of Alternative Scenarios

The primary objective of Phase II is to evaluate the potential effects of different alternative scenarios on the existing conditions of the Headwaters Subwatershed. The Study's Technical Committee selected five alternative scenarios for evaluation. These alternative scenarios vary based on different approaches to land use, storm water management and the establishment of a Natural Heritage System (NHS). These approaches are described in greater detail below.

> The five alternative scenarios provide a basis for evaluating the potential impacts of different "alternative futures" on the environmental resources of the Headwaters Subwatershed. In this regard, the scenarios are not intended to predict future conditions, but rather as a tool to gauge the benefits and negative impacts on the environment of implementing alternative land uses and management practices.

2.1.1 Land Use Alternatives

The five alternative scenarios include two alternative patterns of land use. The first is defined by existing conditions. The second is defined by future development in conformance with the Provincial Growth Plan for the Greater Golden Horseshoe (Places to Grow). These alternative land use patterns are described in further detail below.

2.1.1.1 Existing Land Use

Existing land use within the Headwaters Subwatershed is determined by municipal Official Plans. Each municipality is responsible for developing an Official Plan and ensuring its implementation according to the provisions of the *Planning Act*. An official plan describes municipal policies on how land should be used and is intended to ensure that future planning and development will meet community needs. An official plan deals mainly with issues such as:

- the location of new residential, commercial, industrial and environmental protection areas;
- the need for services like roads, watermains, sewers, parks and schools, and
- the timing and order in which portions of the municipality will grow.

Official Plans of relevance to the Headwaters Subwatershed include those of the Region of Peel, the Town of Caledon, the Town of Orangeville, the Township of East Garafraxa, the Township of Amaranth and the Town of Mono. Since the County of Dufferin does not have an Official Plan, land use planning in this area of the Headwaters Subwatershed is directly solely by the Official Plans from the municipalities within the County.

2.1.1.2 Provincial Growth Plan (Places to Grow)

In 2005 the Government of Ontario issued a Growth Plan (Places to Grow) for the Greater Golden Horseshoe, which includes the Headwaters Subwatershed. The Growth Plan contains estimates of the anticipated growth in the areas subject to the Plan and directs where and how this growth is to occur. Specifically, the Plan provides policies that are intended to achieve the following:

- direct growth to built up areas, while providing strict criteria for settlement boundary expansion;
- identify and support a transportation network and promote transit-supportive densities;
- plan for community infrastructure and ensure sustainable water and wastewater services;
- identify and enhance the conservation of natural systems and prime agricultural areas; and
- support the protection and conservation of water, energy, air and cultural heritage as well as integrated approaches to waste management.

Municipal official plans must conform to the policy direction provided by the Growth Plan.

2.1.2 Stormwater Management Alternatives

The objective of stormwater management is to mitigate the effects of urbanization on the hydrologic cycle. In the absence of proper stormwater management, urbanization can result in a reduction in the baseflow of surface watercourses, a degradation of water quality and an increase in flooding and erosion. These impacts can in turn result in reduced diversity of aquatic life, fewer opportunities for human uses of water resources, and the loss of property and human life (MOE 2009).

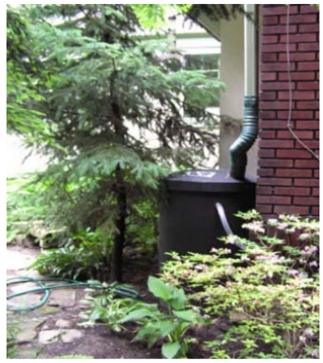
A variety of different stormwater management measures are available to address runoff from the moment precipitation hits the ground until it enters a receiving watercourse. These measures fall into the following three main categories:

- Source (lot-level) control measures
- End-of-pipe measures
- Conveyance control measures

These measures are described in further detail below.

Source (lot-level) control measures are physical measures that are located at the beginning of a drainage system, generally on private property. These measures include rooftop storage, parking lot storage, downspout disconnection, soakaway pits, rain barrels, biofilters and rooftop gardens (Figures 8 and 9). Such control measures can be installed within a variety of land uses, including residential, commercial/industrial and institutional.

Downspout Disconnection



Rain Barrel

Biofilter

Figure 8: Examples of source (lot-level) control measures.

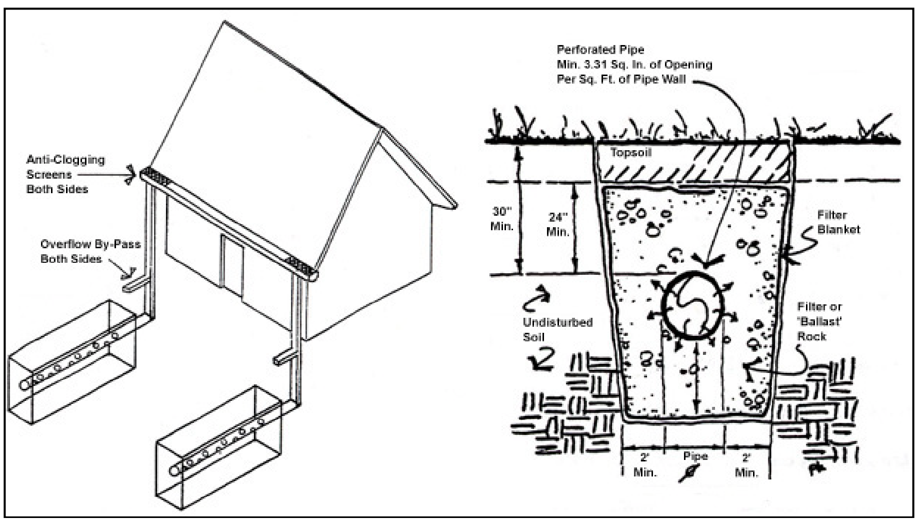


Figure 9: Soakaway pit.

Conveyance control measures are physical measures that are incorporated within the system of swales, ditches, culverts, catch basins, manholes and storm sewers that convey stormwater runoff. Typically, these measures are installed within the right-of-way when a road is reconstructed or resurfaced. Conveyance control measures include grass swales, permeable pavers, pervious pipe systems, biofiltration units and vegetated filter strips (Figures 10-11).

Permeable Paver

Pervious Pipe System

Biofiltration Unit

Figure 10: Examples of conveyance control measures.

Bioretention

Dry Swale

Filter Strip

Figure 11: Additional examples of conveyance control measures.

Source (lot-level) and conveyance control measures may be classified as storage or infiltration measures. Storage measures are designed to detain stormwater. Although the volume of runoff does not decrease, the risk of flooding is reduced because all of the runoff does not arrive at the receiving watercourse at the same time. Infiltration measures promote groundwater recharge. Infiltration measures can achieve water quality enhancement but are best suited to relatively clean stormwater including rooftop and foundation drainage. Pre-treatment of road drainage is necessary to prevent the clogging of infiltration systems and to protect groundwater quality.

End-of-pipe measures include dry ponds, wet ponds, constructed wetlands and oil/grit separators (Figure 12). Such measures mitigate the effects of urbanization which remain after source (lot-level) and conveyance control measures have been applied. End-of-pipe facilities are usually required for flood and erosion control and water quality improvement, although source (lot-level) and conveyance control measures can reduce the size of the end-of-pipe facilities required.

Dry Pond

Wet Pond

Figure 12: Examples of end-of-pipe measures.

The evaluation of the five alternative scenarios considered three different approaches to storm water management, including the following:

- **Business as Usual (BAU) - the application of current stormwater management practices to new development**;
- **Low Impact Development (LID) - the application of LID stormwater management practices to new development; and**
- **Retrofitting - the application of LID stormwater management practices to previously developed areas through retrofitting.**

These approaches are described in further detail below.

2.1.2.1 Business as Usual (BAU)

The current (business as usual) approach to stormwater management typically focuses on the efficient conveyance of runoff from its source to an end-of-pipe treatment facility. This approach mitigates the effects of development on the quantity and the quality of runoff, but does not prevent alteration of the natural hydrologic cycle. As a result, development may still negatively affect a variety of environmental resources. For example, an increase in impervious surfaces (such as roads, rooftops and sidewalks) may reduce infiltration, ultimately limiting the discharge of cool, clean groundwater necessary to support sensitive fish habitat.

2.1.2.2 Low Impact Development

There is a growing concern that, as an increasing proportion of a subwatershed is committed to urban land uses, current stormwater management practices are insufficient to prevent environmental impacts. The next generation of stormwater management that is gaining recognition is called Low Impact Development (LID).

Many definitions have been developed in an attempt to define LID. For the purposes of this report the following definition, as proposed by the United States Environmental Protection Agency (EPA) is used:

> Low Impact Development is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution. LID comprises a set of site design approaches and small scale stormwater practices that promote the use of natural systems for infiltration, evapotranspiration and the reuse of stormwater. These practices can effectively remove nutrients, pathogens and metals from stormwater, and they reduce the volume and intensity of stormwater flows (EPA 2007).

LID strives to protect and maintain the natural hydrologic cycle and typically incorporates a variety of source (lot-level) and conveyance control measures. Relative to the Business as Usual approach to stormwater management, the LID approach more closely maintains the pre-development water balance by promoting infiltration and transferring surface water to groundwater.

LID can be implemented in proposed new developments as part of the design process or in previously developed areas through retrofitting.

2.1.2.3 Retrofitting

In areas developed prior to the implementation of modern stormwater management practices, uncontrolled and untreated stormwater runoff is discharged directly to receiving watercourses. In such areas, the implementation of LID measures through retrofitting can provide a variety of benefits, including the following:

- Improved water quality
- Decreased bank erosion in receiving watercourses
- A more stable hydrologic regime that is more representative of natural conditions
- Improvements to baseflow conditions that have the potential to reduce stress on fish populations during periods of low flows and high temperatures

The feasibility of implementing LID measures through retrofitting is determined by a number of factors, including the following:

- availability of land for LID measures
- technical feasibility of construction (e.g. permeability of soils)
- estimated costs of construction
- environmental benefits
- social benefits

2.1.3 Natural Heritage System Alternatives

The 2005 Provincial Policy Statement (PPS) defines a Natural Heritage System (NHS) as a system made up of natural heritage features and areas, linked by natural corridors which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. These systems can include lands that have been restored and areas with the potential to be restored to a natural state.

The natural areas of the Headwaters Subwatershed are highly fragmented, with a large portion of the NHS interrupted by the rapidly expanding Town of Orangeville. However, the subwatershed continues to support significant terrestrial resources, including the following:

- Three Environmentally Significant Areas (ESA). All three ESAs are significant for their large wetlands and associated hydrological functions, for the presence of rare flora and vegetation communities, and for the sizeable amount of natural habitat.

- Two Provincially Significant Wetland complexes. Both complexes are large (>350 ha) and contribute significant hydrological function to the watershed. The wetlands also support a wide variety of wildlife species and provide habitat for a large number of rare plant species.

- Over 40 large forests and woodlots provide habitat for forest interior species.

- At least two bogs (a regionally rare type of habitat type).

- Seventeen vegetation communities that support three or more rare plant species.

- A number of unique vegetation community assemblages more commonly seen in central and northern Ontario. These assemblages support many rare, unusual and/or significant flora and fauna.

Connections between natural areas tend to be situated along watercourses and these connections vary in their degree of naturalness; some corridors are well-vegetated, but many are lacking sufficient natural cover. In agricultural sections of the subwatershed, riparian vegetation is often limited to narrow bands or has been removed through agricultural clearing.

In the past, only those natural features with special attributes were protected. The current approach towards the establishment of a NHS emphasizes an ecosystem approach. This approach recognizes that to maintain a healthy, natural ecosystem, it is necessary, not only to protect an area's important features, but also its functions and linkages.

The evaluation of the five alternative scenarios considers two different approaches to the establishment of a NHS. The two approaches are described in further detail below.

2.1.3.1 Existing Policies and Practices

This approach is based on existing policies and practices. Under this approach, elements of the NHS are defined by and protected from development under existing legislation, regulations and policies. Table 3 lists the elements that would be incorporated in a NHS established under this approach. The resulting NHS would consist of approximately 1,614 ha, or 27% of the Headwaters Subwatershed (Figure 13).

2.1.3.2 Enhanced

This approach incorporates the NHS defined under existing policies and practices, but also includes additional lands based on generally accepted ecological concepts that are commonly applied to NHS planning. Table 3 lists the elements that would be incorporated in a NHS established under this approach. The resulting NHS would consist of approximately 2,289 ha, or 38% of the Headwaters Subwatershed (Figure 13). Development within these additional lands is not currently prohibited under existing legislation, regulation and policies. As such, the long-term preservation of these additional lands could only be achieved through stewardship-based measures.

2.2 Summary of Alternative Scenarios

The Technical Committee evaluated five alternative scenarios based on different approaches to land use, storm water management and the establishment of a Natural Heritage System (NHS). Table 4 summarizes the five alternative scenarios. Figures 14-18 illustrate these scenarios.

Table 3: Alternative approaches to Natural Heritage System establishment.

NHS Component	Natural Heritage System Alternatives	
	Existing Policies and Practices	Enhanced
Woodlands	• Include all woodlands ≥ 4 ha • Incorporate 30 m buffer on all retained woodlands	• Include all woodlands ≥ 4 ha • Incorporate 30 m buffer on all retained woodlands • Retain additional lands to (i) improve the shape of significant woodlands, (ii) enlarge woodlands with < 4 ha of existing interior forest habitat to create a minimum 4 ha core of interior habitat and/or (iii) enlarge woodlands that almost contain interior forest habitat (90 m from edge) to create a minimum 0.5 ha core of interior habitat. • Include cultural savannas and cultural thickets that intersect 30 m Vegetation Protection Zones
Wetlands	• Within the Greenbelt Area, include all evaluated wetlands or wetlands > 0.5 ha • Outside of the Greenbelt Area, include all Provincially Significant Wetlands and on-line wetlands > 0.5 ha • Incorporate a 30 m buffer on all retained wetlands	• Within the Greenbelt Area, include all evaluated wetlands or wetlands > 0.5 ha • Outside of the Greenbelt Area, include all Provincially Significant Wetlands and on-line wetlands > 0.5 ha • Incorporate a 30 m buffer on all retained wetlands • Retain additional lands to improve the shape of terrestrial habitat adjacent to included wetlands
Life Science Areas of Natural and Scientific Interest (ANSI) and Environmentally Significant Areas (ESA)	• Include all Provincially Significant Life Science ANSIs and all ESAs • Incorporate Vegetation Protection Zones as determined on a site-specific basis	• Include all Provincially Significant Life Science ANSIs • Incorporate Vegetation Protection Zones as determined on a site-specific basis
Valleylands/Watercourses/Fish Habitat	• Include all lands below the crests of slopes • Include all lands within the meander belts of watercourses • Include all engineered flood plains and estimated flood plains • Incorporate a 30 m buffer on all watercourses (except headwater swales), lakes and on-line ponds • Within the urban boundary of Orangeville, include all areas of contiguous woody vegetation (forests, plantations, cultural woodlands and swamps) that intersect the 30 m buffer	• Include all lands below and 30 m beyond the crests of slopes • Include all lands within and 30 m beyond the meander belts of watercourses • Include all engineered flood plains and estimated flood plains • Incorporate a 30 m buffer on all watercourses (except headwater swales), lakes and on-line ponds • Within the urban boundary of Orangeville, include all areas of contiguous woody vegetation (forests, plantations, cultural woodlands and swamps) that intersect the 30 m buffer • Include any cultural savannas and cultural thickets within 50 m of the crests of slopes • Incorporate a 100 m buffer on 4^{th} order or higher rural tributaries • Incorporate a 100 m buffer on the main branches of urban tributaries

NHS Component	Natural Heritage System Alternatives	
	Existing Policies and Practices	Enhanced
Species at Risk Habitat	• Include all natural areas associated with the occurrence of species designated Threatened or Endangered by the federal (COSEWIC) and/or provincial (COSSARO) assessment process	• Include all natural areas associated with the occurrence of species designated Threatened or Endangered by the federal (COSEWIC) and/or provincial (COSSARO) assessment process • Where reasonable, include all natural areas associated with the occurrence of species designated Special Concern by the federal (COSEWIC) and/or provincial (COSSARO) assessment process
Terrestrial Corridors		• Include corridors as defined by the Greenbelt NHS • Retain additional lands to restore connectivity between High Priority Areas

Figure 13: Natural Heritage System alternatives.

Table 4: Alternative scenarios evaluated.

Option Number	Land Use	Storm Water Management	Natural Heritage System
1	Existing	Business as Usual (BAU)	Existing Policies and Practices
2	Places to Grow	Business as Usual (BAU)	Existing Policies and Practices
3a	Places to Grow	LID in new development and retrofitting of existing development	Existing Policies and Practices
3b	Places to Grow	LID in new development and no change in existing development	Existing Policies and Practices
4a	Places to Grow	LID in new development and retrofitting of existing development	Enhanced

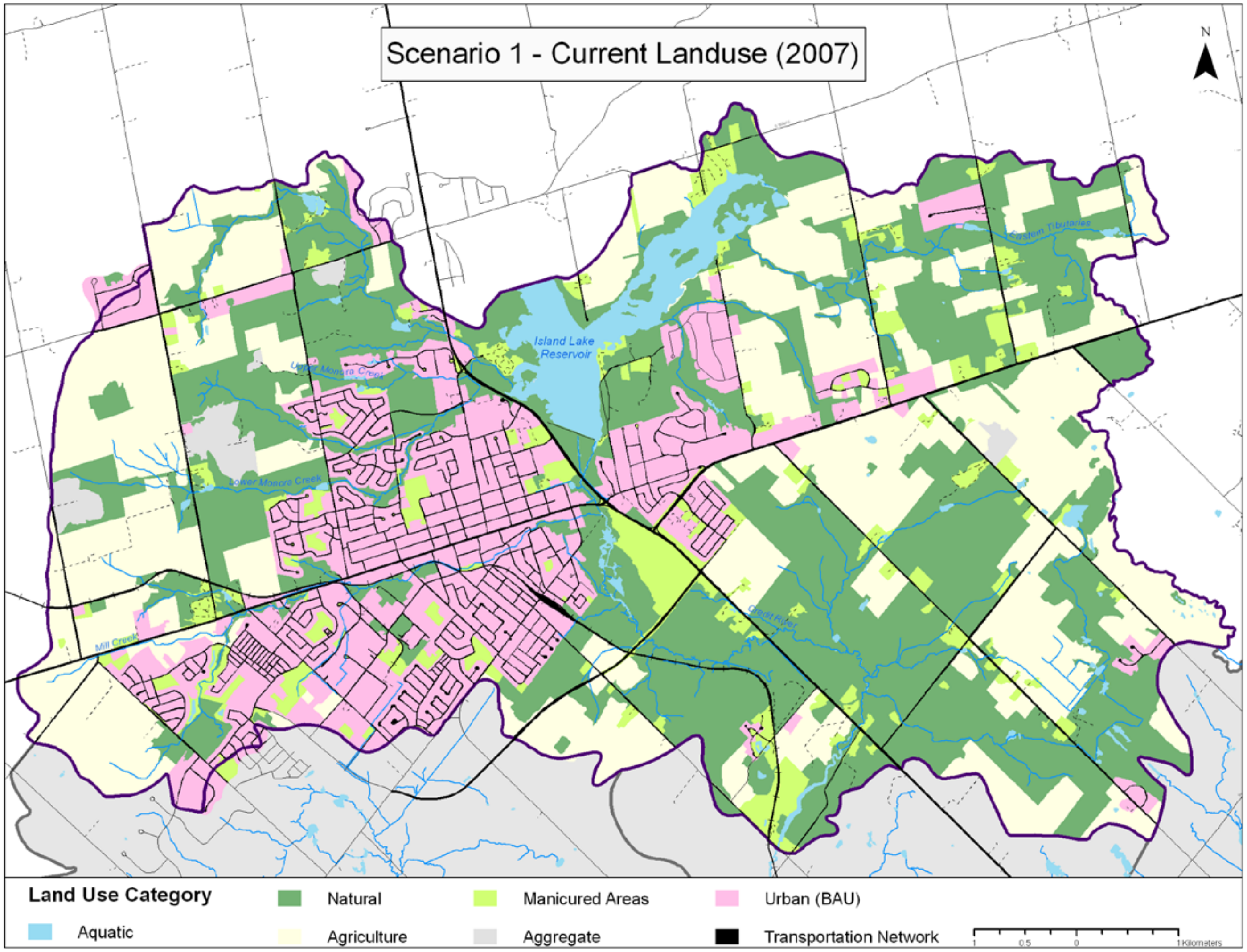


Figure 14: Alternative Scenario 1.

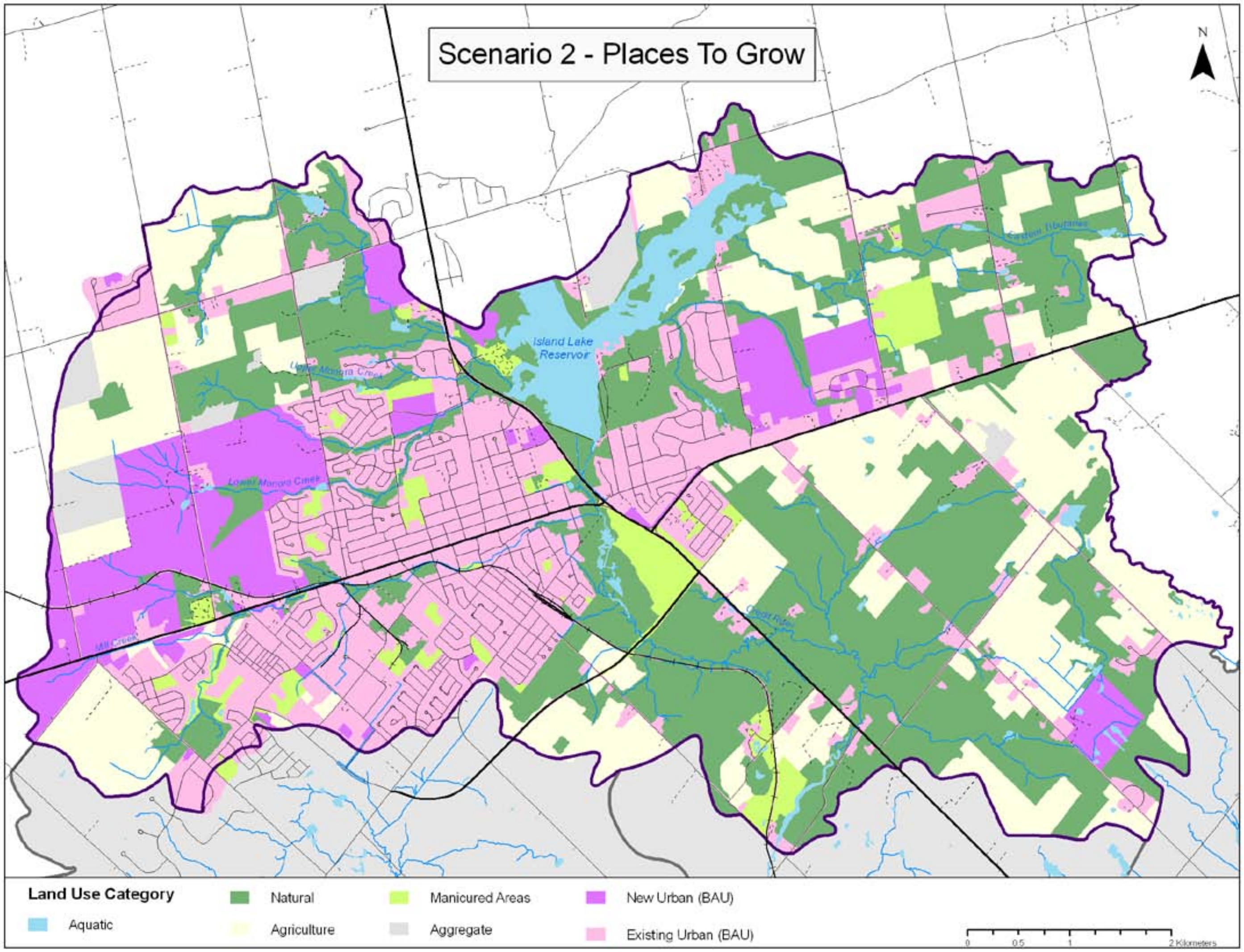


Figure 15: Alternative Scenario 2.

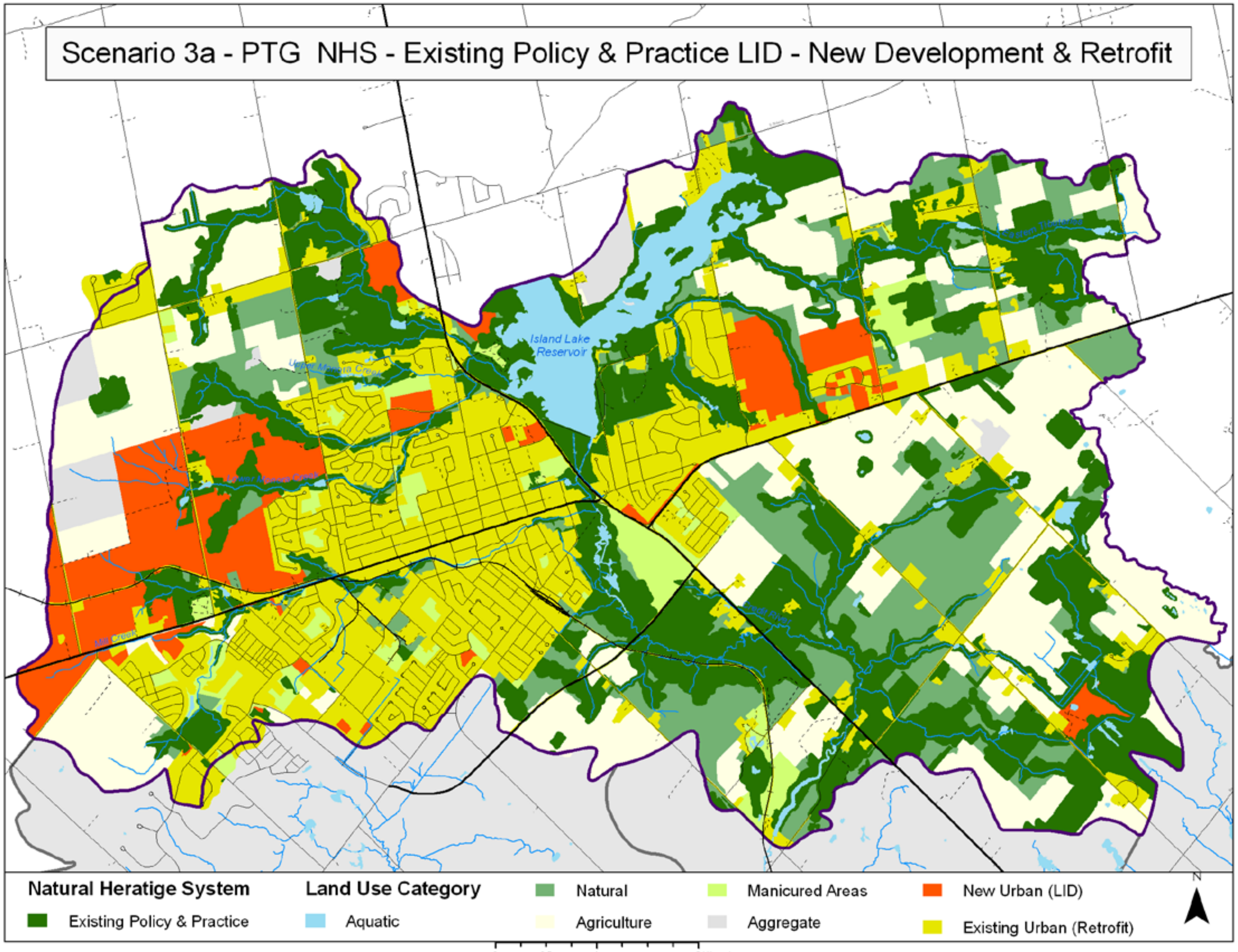


Figure 16: Alternative Scenario 3a.

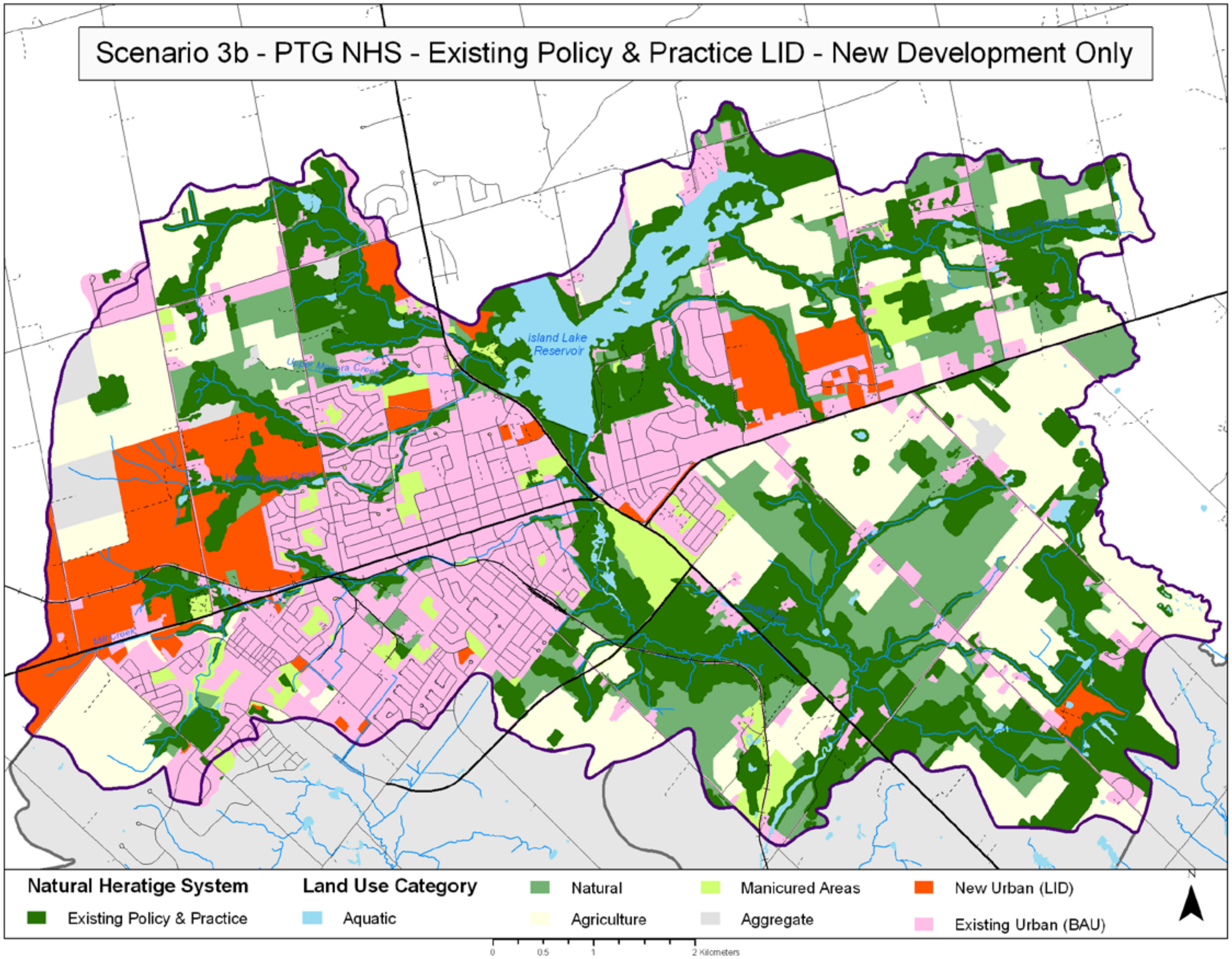


Figure 17: Alternative Scenario 3b.

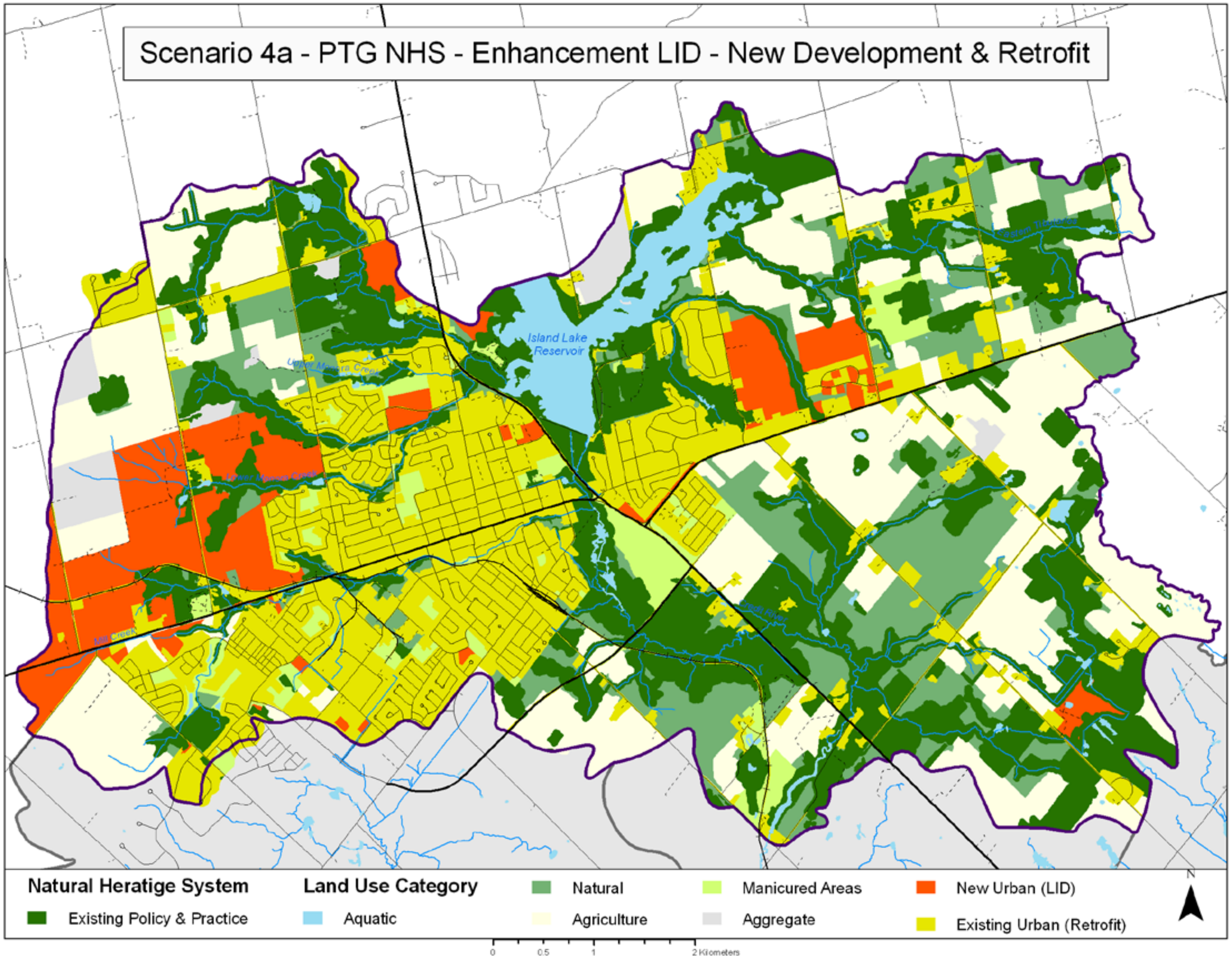


Figure 18: Alternative Scenario 4a.

3 Evaluation Methodology

3.1 Overview of Evaluation Methodology

Once the alternative scenarios were defined, the Technical Committee used a step-wise approach to evaluate their potential effects on the existing conditions of the Headwaters Subwatershed. This approach included the following steps:

- Identify environmental objectives for the Headwaters Subwatershed.
- Establish for each environmental objective various indicators, measurable parameters and targets.
- Conduct hydrologic modelling and other quantitative/semi-quantitative analyses to determine the environmental response of the Headwaters Subwatershed to each of the five alternative scenarios.
- Determine whether the five alternative scenarios degrade, maintain or enhance existing conditions by scoring the environmental response of each against the targets associated with the environmental objectives for the Headwaters Subwatershed.

These steps are described in greater detail below.

3.2 Establishment of Objectives, Indicators, Measurable Parameters and Targets

CVC and its member municipalities completed the Credit River Water Management Strategy (CRWMS) in 1992. The CRWMS established a framework for environmental management, resource stewardship and environmentally-sound land use planning throughout the Credit River watershed based on a watershed-wide Goal and 18 Objectives. The CRWMS also developed Objectives and Targets for each of the Credit River Watershed’s 20 subwatersheds, including the Headwaters Subwatershed.

CVC completed an update of the CRWMS in 2006. One of the key steps in completing the Credit River Watershed Management Strategy Update (CRWMSU) was to revisit and develop a new/revised set of Goals and Objectives to guide future watershed management initiatives.

The CRMWSU received input from its Steering and Technical Committees, members of the public, politicians, senior bureaucrats and representative interest groups. The following Watershed Goal for the Credit River was developed through the CRMWSU process:

GOAL for the CREDIT RIVER WATERSHED
To ensure abundant, safe, clean water for environmentally, socially and economically healthy communities within the Credit River watershed.

The CRMWSU also developed a set of Objectives to describe more specifically how the Watershed Goal was to be achieved.

During Phase I of the Headwaters Subwatershed Study, the Technical Committee used the CRWMSU Objectives as the basis for developing 18 Objectives specifically for the Headwaters Subwatershed. These Objectives describe how the Goals for the Credit River Watershed and the Headwaters Subwatershed are to be achieved. All Objectives are considered to be of equal importance in achieving these goals. The Technical Committee also adopted the process from the CRWMSU to develop a set of Indicators, Measurable Parameters and Targets for each of the 18 Objectives. These terms are defined below.

Indicator – an indicator is piece of information, clue or attribute of the ecosystem that describes the current condition of the ecosystem, or one of its components. Examples include temperature, total suspended solids, aquatic community abundance, erosion potential and wetland cover. An Objective may have one or more Indicators.

Measureable Parameter – a measurable parameter is a quantitative or qualitative way to measure progress toward achieving the Indicator. Several measurable parameters may be used for assessing each indicator. Examples include: midsummer maximum temperature, five sample geometric mean *E. coli* count, biomass/density of fish, cumulative excess stream power (erosion potential), percent cover by wetlands and forests.

Target – a target is a specific aim to be achieved by a Measurable Parameter. Targets can be set for the short, medium and long term and represent the healthy ecological state for the associated Indicator. Examples include: 26°C for coldwater fish, reduction of cumulative excess stream power to 25% of current values, increase forest cover to 30% of watershed area. Some targets apply to the Headwaters Subwatershed as a whole. However, targets for many Indicators were established individually for each catchment zone to reflect site-specific conditions.

Eight of the 18 Objectives developed during Phase I of the Headwaters Subwatershed Study were utilized in the Phase II evaluation of the alternative scenarios. The eight Objectives used in the evaluation (Objectives 4, 5, 6, 7, 8, 9, 15 and 16) relate to hydrology, stream processes (erosion), flooding, groundwater, water quality and aquatic and terrestrial ecology. These Objectives were used in the evaluation because they meet two criteria:

1. The alternative land uses and/or management practices under evaluation have the potential to affect one or more of the Objective's Indicators; and

2. The response of the Indicator(s) to the alternative scenario is quantifiable and can be determined through the hydrologic modelling or other quantitative/semi-quantitative analyses.

The eight Objectives used in the evaluation, and their associated Indicators, Measurable Parameters and Targets are listed in Appendix A.

> A comprehensive evaluation of the alternative development scenarios based on all 18 Objectives for the Headwaters Subwatershed is beyond the scope of this study. The evaluation presented here provides a "big picture" comparison to illustrate the relative merits of the different approaches to land use, storm water management and the establishment of a Natural Heritage System. More detailed studies will be required to implement the selected approaches.

3.3 Analysis

The Technical Committee of the Headwaters Subwatershed Study used hydrologic modelling and various other quantitative/semi-quantitative analyses to determine the environmental response of the various Indicators to each of the five alternative scenarios. These analyses are summarized in Appendix B.

3.4 Evaluation Methodology

The following process was used to evaluate the ability of each of the alternative scenarios to achieve the Objectives for the Headwaters Subwatershed:

1. Hydrologic modelling and various other analyses were used to determine the environmental response of each Indicator (i.e. the value of the Measurable Parameter) to each of the five alternative scenarios.

2. The alternative scenarios were scored by comparing the value of the Measurable Parameter for each Indicator against the established Targets. Each comparison was assigned a score ranging from 0-10. Two systems were used for scoring:

   - Where the Measurable Parameters of the alternative scenarios did not meet a Target, the alternative scenarios were scored proportionally based on the difference between the values of their Measurable Parameter and the Target. For example, a scenario that achieved 20% of a given target was given a score of 2, while a scenario that achieved 80% of the target was given a score of 8.

   - Where the Measurable Parameters of some of the alternative scenarios met or exceeded a target, while others did not, those alternative scenarios that met the Target were given a score of 5. Other scenarios were scored proportionally based on the difference between the values of their Measurable Parameter and the Target. For example, a scenario that was 30% below the target was given a score of 3, while a scenario that exceeded the Target by 30% was given a score of 8.

3. A matrix was established for the Subwatershed as a whole and for each of the five catchment zones to summarize the scores of each Objective based on the scores of each Indicator for each alternative scenario. Indicator scores were averaged so that the overall score for each Objective ranged from 0-10. Each Objective was weighted equally, so that all Objectives contributed equally to the overall score for each alternative scenario.

4. The overall score for each alternative scenario was calculated by summing the overall scores of each Objective. Therefore, the maximum overall score for each alternative scenario was 80 (eight Objectives with a maximum of 10 points/Objective).

4 Evaluation Results

Tables 5-10 summarize the scores of each of the alternative scenarios for each of the five catchment zones and of the Headwaters Subwatershed as a whole. In these tables, red signifies the degradation of environmental conditions as compared to existing conditions. Yellow signifies the maintenance of similar conditions, while green represents an improvement.

The implications of the five alternative scenarios can be assessed by pair-wise comparisons of evaluation results. These pair-wise comparisons are outlined in Table 11. In considering the development proposed under Places to Grow, these comparisons indicate the following:

- The Business as Usual approach to stormwater management will **degrade** existing environmental conditions.

- The application of LID measures to new development will generally **maintain** existing environmental conditions.

- The application of LID measures to new development and the retrofitting of existing developed areas will **maintain or improve** existing environmental conditions.

- The establishment of an enhanced NHS **has limited ability** to mitigate the effects of urbanization on the hydrologic cycle and water quality, but would provide a number of other environmental and social benefits not addressed by this study.

Patterns of existing and proposed land use vary considerably between the five catchment zones of the Headwaters Subwatershed. This has important implications for the interpretation of the evaluation results presented in Tables 5-10, because different land uses vary in their degree of imperviousness, and the extent of hydrological impacts is generally proportional to the degree of imperviousness. Consequently, the potential benefits of the different approaches to stormwater management vary from zone to zone. Thus, for a given catchment zone, the greater the extent of proposed development, the worse the environmental impacts under the BAU approach to stormwater management and the greater the benefits of implementing LID measures. Similarly, for a given catchment zone, the greater the extent of existing development, the greater the benefits of implementing LID measures through retrofitting. This is illustrated in the following example.

The Mill Creek catchment zone is mostly located within the urban boundary of Orangeville and currently has the highest proportion of imperviousness in the Headwaters Subwatershed. This level of imperviousness is only expected to increase, since much of the development under the Places to Grow land use alternative is proposed to be located within this zone. In contrast, urban land uses in the Caledon Tributaries catchment zone are limited and the zone currently has the lowest proportion of imperviousness in the Headwaters Subwatershed. This level of imperviousness will increase only marginally, as relatively little of the development under the Places to Grow land use alternative is proposed to be located within this zone (Figure 17).

The differences in existing and proposed land use between these two catchment zones are reflected in Tables 7 and 9. As expected, the application of LID measures only to proposed new development (Scenario 3b) will only maintain existing environmental conditions in both zones. In contrast, the application of LID measures to proposed new development and to existing developed areas through retrofitting (Scenario 3a) will actually improve existing environmental conditions in the Mill Creek catchment zone but only maintain existing environmental conditions in the Caledon Tributaries catchment zone.

Several other factors must also be considered in reviewing the implications of the alternative scenarios. These factors are described in further detail below.

4.1.1 Patterns of Groundwater Flow and Withdrawal

Patterns of groundwater flow within the Headwaters Subwatershed do not correspond with the drainage divides of surface flows. Within the Subwatershed, groundwater generally flows from west to east. Groundwater originating from the adjacent Grand River and Nottawasaga River Watersheds enters the western portion of the Headwaters Subwatershed from all directions. In turn, groundwater flows out of the eastern portion of the Headwaters Subwatershed to the north and is eventually discharged into the Nottawasaga River.

All drinking water in the Headwaters Subwatershed is obtained from groundwater within the subwatershed. Water is obtained from individual private wells, private communal systems, or municipal systems. Under existing conditions, approximately 9,725 m^3 of water is withdrawn daily. Proposed development could increase this demand to approximately 13,360 m^3/day (Appendix B). In contrast, the overall (i.e. Subwatershed-wide) rate of groundwater recharge under existing conditions is approximately 40,600 m^3/day. Under Scenarios 2, 3a, 3b and 4a this rate ranges from 37,000 m^3/day to 46, 000 m^3/day (Appendix B). This indicates the following:

- Existing rates of groundwater recharge exceed existing or proposed rates of withdrawal for drinking water.

- Development may reduce existing rates of groundwater recharge. However, the rate of groundwater recharge can be increased above existing levels through the application of LID measures, particularly to existing developed areas through retrofitting.

The wells that supply the majority of the drinking water are not uniformly distributed within the Headwaters Subwatershed but rather are concentrated in the western portions of the Monora Creek Tributaries and Mill Creek catchment zones. The major impacts of increased pumping would be the drawdown of groundwater in the vicinity of the wells, resulting in a reduction in baseflow in Mill Creek, Monora Creek and Shaw’s Creek, which is located in adjacent Subwatershed 17.

This suggests that LID measures may be particularly important to maintain baseflow in the Mill Creek and Monora Creek catchment zones. However, because existing developed areas in these catchment zones are located downgradient of the water wells, their retrofit with LID measures may not benefit water supply.

4.1.2 Influence of Island Lake and the Sewage Treatment Plant

Island Lake influences the hydrology and water balance of the Headwaters Subwatershed. Island Lake receives the discharge from both the Monora Creek Tributaries and Eastern Tributaries catchment zones (approximately 40% of the total surface runoff of the subwatershed) and in so doing attenuates peak flows from these catchment zones. Island Lake also promotes evapotranspiration. Each year approximately one million m^3 of water evaporates from Island Lake, which constitutes between 5% and 7% of the total annual surface water input to the subwatershed.

The outflow from Island Lake is intended to augment flow in the Credit River and to increase assimilative capacity to accommodate discharge from the downstream Town of Orangeville Sewage Treatment Plant. A provincial Permit to Take Water (PTTW) specifies how much water should be released each month. PTTW requirements are difficult to meet, particularly during dry months.

Under existing conditions, effluent from the Town of Orangeville Sewage Treatment Plant is discharged into the Credit River at approximately 0.09 m^3/second (Appendix B). This discharge comprises a considerable portion of the baseflow of the Credit River, particularly under low flow conditions, when up to 50% of the flow in the Upper Credit River originates from the Sewage Treatment Plant. Proposed development would increase the Sewage Treatment Plant’s rate of discharge to approximately 0.14 m^3/second. In contrast, the average baseflow of the Upper Credit River under existing conditions is approximately 0.257 m^3/second. Under Scenarios 2, 3a, 3b and 4a this rate ranges from 0.250 m^3/second to 0.260 m^3/second (Appendix B).

Therefore, proposed development will result in a 50% increase in the rate of effluent discharge and could potentially reduce baseflow in the Credit River. However, baseflow could be increased above existing levels through the application of LID measures, particularly to existing developed areas through retrofitting. Given the limited baseflow in the Credit River under existing conditions, the application of LID measures may be important to maintaining/enhancing baseflow in the Credit River to support future discharge from the Sewage Treatment Plant.

Table 5: Evaluation results for the Headwaters Subwatershed overall (all five catchment zones).

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.67	0.33	7.00	3.33	7.00
5	2	10.00	0.00	10.00	4.50	10.00
6	1	2.00	0.00	10.00	2.00	10.00
7	1	2.00	0.00	5.00	4.00	5.00
8	3	5.00	4.00	9.00	4.33	8.67
9	9	3.11	1.67	6.22	4.44	6.00
15	8	9.00	9.00	9.00	9.00	9.00
16	1	5.00	1.00	10.00	5.00	10.00
TOTAL SCORE (Maximum 80)		**42.78**	**16.00**	**65.22**	**36.60**	**65.67**

Table 6: Evaluation results for the Monora Creek Tributaries catchment zone.

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.66	0.00	8.33	0.50	7.33
5	2	2.00	0.00	10.00	6.00	5.00
6	1	NA	NA	NA	NA	NA
7	1	NA	NA	NA	NA	NA
8	4	6.25	2.50	7.75	7.25	6.50
9	9	4.44	2.22	7.56	6.11	6.33
15	8	8.00	7.00	7.00	7.00	7.00
16	1	5.00	0.00	8.00	8.00	10.00
TOTAL SCORE (Maximum 60)		**32.35**	**11.72**	**48.64**	**34.86**	**42.16**

Table 7: Evaluation results for the Mill Creek catchment zone.

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.67	0.00	9.00	4.67	8.67
5	2	2.00	0.00	5.00	2.50	5.00
6	1	NA	NA	NA	NA	NA
7	1	NA	NA	NA	NA	NA
8	4	6.25	0.00	8.00	5.75	8.00
9	9	2.89	1.33	7.89	5.89	7.78
15	8	3.00	3.00	3.00	3.00	3.00
16	1	5.00	3.00	8.00	8.00	10.00
TOTAL SCORE (Maximum 60)		**25.81**	**7.33**	**40.89**	**29.81**	**42.45**

Table 8: Evaluation results for the Eastern Tributaries catchment zone.

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.67	0.00	4.00	3.67	4.33
5	2	10.00	0.00	5.00	5.00	5.00
6	1	NA	NA	NA	NA	NA
7	1	NA	NA	NA	NA	NA
8	3	5.00	2.67	7.00	5.67	6.56
9	9	6.22	5.33	6.33	6.33	6.22
15	8	9.00	9.00	9.00	9.00	10.00
16	1	5.00	0.00	10.00	10.00	10.00
TOTAL SCORE (Maximum 60)		**41.89**	**17.00**	**41.33**	**39.67**	**42.11**

Table 9: Evaluation results for the Caledon Tributaries catchment zone.

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.67	5.00	6.33	5.33	7.00
5	2	10.00	4.50	6.50	6.50	5.00
6	1	NA	NA	NA	NA	NA
7	1	NA	NA	NA	NA	NA
8	4	6.25	3.50	4.75	3.50	5.00
9	9	6.00	3.33	6.00	6.11	6.33
15	8	8.00	8.00	9.00	9.00	10.00
16	1	5.00	4.00	10.00	8.00	8.00
TOTAL SCORE (Maximum 60)		**41.92**	**28.33**	**42.58**	**38.44**	**41.33**

Table 10: Evaluation results for the Credit River catchment zone.

Objective	Number of Indicators	Total Score of Indicators				
		Scenario 1	Scenario 2	Scenario 3a	Scenario 3b	Scenario 4a
4	3	6.67	0.33	7.00	3.33	7.00
5	2	10.00	0.00	10.00	4.50	10.00
6	1	NA	NA	NA	NA	NA
7	1	NA	NA	NA	NA	NA
8	3	5.00	4.00	9.00	4.33	8.67
9	9	3.11	1.67	6.22	4.44	6.00
15	8	9.00	9.00	9.00	9.00	9.00
16	1	5.00	1.00	10.00	5.00	10.00
TOTAL SCORE (Maximum 60)		**38.78**	**16.00**	**51.22**	**30.60**	**50.67**

Table 11: Pair-wise comparisons to assess the implications of the alternative scenarios.

Comparison	Assessment
Option 1 versus Option 2	Implications of land use alternatives
Option 2 versus Option 3a	Implications of enhanced stormwater management: Low Impact Development in new development and retrofitting of existing development
Option 3a versus Option 3b	Implications of retrofitting
Option 3a versus Option 4a	Implications of enhanced Natural Heritage System

Key findings are described in further detail in Appendix C.

5 Section 5 – Conclusions and Recommendations

5.1 Conclusions

This Report provides a "big picture" comparison to illustrate the relative merits of the different approaches to land use, storm water management and the establishment of a Natural Heritage System. Based on the evaluation results presented in Section 4, the following general conclusions can be made:

1. The application of the current (Business as Usual) approach to stormwater management to the new development proposed under the Places to Grow land use alternative will result in further environmental degradation of the Headwaters Subwatershed, including the following:

    - increase in flood risk
    - increase in potential for erosion
    - reduction in groundwater recharge
    - degradation of water quality
    - adverse impacts on fisheries

2. The application of LID measures to new development alone will generally mitigate the associated adverse effects on the hydrologic cycle and help to maintain the ecological integrity of the Headwaters Subwatershed.

3. The application of LID measures to new development and to existing developed areas through retrofitting provides the greatest environmental benefits and improves on existing conditions by reducing flow peakiness, erosion potential, the risk of flooding and the contamination of surface runoff, especially for particulate-bound contaminants.

4. Different land uses vary in their degree of imperviousness and the extent of hydrological impacts is proportional to the degree of imperviousness. Since the patterns of existing and proposed land use vary between catchment zones, the benefits of LID also vary between catchment zones. Generally, the greater the proposed development, the greater the benefits of implementing LID measures as part of the design process. Similarly, the greater the extent of existing development, the greater the benefits of implementing LID measures through retrofitting. The implementation of LID measures through retrofitting would particularly benefit the Monora Creek Tributaries, Mill Creek and Credit River catchment zones.

5. All drinking water consumed in the Headwaters Subwatershed is obtained from groundwater sources within the subwatershed. The application of LID measures will help to maintain baseflow in watercourses in the vicinity of water wells. However, because existing development in these areas is located downgradient of the water wells, their retrofit with LID measures may not benefit water supply.

6. The Upper Credit River currently provides limited assimilative capacity to accommodate discharge from the Town of Orangeville Sewage Treatment Plant. Since proposed development will increase the rate of discharge, the application of LID measures may be important to maintaining/enhancing baseflow in the Credit River to support future discharge rates.

7. Relative to existing policies and practices, the enhanced approach to the establishment of a NHS best meets Subwatershed targets to create an integrated network of natural heritage features. This approach has limited ability to mitigate the effects of urbanization on the hydrologic cycle and water quality, but would provide a number of other environmental and social benefits not addressed by this study. These benefits include carbon sequestration, opportunities for outdoor recreation (e.g. fishing, bird watching and hiking) and the use of renewable natural resources (e.g. sustainable harvest of wood products).

8. Given these conclusions, Scenario 3a is preferred. This scenario incorporates the following approaches:

    - future development in conformance with the Provincial Growth Plan for the Greater Golden Horseshoe (Places to Grow);

    - the application of the LID approach to stormwater management to new development and to existing developed areas through retrofitting; and

    - the establishment of an enhanced NHS that includes elements defined under existing policies and practices as well as additional lands based on stewardship.

5.2 Implementation

Practical implementation of the preferred approaches to land use, storm water management and the establishment of a NHS will require consideration of the following:

- review of municipal/agency policies
- identification of roles and responsibilities of stakeholders
- assessment of potential funding sources
- prioritization of projects
- determination of public involvement
- detailed follow-up studies to address site-specific conditions

5.3 Recommendation

Phase III of the Headwaters Subwatershed Study is the next step towards the completion of the Headwaters Subwatershed Study.

As noted in Section 1.3.2, Phase III will focus on the implementation of the recommended management strategies. Phase IIII will describe what is required to achieve the goals and objectives established for the Headwaters Subwatershed; will identify roles and responsibilities of the various stakeholders for implementing the various recommendations and will identify long-term monitoring goals.

Phase III of the Headwaters Subwatershed Study is recommended to proceed to implement the management strategies recommended in this report.

Appendix A

Objectives, Indicators, Measurable Parameters and Targets

Appendix B

Analyses

Appendix C

Key Findings

Hydrology

Peakiness is the ratio of stream flow volumes under peak flow and base flow conditions. The Mill Creek catchment zone currently exhibits the highest rate of peakiness in the Headwaters Subwatershed. This undoubtedly reflects the zone's relatively high rates of urban and commercial/industrial land uses, which results in it having the highest rate of imperviousness in the Headwaters Subwatershed.

Relative to Scenario 1 (existing conditions) peakiness increases most under Scenario 2 and somewhat less under Scenario 3b. In contrast, peakiness decreases most under Scenario 4a and less under Scenario 3a. These results clearly illustrate that different approaches to stormwater management and the establishment of a Natural Heritage System vary in their ability to mitigate the impacts of urbanization on the hydrologic cycle (Table 1).

Stream Processes

Relative to Scenario 1 (existing conditions) erosion potential increases under Scenario 2. These increases in erosion potential generally exceed Targets. In contrast, erosion potential decreases under the other scenarios. These decreases are most pronounced under Scenario 4a, followed by Scenarios 3a and 3b. Again, these results illustrate that different approaches to stormwater management and the establishment of a Natural Heritage System vary in their ability to mitigate the impacts of urbanization on the hydrologic cycle (Table 1).

Flooding

Under existing conditions 18 structures within the Headwaters Subwatershed are at risk of flooding during the 5-year storm event. A further 21 structures are at risk of flooding during the 100-year storm event. Relative to Scenario 1 (existing conditions) the risk of flooding increases under Scenario 2 but decreases under the other scenarios. The risk of flooding decreases slightly under Scenario 3b. Scenarios 3a and 4a result in a similar but more pronounced decrease in flood risk than Scenario 3b.

These results indicate that different approaches to stormwater management vary in their ability to mitigate the impacts of urbanization on the risk of flooding. However, different approaches to the establishment of a NHS vary little in their ability to mitigate flood risk (Table 2).

Table 1: Hydrological response to Scenarios 2, 3a, 3b and 4a relative to existing conditions.

<table>
<tr><th>Scenario Number</th><th>Storm Water Management</th><th>Natural Heritage System</th><th>Effect on Existing Conditions</th></tr>
<tr><td>2</td><td>Business as Usual (BAU)</td><td>Existing Policies and Practices</td><td rowspan="4">Degrades
↓
Maintains
↓
Enhances</td></tr>
<tr><td>3b</td><td>LID in new development and no change in existing development</td><td>Existing Policies and Practices</td></tr>
<tr><td>3a</td><td>LID in new development and retrofitting of existing development</td><td>Existing Policies and Practices</td></tr>
<tr><td>4a</td><td>LID in new development and retrofitting of existing development</td><td>Enhanced</td></tr>
</table>

Table 2: Effect of Scenarios 2, 3a, 3b and 4a on flood risk relative to existing conditions.

<table>
<tr><th>Scenario Number</th><th>Storm Water Management</th><th>Natural Heritage System</th><th>Effect on Flood Risk</th></tr>
<tr><td>2</td><td>Business as Usual (BAU)</td><td>Existing Policies and Practices</td><td rowspan="4">Increase
↓
Slight Decrease
↓
Large Decrease</td></tr>
<tr><td>3b</td><td>LID in new development and no change in existing development</td><td>Existing Policies and Practices</td></tr>
<tr><td>3a</td><td>LID in new development and retrofitting of existing development</td><td>Existing Policies and Practices</td></tr>
<tr><td>4a</td><td>LID in new development and retrofitting of existing development</td><td>Enhanced</td></tr>
</table>

Groundwater

Under existing conditions, the highest rates of groundwater recharge occur in the Caledon Tributaries (283 mm/year) and Eastern Tributaries (273 mm/year) catchment zones. The Mill Creek catchment zone has the lowest rate of groundwater recharge (217 mm/year) in the Headwaters Subwatershed. These conditions reflect differences in imperviousness between the catchment zones.

Limited development is proposed in the Caledon Tributaries catchment zone so rates of groundwater recharge vary little with alternative scenarios. In all of the other zones, rates of groundwater recharge vary considerably with the alternative scenarios and reflect the distribution of proposed development (Figure 16). Specifically:

- Scenario 2 results in reduced (between 1.1% and 22.9%) rates of groundwater recharge in all of the other catchment zones relative to existing conditions. The reduction is greatest in the Mill Creek catchment zone.

- Scenarios 3a results in the greatest (between 5.2% and 51.5%) increases in the rates of groundwater recharge in all other zones relative to existing conditions. The increase is greatest in the Mill Creek catchment zone. Scenario 4a results in similar (but slightly lower) increases in the rates of groundwater recharge.

- Scenario 3b results in less pronounced (between 2.0% and 20.6%) increases in the rates of groundwater recharge in the Mill Creek, Caledon Tributaries and Eastern Tributaries catchment zones. Again, the increase is greatest in the Mill Creek catchment zone.

Under existing conditions, the highest rate of groundwater discharge occurs in the Credit River catchment zone (approximately 22,000 m^3/day). The lowest rates of groundwater discharge occur in the Caledon Tributaries (approximately 1,900 m^3/day) and the Eastern Tributaries (approximately 2,800 m^3/day) catchment zones.

Rates of groundwater discharge vary relatively little with alternative scenarios in the Caledon Tributaries and the Eastern Tributaries catchment zones. This reflects the limited development proposed for these zones (Figure 16). In the remaining zones, rates of groundwater discharge generally decrease under Scenarios 2 (between 0.8% and 28.5%), remain similar under Scenario 3b and increase under Scenario 3a (between 4.8% and 61.6%). Increases in the rates of groundwater discharge under Scenario 4a are similar (but slightly lower) than the increases in the rates of groundwater discharge associated with Scenario 3a. As with groundwater recharge, the Mill Creek catchment zone shows the greatest response to the alternative scenarios.

Average water table elevations generally vary little with the alternative scenarios. The greatest response is shown by the Mill Creek catchment zone; less response is shown by the Credit River catchment zone. In both zones, average water table elevations decrease under Scenarios 2 and generally increase under Scenarios 3a, 3b and 4a. Increases in average water table elevation under Scenario 4a are similar (but slightly lower) that the increases associated with Scenario 3a.

These results indicate that different approaches to stormwater management vary considerably in their ability to mitigate the impacts of urbanization on groundwater recharge/discharge. Somewhat counter-intuitively, these results also indicate that the enhanced approach to NHS establishment does not promote groundwater recharge/discharge (Table 3). This may reflect increased rates of evapotranspiration in naturally vegetated areas, with the attendant reduction in recharge.

Table 3: Effect of Scenarios 2, 3a, 3b and 4a on groundwater relative to existing conditions.

Scenario Number	Storm Water Management	Natural Heritage System	Effect on Groundwater Recharge/Discharge
2	Business as Usual (BAU)	Existing Policies and Practices	Reduces
3b	LID in new development and no change in existing development	Existing Policies and Practices	
4a	LID in new development and retrofitting of existing development	Enhanced	
3a	LID in new development and retrofitting of existing development	Existing Policies and Practices	Improves

Water Quality

Under existing conditions, the water quality of all five catchment zones shows some form of impairment. Generally, the water quality of the Eastern Tributaries and Caledon Tributaries catchment zones is least impaired. The water quality of the Mill Creek catchment zone is the most impaired, with elevated levels of metals, bacteria and suspended solids. This impairment reflects the zone's relatively high rates of urban and commercial/industrial land uses, which results in it having the highest rate of imperviousness in the Headwaters Subwatershed.

Water quality varies relatively little with alternative scenarios in the Caledon Tributaries and the Eastern Tributaries catchment zones. This reflects the limited development proposed for these zones (Figure 16). In the remaining zones, Scenario 2 generally results in a degradation of water quality relative to existing conditions. Scenario 3b generally results in an improvement in water quality. However, the greatest improvements in water quality generally occur under Scenarios 3a and 4a.

These results indicate that different approaches to stormwater management vary in their ability to mitigate the impacts of urbanization on water quality. However, different approaches to the establishment of a NHS vary little in their ability to impact water quality (Table 4).

Table 4: Effect of Scenarios 2, 3a, 3b and 4a on water quality relative to existing conditions.

Scenario Number	Storm Water Management	Natural Heritage System	Effect on Water Quality
2	Business as Usual (BAU)	Existing Policies and Practices	Degrades ↓
3b	LID in new development and no change in existing development	Existing Policies and Practices	Slight Improvement ↓
3a	LID in new development and retrofitting of existing development	Existing Policies and Practices	
4a	LID in new development and retrofitting of existing development	Enhanced	Greatest Improvement

Natural Heritage Features

The identification, protection and enhancement of an integrated network of natural heritage features (e.g. forests and wetlands) and the connecting links between them are fundamental to maintaining biodiversity in the Headwaters Subwatershed. The extent to which such natural heritage features are retained varies considerably with the alternative scenarios.

Relative to Scenario 1 (existing conditions) the extent of retained natural heritage features decreases under Scenario 2, but increases equally under Scenarios 3a and 3b. Scenario 4a results in the greatest extent of retained natural heritage features. These results indicate that the existing approach to the establishment of a NHS will retain natural heritage features, but that a greater extent of natural heritage features is retained under the enhanced approach to NHS establishment.