Submitted to:

Municipality of Clarington

Soper Creek Subwatershed Study

Draft Final Phase 2 and 3 Report

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1 Introduction

The Soper Creek subwatershed is located within the Regional Municipality of Durham, in the Municipality of Clarington (**Figure 1.1**). The Soper Creek subwatershed is one of the largest subwatersheds located within the Municipality of Clarington with an area of approximately 7729 ha. The subwatershed is vulnerable to the increasing effects of land use and the impacts of urban development.

This document constitutes **Phases 2 and 3 of the Soper Creek Subwatershed Study (SWS)**, which updates the hydrologic and hydraulic models; finalizes constraints mapping; identifies measures to protect, enhance or restore environmental features and functions; formulates alternative subwatershed management strategies; evaluates these strategies based on a range of environmental, social and cost considerations, together with stakeholder input; and selects a recommended subwatershed strategy from among the alternatives.

The Municipality of Clarington is a rapidly growing population center located on the shores of Lake Ontario on the eastern side of the Greater Toronto Area (GTA). With a 2021 population of 105,300, growth is expected to push the population to 124,685 by 2031 (Municipality of Clarington Official Plan, 2018). This represents a growth of 19,385 people, or an increase in the population of 18.4%. While this growth represents an opportunity, it also has the potential to cause significant impact to the local environment which has already been greatly influenced by agricultural cultivation and expanding urban development.

In 2011, the Municipality of Clarington retained Central Lake Ontario Conservation (CLOCA) to prepare an Existing Conditions Report and Watershed Plan for the Bowmanville and Soper Creek Watershed with the cooperation of Conservation Ontario and Durham Region. A Watershed Plan was subsequently published in 2013 by CLOCA. Since the preparation of these documents, Clarington Council has adopted a new land use policy framework through Amendment No. 107 to the Clarington Official Plan and the consolidation of the plan. As part of the Secondary Planning process for the detailed land uses within the watershed, a Subwatershed Study is required.

The Subwatershed Study will take an environment-first approach, fulfill the requirements of the Clarington Official Plan (OP), and also inform the preparation of the following Secondary Plans by guiding development in a manner that respects the local natural heritage system, natural hazards and supports long-term environmental sustainability:

- Soper Springs Secondary Plan; and
- Soper Hills Secondary Plan.

Additionally, the study area contains portions of the Clarington Technology Business Park Secondary Plan and the Bowmanville East Urban Centre Secondary Plan that is currently being updated, although these portions are not the focus of the study.

1.1 Study Area and Land Uses

1.1.1 Subwatershed Study Area

Soper Creek flows out of the Oak Ridges Moraine and then southeast into Lake Ontario. The Watershed is divided into four subwatersheds: Mackie, Soper North, Soper East, and Soper Main. This study focuses more intently on Soper East and Soper Main subwatersheds in order to provide characterization of areas of planned urbanization in the Soper Hills Secondary Plan Area and the Soper Springs Secondary Plan Area. Land use within the Bowmanville Urban Boundary of the Soper Creek subwatershed is mainly residential, active agriculture, and expanding urban development. The study area is outlined in red on **Figure 1.1**.

1.1.2 Land Uses

Historically, land use throughout this subwatershed was predominately agricultural and residential, with portions of natural and naturalized cover. The Oak Ridges Moraine (ORM) and Greenbelt cover the northern portions of the subwatershed, restricting urban development through these areas. Two major highways (401 and 407) cross the subwatershed; the Highway 407 corridor was completed in 2019. Presently, agriculture is the primary land use designation, followed by natural areas and residential (CLOCA, 2013).

1.1.3 Provincially Designated Areas

Four provincially designated areas are present within or directly adjacent to the study area, as shown in **Figure 1.1**. They include:

- **Bowmanville Coastal Wetland Complex/Bowmanville Coastal Marsh and Fen Candidate Life Science** – Provincially Significant Wetland (PSW) located where Soper Creek meets Bowmanville Creek. The majority of the wetland is found outside of the Soper Creek subwatershed boundary, southward from the Bowmanville Creek confluence point to Lake Ontario.
- **Stephan's Gulch Earth Science ANSI** – This feature is located approximately 2 km north of the Urban Boundary.
- **Soper Valley Life Science ANSI** – This feature is located approximately 1.5 km north of the Urban Boundary.
- **Greenbelt** – Lands included in the provincial Greenbelt are located within the Soper Creek subwatershed boundary and along the very north edge of the Bowmanville Urban Boundary

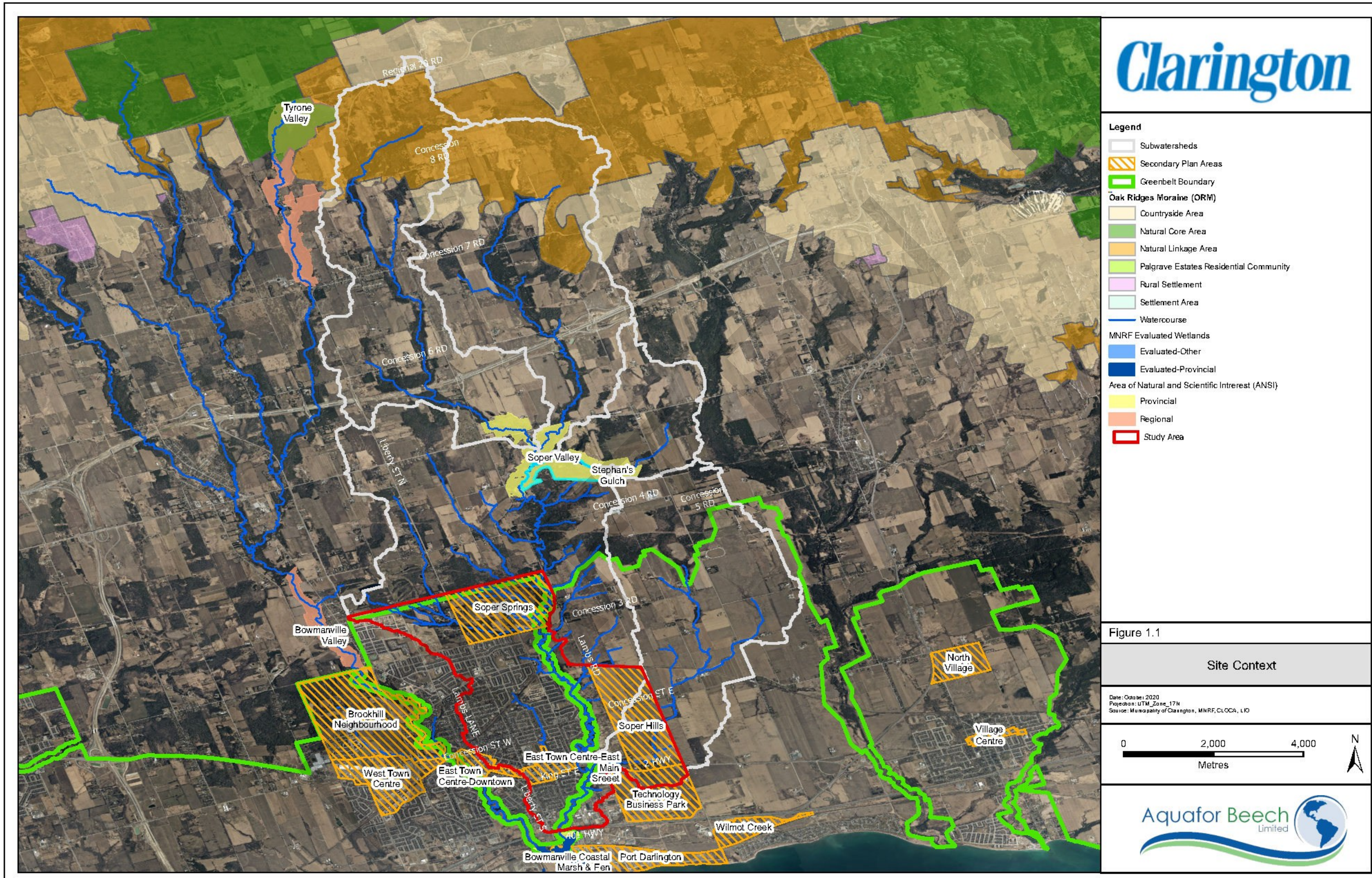

Figure 1.1: Study Area: Soper Creek Subwatershed

1.2 Subwatershed Study Goals, Objectives, and Phasing

The overall goal of this Subwatershed Study may be defined as follows:

> "**Development of a management plan that allows sustainable urban growth, while ensuring maximum benefits to the natural and human environments on a watershed basis.**" – Watershed Planning in Ontario

The Subwatershed Study is undertaken in three phases. The objectives of this study are summarized below, according to the three study phases. **This report has been prepared to present the results for Phases 2 and 3 of the process.**

Phase 1: Subwatershed Characterization

- Identify and evaluate the location, extent, significance, and sensitivity of the existing natural features of the study area, together with their potential interrelationship with other natural features;
- Identify sensitive areas and natural hazard lands, together with recommended buffers, and select preliminary management practices for these lands; and
- Develop preliminary constraints and opportunities mapping to identify developable and non-developable lands which will inform the development and update of Secondary Plans within the Study Area.

Phase 2: Subwatershed Management Strategies

- Identify potential land use impacts to natural features and functions (Impact Assessment);
- Identify protective measures (best management practices, or BMPs) that, when implemented, will protect, enhance or restore environmental features and functions;
- Formulate alternative subwatershed management strategies;
- Evaluate each strategy, based on a range of environmental, social and cost considerations, together with stakeholder input; and
- Select from among the alternatives a recommended subwatershed strategy (or plan).

Phase 3: Implementation and Monitoring Plans

- Develop an Implementation Plan to ensure the long-term integrity of the Recommended Plan, including the identification of issues and areas where further detailed studies may be required at the draft plan of subdivision stage of the planning process;
- Identify any future recommended monitoring studies or contingency plans; and
- Integrate the Subwatershed Study findings with Municipal Official Plan Policy and ongoing Secondary Plans.

1.3 Class Environmental Assessment (EA) Process

This Subwatershed Study is being conducted in the spirit of a Municipal Class Environmental Assessment (Class EA). One public meeting was held at the end of the Phase 1 Subwatershed Study, in December 2022, one update meeting was held in December 2023, and the final will be held at the end of Phase 3.

The relationship between the components of the Subwatershed Study process and the Class EA process is depicted in **Figure 1.2**.

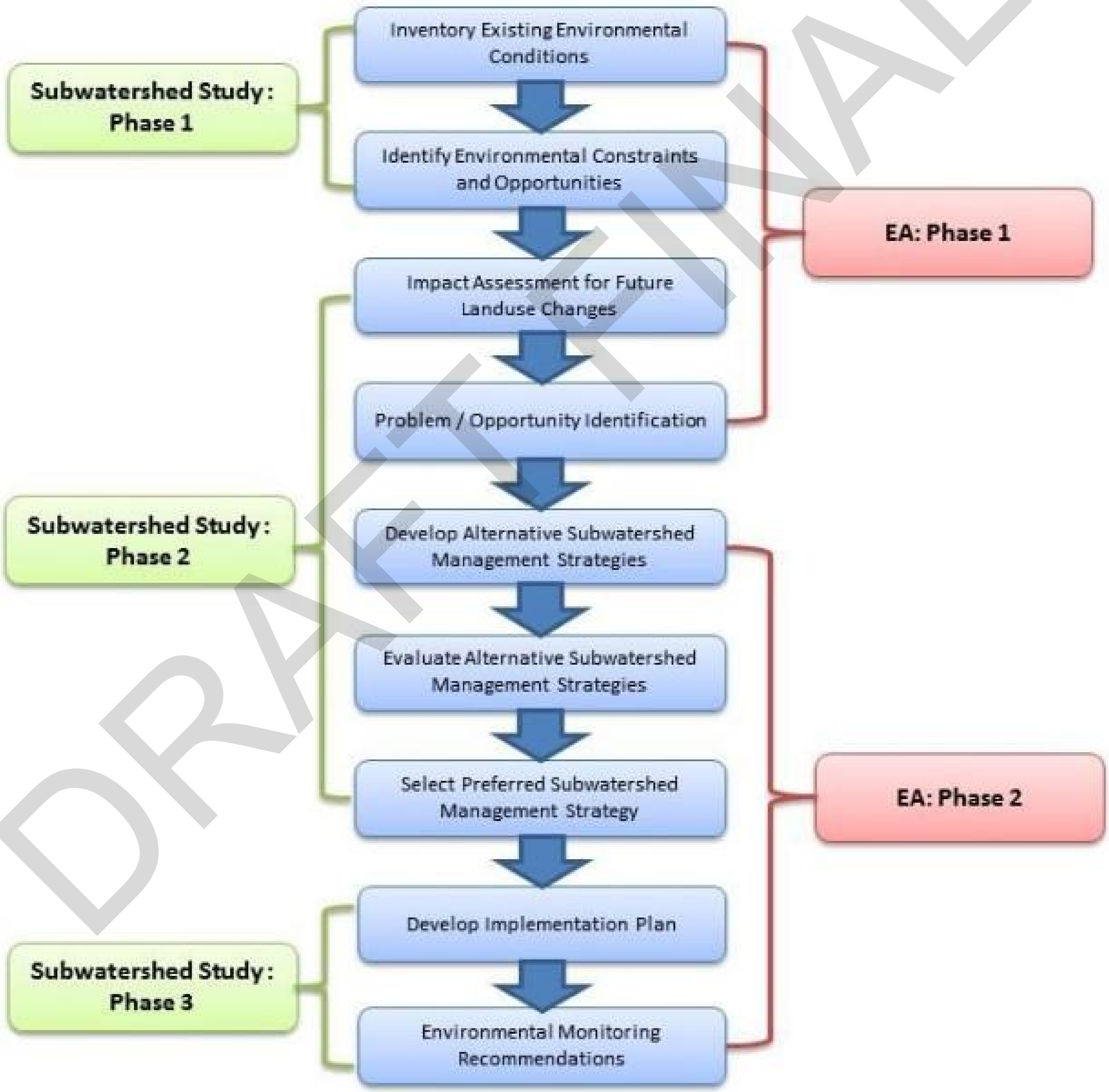

Figure 1.2: Subwatershed Study & Environmental Assessment Study Process

1.4 Secondary Planning within the Soper Subwatersheds

Secondary Plans are land use planning tools that formally address specific opportunities and constraints related to land use in certain defined geographic areas. They are typically undertaken in areas where detailed direction is needed for matters beyond the general framework provided by the Official Plan. Secondary Plans play an important role in the Municipality of Clarington's Official Plan. The preparation or amendment of a Secondary Plan follows the same procedures as an Official Plan Amendment under the Planning Act. This includes the preparation of supporting technical studies, public engagement, notice and holding of public meetings and adoption procedures.

The Clarington Official Plan (Consolidated June 2018), requires that new residential areas greater than 20 ha are to be planned by means of Secondary Plans. This neighbourhood scale planning allows for a more detailed analysis of land use and transportation issues and specific ways to achieve the objectives of the Clarington Official Plan, including meeting density and infill targets.

The preparation of any Secondary Plan requires input from supporting technical studies. The collective recommendations (opportunities and constraints) from these technical studies will influence the developable area of the Secondary Plan, influence the mix and location for the various land uses, as well as recommend design and development parameters. Subwatershed studies are important supporting technical documents to the Secondary Planning process because they establish the base environmental parameters for neighbourhood planning, including not only the natural heritage and hydrological systems but also establish high-level drainage planning for the Secondary Plan Areas. Subwatershed studies include strategies to support the Municipality's Official Plan and identify the responsible management strategies for subwatershed areas with the primary focus of protecting natural ecosystem functions, flooding and erosion. Subwatershed studies analyse the cumulative effects of changes in land use, identify areas of risk, and make recommendations on areas for enhancement to allow for a protected and connected Natural Heritage System.

Three Secondary Plans fully or partially within the Soper Creek Subwatershed boundary have already been completed: the East Town Center – East Main Street, East Town Center – Downtown, and Technology Business Park Secondary Plans. This Soper Creek SWS will inform the preparation of two additional Secondary Plans, depicted on **Figure 1.3** and described as follows:

1) The **Soper Springs Secondary Plan** area is located entirely within the Soper Creek subwatershed, and is bounded by Liberty St. N. to the west, Lambs Rd. to the east, Concession Rd. 3 to the south, and the Bowmanville Urban Boundary to the north. The Secondary Plan area as a whole includes Environmental Protection lands associated with forested tributaries to Soper Creek. The total land area is approximately 186 ha.

2) The **Soper Hills Secondary Plan** area is located entirely within the Soper Creek subwatershed, on the east side of the Bowmanville Urban Area. It is bounded by Lambs Rd. to the west, the Bowmanville Urban Boundary to the east, Durham Highway 2 to the south, and a CP Rail line to the north. The total area of the Secondary Plan lands is approximately 193 ha.

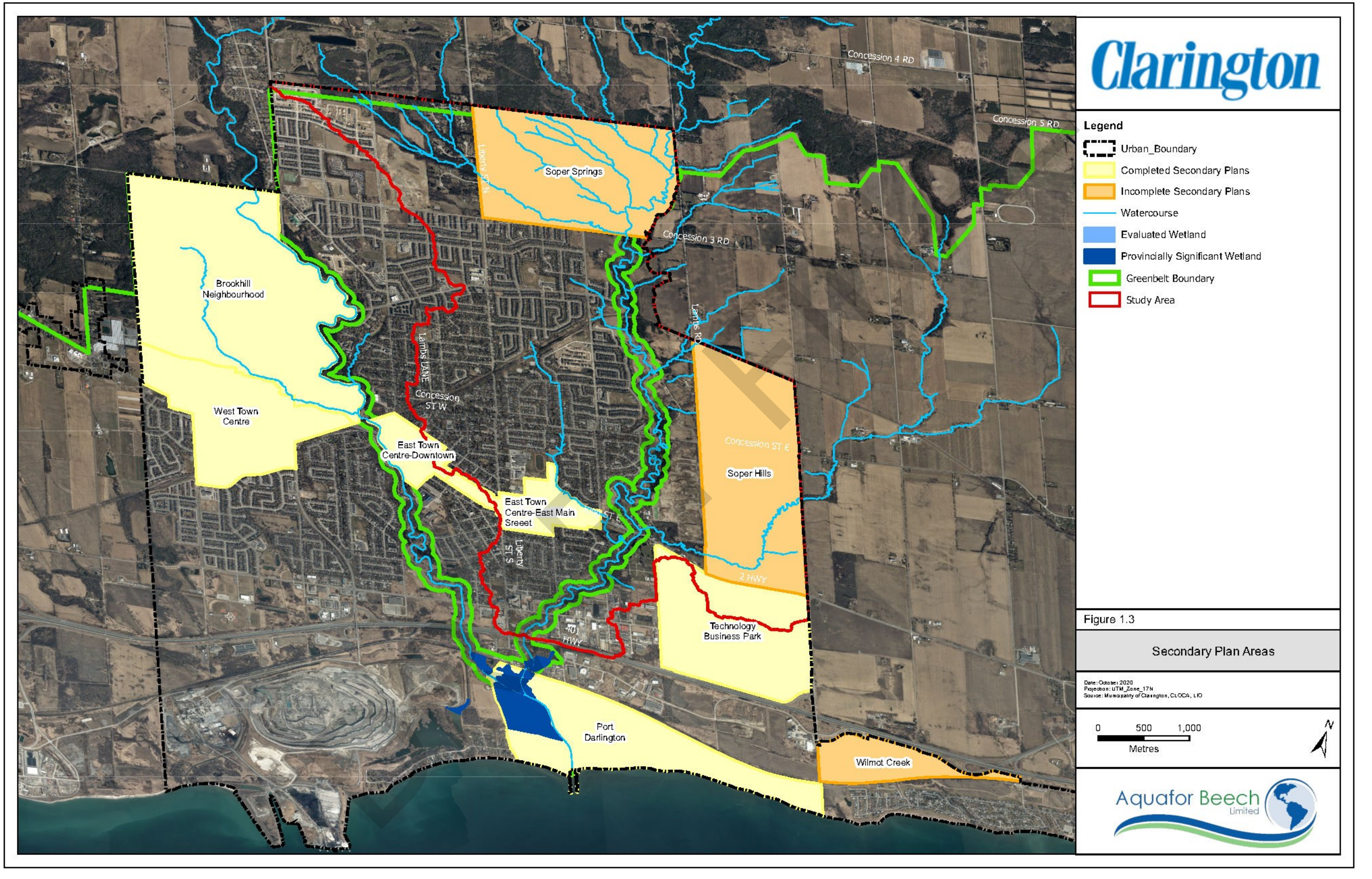

Figure 1.3: Secondary Plan Areas

2 Subwatershed Planning – Master Plan

The process of Subwatershed Planning has evolved over the last 20-30 years (**Figure 2.1**). The typical Subwatershed Plan of the 1980s, which was commonly termed "Master Drainage Plan", was primarily concerned with two issues: flooding and erosion. In the latter part of the 1980s, the plan evolved and typically dealt with the above issues as well as water quality and occasionally aquatic resources.

Subwatershed Plans have continued to evolve and now deal with numerous inter-related environmental issues, including:

- surface water flooding, erosion, and water quality;
- groundwater quantity and quality;
- water budget (groundwater recharge, baseflows and peak flows);
- terrestrial and aquatic habitat;
- wetlands and woodlands, including woodlots and forests;
- Species at Risk;
- environmentally sensitive areas; and
- recreation and aesthetics.

Furthermore, the plans are ecosystem-based, with the potential interaction between each of the environmental features being strongly considered.

Integration of the Land Use Planning Process with Water Resource Management Planning has also evolved over the last 20-30 years. Whereas the historic practice in the mid-eighties involved the development of Official, Secondary and Draft Plans with nominal consideration of environmental consequences; present practice considers the two planning processes in unison.

As a result of ongoing updated policies, this Subwatershed-wide Master Plan becomes an integral part of the overall planning process to provide a solid foundation related to the environmental features that will be protected, enhanced, or restored under present conditions, and as land use changes occur.

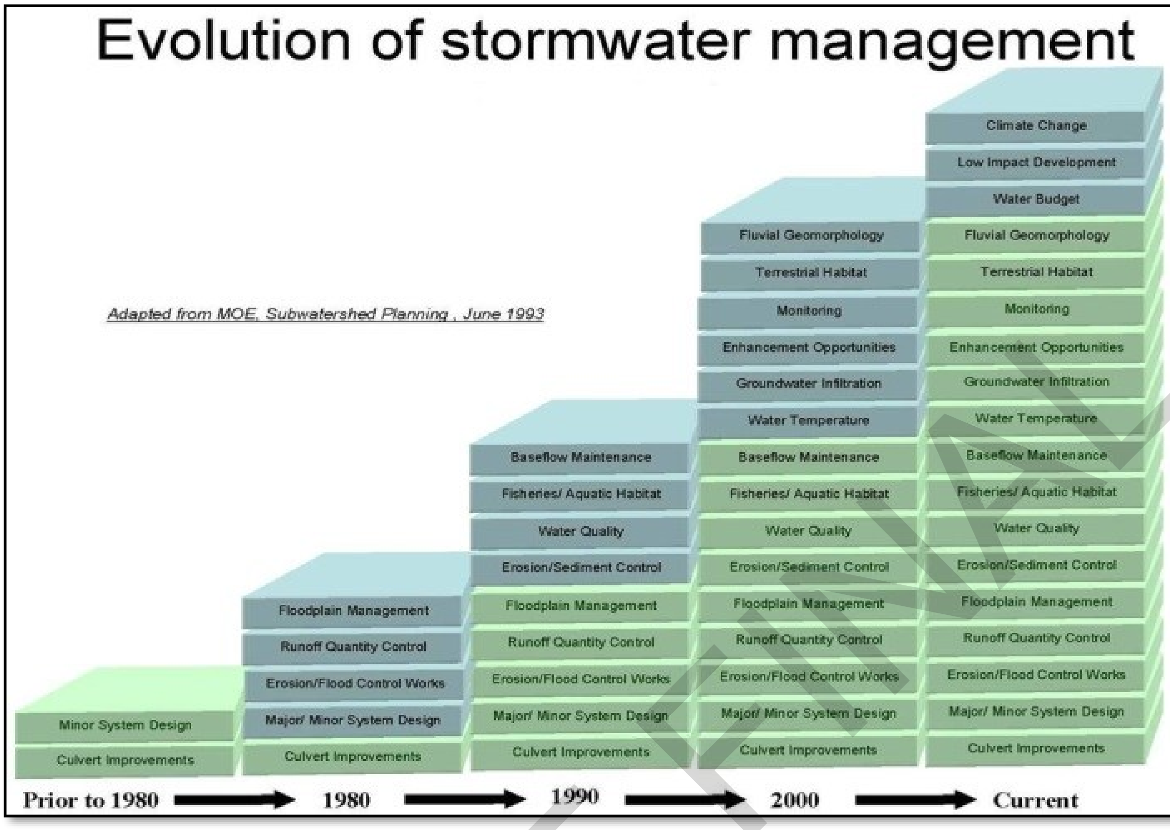

Figure 2.1: The Evolution of Stormwater Management in Ontario (adapted from MECP, 1993)

2.1 Provincial Stormwater Guidance Manuals

The "state-of-the-art" in stormwater management has been evolving rapidly. The MECP's 2003 Stormwater Management Planning and Design Manual (SWMPDM) provides an integrated approach to stormwater management that has been utilized across the province since its publication. The SWMPDM incorporates water quantity and erosion considerations. The SWMPDM provides technical and procedural guidance for the planning, design, and review of stormwater management practices. The focus of the manual was broadened to incorporate the current multi-objective approach to stormwater facility planning to address targets related to hazards, water quality, fish habitat and recreation. Fundamental stormwater management objectives which are included in the 2003 SWMPDM include:

- Groundwater and baseflow characteristics are preserved;
- Water quality will be protected;
- Watercourses will not undergo undesirable and costly geomorphic change;
- There will not be any increase in flood damage potential; and ultimately,
- That an appropriate diversity of aquatic life and opportunities for human uses will be maintained.

A central theme of the SWMPDM is the application of a "treatment train", a term that is used to describe the combination of controls – source, conveyance and end-of-pipe controls - usually required in an overall stormwater management strategy to ensure that objectives are achieved. The SWMPDM states that:

> "the recommended strategy for stormwater management is to provide an integrated **treatment train approach** to water management that is premised on providing control at the lot level and in conveyance (to the extent feasible) followed by end-of-pipe controls. This combination of controls is the only means of **meeting the multiple criteria for water balance, water quality, erosion control and water quantity**."

The 2003 SWMPDM remains the go-to reference material for end-of-pipe stormwater management criteria and design requirements for wet ponds, constructed wetlands, hybrid wet pond/wetland systems, dry ponds and centralized infiltration facilities.

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. It is now understood that to effectively mitigate the impacts from urbanization, stormwater strategies must include a means to **reduce runoff volume** with the objective of maintaining the pre-development water balance. To meet the multiple objectives of stormwater management on a broad-scale, it is expected that a combination of source, conveyance and end of pipe controls will be required within Ontario's stormwater systems, an approach that has been supported by CLOCA and the Municipality. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a LID Stormwater Management Guidance Manual. The draft manual outlines a Runoff Volume Control Target (RVC_T) to be used for new development; similar targets have since been implemented in the Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA).

3 Subwatershed Planning and the Secondary Plan Process

The Soper Creek Subwatershed Study was undertaken through an integrated approach with **the Soper Springs Secondary Plan** and the **Soper Hills Secondary Plan**. The Phase 1 subwatershed characterization report provided a detailed summary of existing conditions associated with subwatershed health, and defined constraints to development associated with natural heritage features and natural hazards. The subwatershed characterization report also provided direction for policy development related to natural heritage features, natural hazards, headwater drainage features, and provided recommendations for water balance requirements.

The secondary plan teams used the constraints mapping identified through Phase 1 characterization to define a land use plan that would simultaneously meet the community development goals as outlined in the Municipality of Clarington's Official Plan and the Durham Region Official Plan, while respecting constraints associated with natural heritage features, natural hazards, headwater drainage features, and associated setbacks. Within these land use plans, the following details essential to the development of this Soper Creek Subwatershed Study Phase 2 and 3 Report were identified:

- Land use types and intensities
- Parks and green spaces
- Road networks
- Stormwater management facilities

The land use plans are used in this study to define the hydrologic and hydraulic impact of development on Soper Creek and finally to determine the approach to stormwater management that will be used to mitigate the impact of development on the local water balance, water quality, erosion and flooding.

3.1 Secondary Plans

There are two secondary plans being considered as part of the Soper Creek Subwatershed Study. These secondary plans are the Soper Springs Secondary Plan, and the Soper Hills Secondary Plan, as discussed in **Section 1.4**. The Secondary Plans for Soper Hills and Soper Springs have advanced to preferred alternative land use planning (**Figure 3.1** and **Figure 3.2**). Should land use be revised within the secondary planning process, the associated impacts must be investigated through updates to hydrologic modelling, hydraulic modelling and a refined stormwater strategy.

Figure 3.1 identifies the land use plan for the Soper Hills Secondary Plan Area. **Figure 3.2** identifies the land use plan for the Soper Springs Secondary Plan Area.

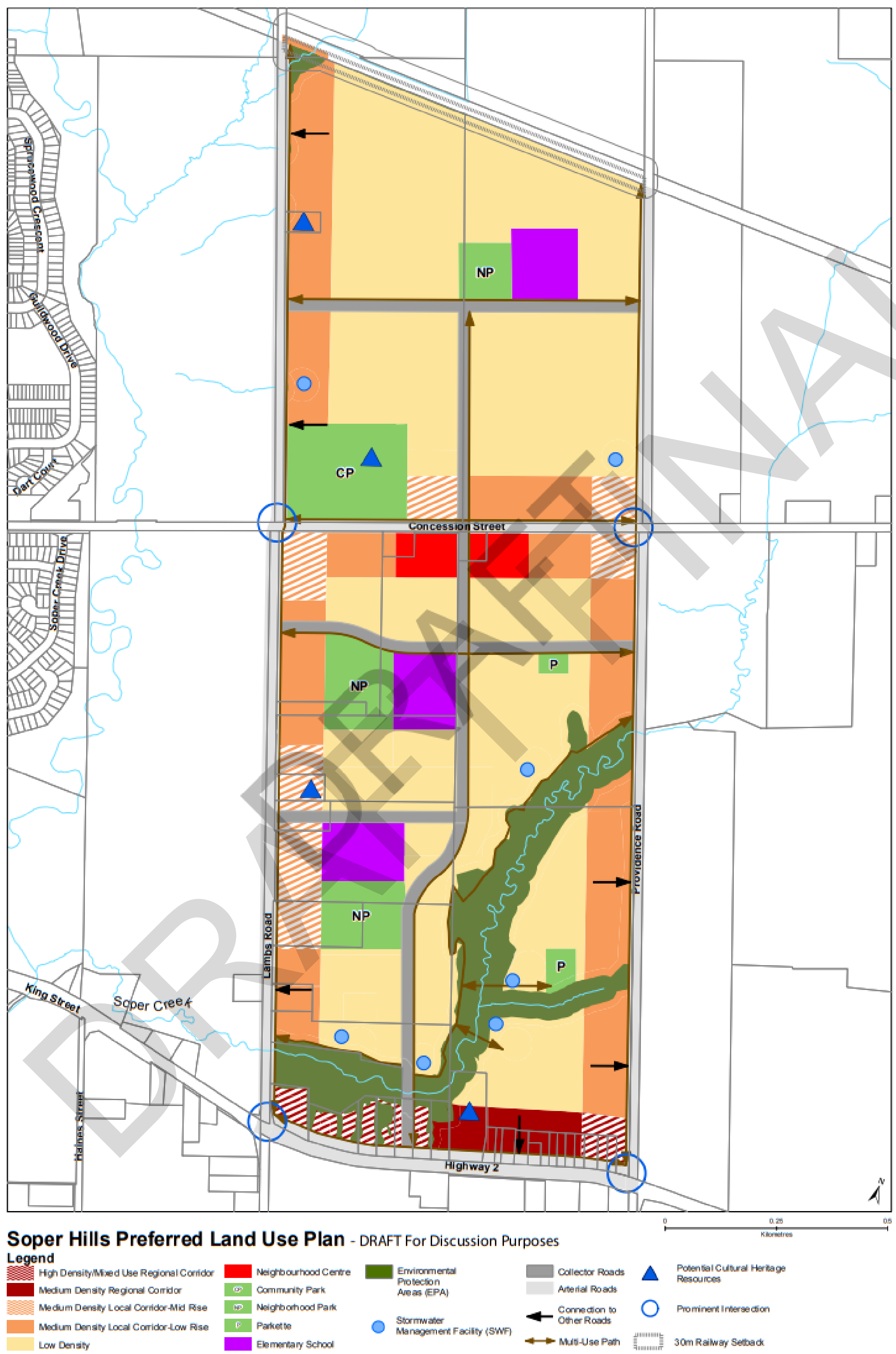

Figure 3.1: Soper Hills Secondary Plan – Preferred Land Use Plan

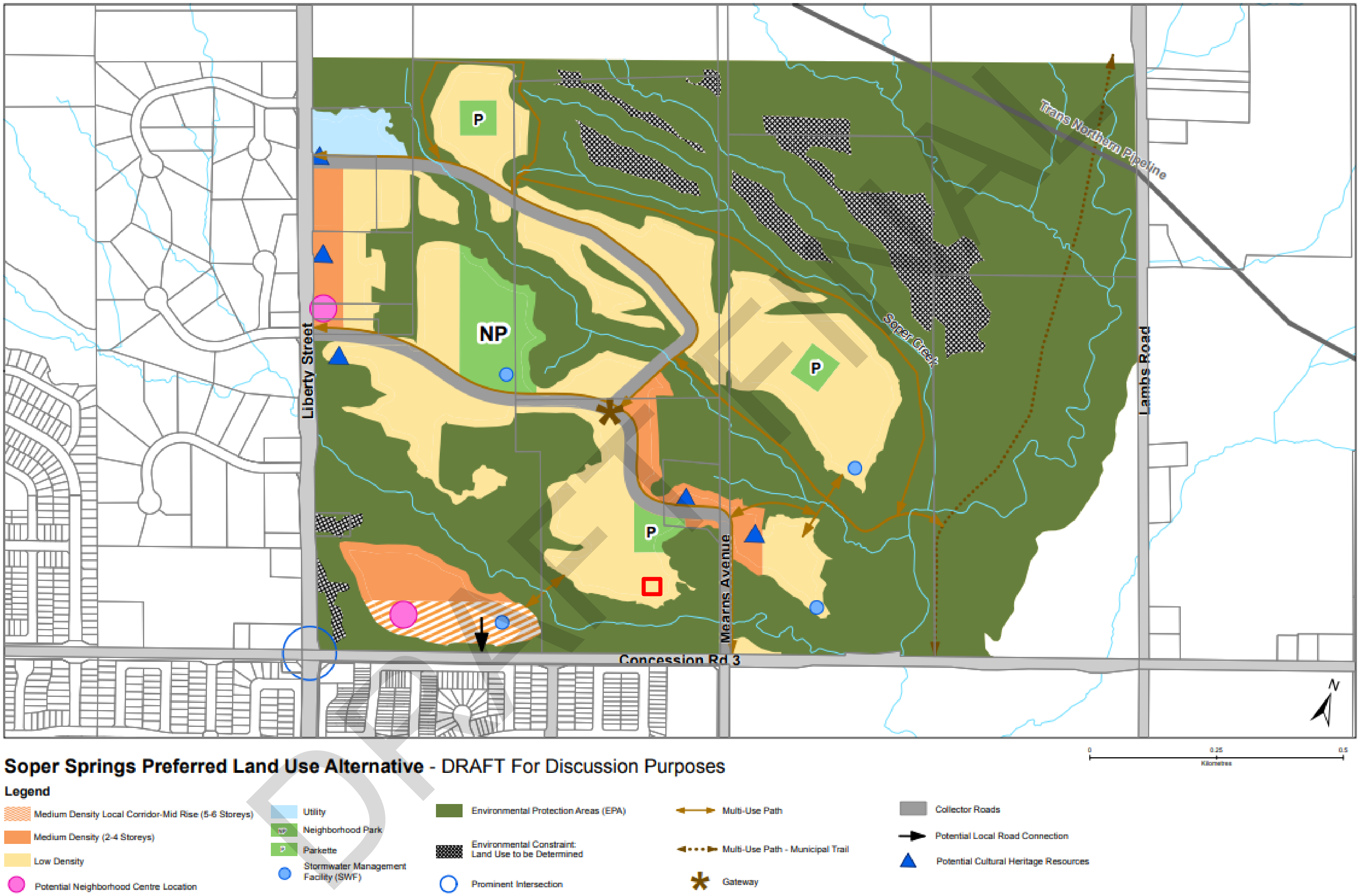

Figure 3.2: Soper Springs Secondary Plan – Preferred Land Use Plan

Within the Soper Springs Secondary Plan area we note that there are two proposed SWM Facilities located within the central portion of the secondary plan. The first SWM facility is located within in the Neighborhood Park in the central portion of the secondary plan may while the other is located at the south east portion of the secondary plan. Based on a review of existing topographical features, we note that directing drainage to the SWM facility is located within in the Neighborhood Park may prove challenging as the natural fall in the secondary plan is from a north west to south east direction. Based on a review of proposed grading plans in the Soper Springs Secondary plan and detailed discussions with both Clarington and CLOCA, the Neighborhood Park SWM facility has been relocated to the red box location as illustrated in **Figure 3.2**. This new location utilizes the existing topography within the secondary plan area to permit direct drainage to the SWM facility while minimizing onsite grading. Accordingly, we have maintained this new SWM pond location within the hydrologic modelling of the Soper Springs area.

4 Future Subwatershed Conditions

Soper Creek Subwatershed was characterized by CLOCA for existing and future conditions in "Hydrologic Modeling for Bowmanville & Soper Creeks" (CLOCA, 2010). For the Soper Creek Subwatershed, existing conditions were based on the 2011 and 2013 CLOCA studies and the future conditions model was forecast based on the proposed land uses identified through the Soper Hills and Soper Springs Secondary Plans.

4.1 Existing and Future Conditions

4.1.1 Existing Conditions

Existing land use for Soper Creek Subwatershed was determined based on CLOCA's existing model. **Figure 4.1** presents the existing land use within Soper Creek Subwatershed, obtained from CLOCA (2011). The study area is shown to be largely agricultural and/or natural areas.

4.1.2 Future Conditions

The proposed land use map has been developed through the Secondary Plan processes. Land use plans are available for the Soper Springs and Soper Hills Secondary Plans. **Figure 4.2** presents the future land uses as proposed within the Secondary Plans. Any subsequent changes in the Secondary Plan land uses were not included in this study. **Section 8.4** identifies how any discrepancies between this land use plan and the approved land use plan are to be addressed.

Soper Springs lands are proposed to be developed mainly as urban residential, while Soper Hills lands are proposed to be developed as mix of residential neighbourhoods with amenities such as shopping, services, and schools.

Locations of future stormwater management facilities were identified in the Soper Hills and Soper Springs Secondary Plans, and include seven (7) facilities in Soper Hills and four (4) facilities in Soper Springs. These facility locations were carried forward through the Subwatershed Study. Both Secondary Plans have policy that allows for changes to pond locations, if required in the future.

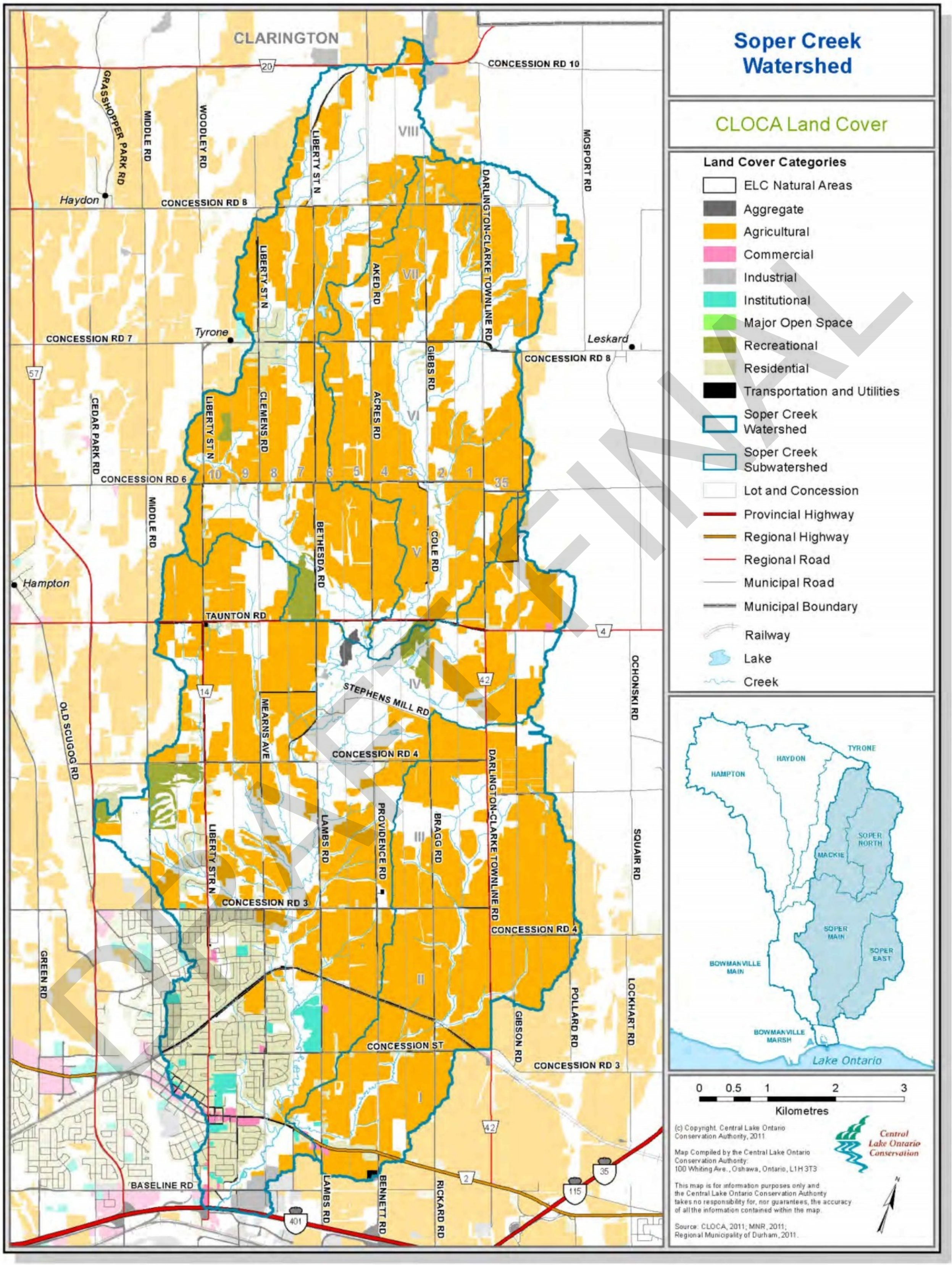

Figure 4.1: Soper Creek Existing Land Use (CLOCA, 2011)

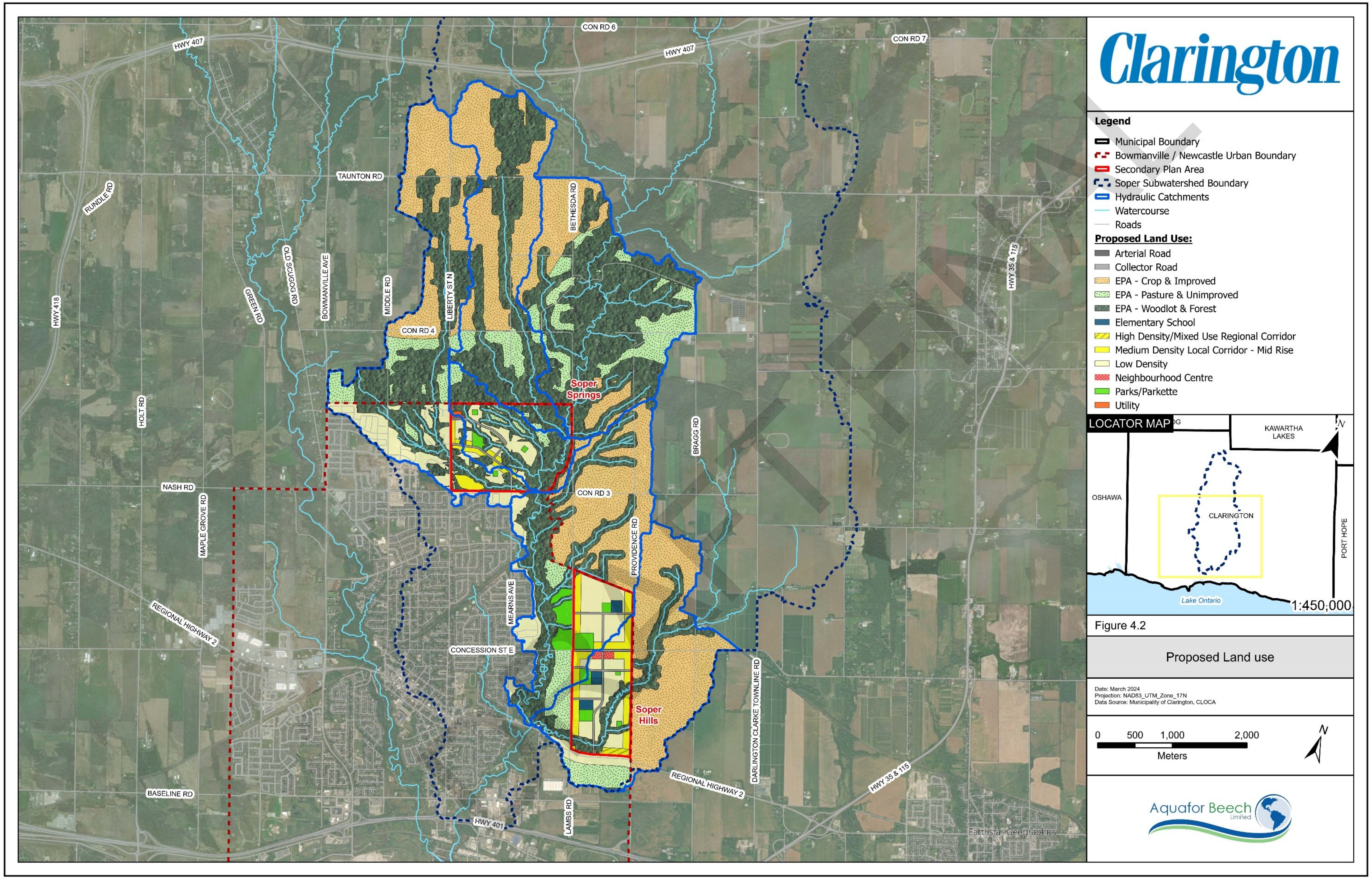

Figure 4.2: Proposed Land Use by Secondary Plans

4.2 Potential Impacts Associated with Land Use Changes

Existing and proposed land uses within Soper Creek Subwatershed were reviewed in **Section 4.1**. As noted, Soper Springs will be developed with residential land use as well as Soper Hills with associated neighbourhood amenities, such as shopping, services, and schools.

This section provides a brief overview of the general stormwater impacts which are directly associated with changes to the hydrologic regime due to urban development. This includes impacts to:

- the overall hydrologic cycle or water balance;
- water quality;
- stream erosion; and
- flooding.

Note that, in addition to the direct impacts noted above, stormwater impacts from urban development can also have a significant effect on many other natural resources including aquatic and terrestrial communities and their habitat.

4.2.1.1 Potential Impact to Groundwater and Water Balance

High Volume Recharge Areas (HVRA) located within the Soper Creek Subwatershed tend to correspond to the location of surficial sand and gravel deposits. In addition, Significant Groundwater Recharge Areas (SGRAs) exist in the upper reaches of Soper Creek. Post-development, maintaining the existing groundwater recharge volumes and minimizing changes to the overall site (and feature-based) water budgets are required.

Without controls, the impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface water runoff instead (**Figure 4.3**). This alteration to the water budget, in turn, can contribute to increased rates of flooding, erosion, and pollutant loadings, having a negative impact to the surrounding natural heritage features. The corresponding reduction in groundwater levels can also result in reduced supplies of clean, cool baseflows to area streams, thereby negatively impacting downstream aquatic communities. As such, mitigating the impacts to the overall site and feature-based water balances is a requirement of development approval.

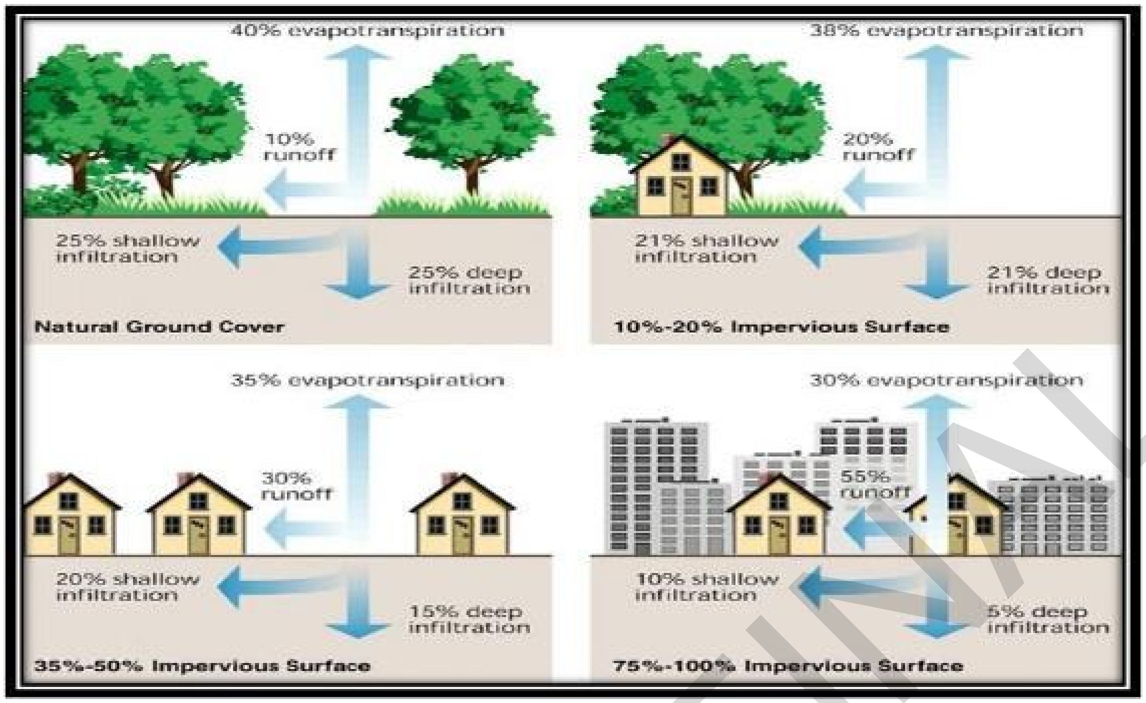

Figure 4.3: **Example of General Water Budget Impacts Due to Development**

4.2.1.2 Potential Impact to Water Quality

The protection of surface water quality within the study area is a key objective. Water quality has a strong influence on the health of fish and other aquatic communities, and also determines the suitability of water for drinking, recreation, fishing, wildlife and general aesthetics.

Stormwater runoff from urban sources typically contains elevated levels of contaminants such as sediment (i.e., suspended solids), nutrients (e.g., phosphorous, etc.), metals (e.g., copper, lead, zinc, etc.), and bacteria. Therefore, without controls, future urban development will result in increased pollutant loadings to the area streams. This, in turn, can contribute to degraded aquatic habitat and increased health risks associated with various recreation activities (**Figure 4.4**).

Figure 4.4: **Water Quality Impacts**

4.2.1.3 Flood and Erosion Impacts

With urbanization, there is a typical hydrologic response from the developed land. This generally involves an increase in peak flow rates and runoff volumes, and a decrease in the time-to-peak flow. These effects commonly occur with increased impervious surface areas and improved stormwater drainage systems which are typical of the change from rural to urban land use. The increased runoff volumes and flow rates can result in increased rates of erosion and flooding (**Figure 4.5**).


Figure 4.5: **Examples of Flooding and Erosion Impacts**

4.2.2 Potential Terrestrial and Aquatic Ecological Impacts

This section provides a preliminary discussion of impacts to the natural environment resulting from land use changes and urban development. Additional discussion specific to the study area has been provided in later sections of this report.

Natural heritage features within the study area were identified and discussed in detail in the Soper Creek Subwatershed Study Phase 1 report. Potential impacts to the identified ecological features and functions may be generally attributed to two categories: direct loss of features or functions (e.g., due to removal of vegetation, channelization or piping of watercourses, changes to water chemistry due to stormwater/wastewater input, etc.); and fragmentation or isolation of natural areas due to the creation of barriers (e.g., roads) which limit movement and dispersal of species using those areas. Indirect negative impacts may also occur where land use changes adjacent to natural areas bring an increase in noise, light, or human activity that affects species' behaviour (e.g., vocalization). There is also the potential for positive impacts to occur in locations where naturalization or restoration efforts are carried out and where naturalized Vegetation Protection Zones (VPZs) are established surrounding existing natural features.

Preservation of natural cover on the landscape is crucial for maintaining the health and functionality of a watershed, as natural cover provides wildlife habitat, supports water quality and SWM Quantity Control , and contributes to air quality and carbon sequestration. The Soper Creek subwatershed includes a large area of land within the urban boundary; it has already experienced a high degree of clearing/development with additional intensive development proposed throughout. Phase 1 of the SWS identified features and areas which met the criteria for inclusion in the municipal Natural Heritage System; these features have been carried forward as environmental constraints and must have an appropriate VPZ applied in keeping with the requirements of the Municipality of Clarington's OP and any additional applicable requirements (e.g., recommendations of this SWS). Features which did not meet the minimum requirement for inclusion in the NHS are not protected features per existing policies and regulations, but their removal would still represent a loss of natural heritage on the landscape which, in a subwatershed that has already experienced a high loss of natural cover, should be discouraged. Retention of these features in parklands, stormwater management blocks, or other similar features is recommended. If these features/areas are proposed for removal, ecological offsetting is strongly recommended at the site plan or similar stage of proposed development to ensure no net loss of natural cover, and may be required as a condition of draft plan approval where impacts to or removal of natural features or areas are proposed.

Land use changes can create barriers to ecological processes (e.g., wildlife movement, seed dispersal) where previously such barriers did not exist. Roads, in particular, act as barriers to wildlife movement and often result in wildlife mortality due to collisions with vehicles. Where new roads are proposed in the study area, it is first and preferentially recommended that these be sited such that they do not encroach on natural heritage features. Where siting of roads cannot avoid impacting natural areas or potential linkages, it is recommended that measures are incorporated to facilitate wildlife movement – e.g., oversized drainage culverts with a terrestrial 'bench' to allow wildlife passage, or dedicated wildlife tunnels separate from the drainage culverts, with the associated exclusion fencing placed along habitat boundaries to direct wildlife to the crossing locations. Existing aquatic culverts may be retrofit or replaced during redevelopment to provide similar wildlife crossing considerations as well as to remove barriers to fish passage and improve aquatic habitat. In all cases, the culvert design process should ensure appropriate sizing and siting to allow for water flow, fish passage, and terrestrial wildlife movement.

Further discussion related to natural heritage and related requirements is provided in **Sections 7.2** and **8.4.2**.

5 Alternative Stormwater Strategies

Four potential stormwater management control approaches were considered as part of the process, and are described in the subsequent sections below:

1. Do Nothing
2. Traditional (Conventional) Stormwater Management
3. Low Impact Development (LID)
4. Traditional Stormwater Management and LID

5.1 Do Nothing Approach

This scenario illustrates the impacts if no stormwater management is applied. For this study, the "Do Nothing" approach refers to not providing any form of water quantity control for new development within the Soper Creek watershed. Development using this approach would cause significant environmental and ecological degradation, contravene municipal, provincial and federal policy, as well as fail to meet the study purpose.

5.2 Traditional (Conventional) Stormwater Management

The traditional stormwater management approach involves establishing an end-of-pipe stormwater management facility (i.e. a wet pond or hybrid wetland-wet pond) within each new development area. For new development areas, siting and preliminary design of the stormwater management facility was undertaken as part of the Secondary Plan process for Soper Springs and Soper Hills. It is most technically and economically feasible to site stormwater management facilities at site locations that are conducive to gravity drainage without excessive land grading. Stormwater management facilities typically discharge to natural drainage features (creeks, rivers, wetlands and lakes) or engineered conveyance structures such as ditches, swales, channels or pipes.

Wet ponds or hybrid wetland-wet ponds use active storage detention and elongated flow paths through the facility to settle suspended sediments and associated pollutants. Both facility types require a forebay for pre-treatment and easier maintenance. While both facilities can be designed to meet MECP's enhanced level of water quality treatment corresponding to a long-term sediment removal efficiency of 80%, the wetland component of a hybrid design provides enhanced biological removal during the summer months.

Figure 5.1: A wet pond SWM facility provides water quality treatment via the settlement of suspended pollutants and SWM Quantity Control via the temporary detention and peak flow reduction

5.3 Low Impact Development (LID) Approach

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff volume and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows. Additional information regarding LID practices can be found in the March 2020 Presentation in **Appendix A**. The key principles for Low Impact Development Design are to "soak it up or slow it down":

1. **Use existing natural systems as the integrating framework for planning;**
   - Consider regional and watershed scale contexts, objectives and targets;
   - Look for stormwater management opportunities and constraints at watershed/subwatershed and neighbourhood scales;
   - Identify and protect environmentally sensitive resources; and,
   - Restore, enhance, and expand natural areas.
2. **Focus on runoff prevention**
   - Minimize impervious cover through innovative site design strategies and application of permeable surfaces;
   - Incorporate green roofs and rainwater harvesting systems in building designs;
   - Drain roofs to pervious areas with amended topsoil or stormwater infiltration practices; and,
   - Preserve existing trees and design landscaping to create urban tree canopies.

3. **Treat stormwater as close to the source area as possible**
   - Utilize decentralized source and conveyance stormwater management practices as part of the treatment train approach;
   - Flatten slopes, lengthen overland flow paths, and maximize sheet flow; and,
   - Maintain natural flow paths by utilizing open drainage (e.g., swales).
4. **Create multifunctional landscapes**
   - Integrate stormwater management facilities into other elements of the development to conserve developable land;
   - Utilize facilities that provide filtration, peak flow attenuation, infiltration and water conservation benefits;
   - Design landscaping to absorb runoff, decrease need for irrigation, urban heat island effect and enhance site aesthetics.

Both the Municipality of Clarington and CLOCA accept the use of LID best practices for stormwater management. LID best practices will be accepted to meet design criteria associated with water quality, erosion control, or water balance, but not for quantity control. However, LID practices on residential lots are not accepted for meeting water quality, erosion control, or water balance criteria because homeowners frequently modify their properties and there is no guarantee of the facility's longevity. Slides from this presentation are included as **Appendix A.**

To provide water quality, water balance, and erosion targets, an aggressive LID approach would be required. This approach would see LID practices integrated on municipal property (road ROWs, parks, municipal buildings, etc.) and on private property (commercial, institutional and industrial (ICI) properties). This approach requires performance verification and a maintenance framework to be approved by CLOCA.

Low Impact Development stormwater management practices that are accepted to meet design criteria associated with water quality, erosion control or water balance are listed in **Table 5.1,** including their general classification.

Table 5.1: LID Stormwater Management Practices

LID BMP	Notes
Soakaways, Infiltration Trenches and Perforated Pipe Systems (including pervious catch basins)	Suitable for use within the road right-of-way or on public and private (ICI) sites to control runoff at the source
Bioretention/ Bioswales (a.k.a. rain gardens)	
Rain water harvesting	Suitable for use on public and private (ICI) sites to control runoff at the source
Permeable Pavements	

In addition to the LID BMPs listed in **Table 5.1**, the use of scarified subsoil, amended topsoil, and extra topsoil depth on yards is recommended on all sites to reduce post-development runoff volume, but these amendments will not be accepted to meet water quality, erosion control or water balance criteria.

Specific types of LID practices that are generally appropriate for different land uses are listed in **Table 5.2**.

Table 5.2: Municipal LID Applicability by Land Use

Land Use		Single Family Residential	Multi-Family (Medium Density)	Multi-Family (High Density)	Industrial, Commercial & Institutional
Soil Amendments		✓	✓	✓	✓
Perforated Pipe (PP)	PP as Storm Sewer	✓	✓	✓	✓
	Parallel PP (“3rd Pipe”)	✓	✓	✓	✓
	Grassed Swale PP System	✓	✓	✓	✓
Permeable Pavements			✓	✓	✓
Bioretention, Bioswales and Enhanced Swales			✓	✓	✓
Rainwater Harvesting				✓	✓

5.3.1 LID Approach for Municipal ROW

LID SWM practices that would be incorporated into an overall municipal stormwater management approach include:

Soil Amendments - Compost amendments are tilled or mixed into existing soils thereby enhancing or restoring soil properties by reversing the loss of organic matter and compaction (**Figure 5.2)**. They also are used to make Hydrologic Group C and D soils suitable for on-site stormwater BMPs such as downspout disconnection, filter strips, and grass channels etc. Soil amendments benefits include increased infiltration, stormwater storage in the soil matrix, survival rate of new plantings, root growth and stabilization against erosion, improved overall plant/tree health and decreased need for irrigation and fertilization of landscaping. Amended soils are suitable for any pervious area where soils have been or will be compacted by the grading and construction process. While soil amendments will never be used solely to meet stormwater management objectives, they are effective in reducing the overall runoff volume, will contribute to a lower peak discharge, and can help improve water quality by reducing contaminate loads. Soil amendments can be applied on private property and do not require ongoing maintenance activities.

Perforated Pipe Systems - Perforated pipe systems, also called exfiltration systems, can be thought of as long infiltration trenches that can be designed for both conveyance and infiltration of stormwater runoff (**Figure 5.2)**. They are underground stormwater systems composed of perforated pipes installed in gently sloping granular stone beds lined with geotextile fabric that allows infiltration of runoff into the granular bed and underlying native soil. Perforated pipe systems can be used in place of almost any conventional storm sewer pipes where topography, water table depth, and runoff quality conditions are suitable. They are capable of handling runoff from roofs, walkways, parking lots, and roads. For road applications, these systems can be located within boulevard areas or beneath the roadway surface itself. There are three configurations of perforated pipe systems that are feasible within residential road rights-of-way. The first is a perforated pipe system that functions as the minor system conveyance. The second is a perforated pipe that runs parallel and discharges to the conventional storm sewer. Because the conventional storm sewer meets conveyance requirements, the parallel pipe (also known as a "3rd pipe system") can be sized to infiltrate smaller volumes. This configuration is shown in the associated figure and is consistent with the PCSWMM modeling approach used for this study. The third configuration is a catch basin lead to either a perforated or solid pipe that conveys flows to an infiltration chamber within the municipal ROW. There are also perforated pipes available up to 1200mm in diameter that can be used instead of a solid walled storm sewer to promote infiltration.

Soakaway Pits, Infiltration Trenches and Chambers - Soakaways, infiltration trenches and chambers can be used to reduce runoff volume and maintain or enhance recharge (**Figure 5.2)**. Most surface areas can be directed to infiltration practices without pre-treatment. Roads and parking lots should be provided with pre-treatment devices to prevent clogging and extend their lifecycle.

These practices are also known as infiltration galleries, trench drains and / or dry wells, and are excavations in the native soil that are lined with geotextile fabric and filled with clean granular stone. They are typically designed to accept runoff from a relatively clean water source such as a roof or pedestrian area. Where possible, they should be installed where native soils allow for infiltration; however, like other infiltration techniques, underdrains can be installed where poorly drained soils are present. These practices can be designed in a broad range of shapes and sizes.

Infiltration chambers are a variant that use prefabricated modular plastic or concrete structures (as opposed to only aggerates) installed over a granular base to provide maximum void space (up to 90%) and provide structural support. These systems provide more storage capacity than equivalently sized soakaways and have minimal footprints. Infiltration chambers are ideal for heavily urbanized sites because they can be installed below parking lots or other impervious surfaces. Infiltration chambers have also been successfully installed below recreational fields and public urban courtyards. They can be designed in many configurations to suit site constraints.

Figure 5.2: Example LID Practices from Top Left to Right: Soil Amendment (Mississauga, ON), Exfiltration System (Etobicoke ON); Exfiltration System (Guelph, ON); Perforated Pipe (Toronto, ON)

Bioretention, Bioswales and Enhanced Grass Swales - As a stormwater filtration and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. The primary component of the practice is the bioretention soil media (**Figure 5.3**). This component is comprised of specific ratio of sand, fines and organic material. Another important element of bioretention practices is vegetation, which can be either grass or a more elaborate planting arrangement such as an ornamental garden.

Bioretention can be integrated into a diverse range of landscapes including as roadside practices, open space, and as part of parking lots and landscaped areas a perimeter control. Perimeter controls are placed adjacent to the impermeable surface (i.e. parking lot) typically at the low point where it can efficiently collect runoff. Bioretention practices are commonly referred to as “rain gardens”. Depending on the native soil infiltration rate and site constraints, bioretention practices may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (commonly called a biofilter) where infiltration is not desired or where contaminated soils are encountered.

Bioswales are similar to bioretention cells. They include a filter media bed, gravel storage layer and optional underdrain components. The main difference is that bioswales are also designed to provide linear conveyance via their swale-like surface geometry and slope. Pre-treatment and rock check dams are often included in the design. In general, bioswales are open channels designed to convey, treat and attenuate stormwater runoff. Vegetation or aggregate material on the surface of the swale slows the runoff water to allow sedimentation, filtration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil. Bioswales may be planted with grasses or have more elaborate landscaping. They are implemented to provide water quality treatment and water balance benefits beyond those of a conventional ditch. Bioswales are sloped to provide conveyance, but due to their permeable soil media and gravel, surface flows are only expected during intense rainfall events. Bioswales are the most commonly applied LID as part of complete streets and parking lots.

Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff (also referred to as enhanced vegetated swales). Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs. Enhanced grass swales are not capable of providing the same water balance and water quality benefits as dry swales, as they lack the engineered soil media and storage capacity of that best management practice (**Figure 5.3**).

Figure 5.3: Example LID Practices from Top Left to Right: Bioretention (Toronto, ON); Bioretention (Bostwick Community Centre, London, ON); Grass Swale (Mississauga, ON)

5.3.2 LID Approach for Private Property

The BMPs already described above (Soil Amendments, Perforated Pipe, Permeable Pavements, Bioretention & Bioswales, Enhanced Swales, and Soakaway Pits, and Infiltration Trenches and Chambers) are suitable for municipal ROW and on private property. The following BMPs are also suitable for private property.

Rainwater Harvesting - Rainwater harvesting is the process of intercepting, conveying and storing rainwater for future use. Harvesting rainwater for domestic purposes has been practiced in rural Ontario for well over a century. Roof runoff is the ideal source for this practice due to the large surface area and minimal exposure to contaminants. Rainwater harvesting not only reduces the volume of runoff that is conveyed offsite, but also reduces the onsite usage of potable water for irrigation and associated costs (**Figure 5.4**).

Rainwater harvesting systems convey runoff to a storage tank or cistern. Prefabricated storage units can range in size from simple rain barrels that tie into downspouts to precast concrete tanks capable of storing tens of thousands of litres or more from much larger catchment areas. Cisterns can be located inside a building or outside.

Rainwater that is collected in a cistern can be used for non-potable indoor or outdoor uses. Sufficient pre-treatment options include gravity filtration or first flush diversion. The irrigation of landscaped areas and washing of site features and vehicles are common uses of harvested rainwater. The 2017 Ontario Building Code explicitly allows the use of harvested rainwater for toilet and urinal flushing (See Section 7.1.5.3 of the Code).

Permeable Pavements - Permeable pavement is a collective term that describes LID BMPs that can be used in place of conventional asphalt or concrete pavement (**Figure 5.4**). These alternatives contain pore spaces or joints that allow stormwater to pass through to a stone base for infiltration into underlying native soil or temporarily detained for SWM Quantity Control purposes. Typical types of permeable pavement include:

- pervious concrete;
- porous asphalt;
- permeable interlocking concrete pavers (PICP) (i.e., block pavers);
- plastic or concrete grid systems (i.e., grid pavers or grass pavers); and
- rubberized granular surfaces, bricks and pads.

Permeable Pavements can be implemented as sidewalks, driveways, multi-use pathways, on-street (lay-by) parking, alleyways, road shoulders and even minor or local roadways themselves but are most commonly applied in parking lots. When implemented as within a parking lot, permeable pavement can be implemented as:

- Full permeable pavement parking surface (drive lanes and parking stalls); and
- Partial permeable pavement parking surface where permeable pavement is strategically constructed within the parking stall areas only and the central drive-lanes remain as conventional asphalt. In this manner, the permeable pavement systems can accept runoff from impervious areas (i.e. drive lanes).

An ongoing maintenance plan is required for permeable pavements, to ensure clogging of void space does not occur.

Figure 5.4: Example LID Practices from Left to Right: Green Roof (Portland, OR); Rainwater Harvesting (Portland OR); Permeable Pavements (London, ON)

5.4 Traditional (Conventional) Stormwater Management and LID Approach

LID stormwater management practices used together with conventional stormwater management as part of an overall holistic treatment train approach have been shown to better meet stormwater management targets and objectives, provide better performance, are more cost effective, have lower maintenance burdens, and are more protective during extreme storms than conventional stormwater practices alone. The underlying concept is that each LID stormwater management and traditional practice within the treatment train provides successive storage, attenuation and water quality benefits.

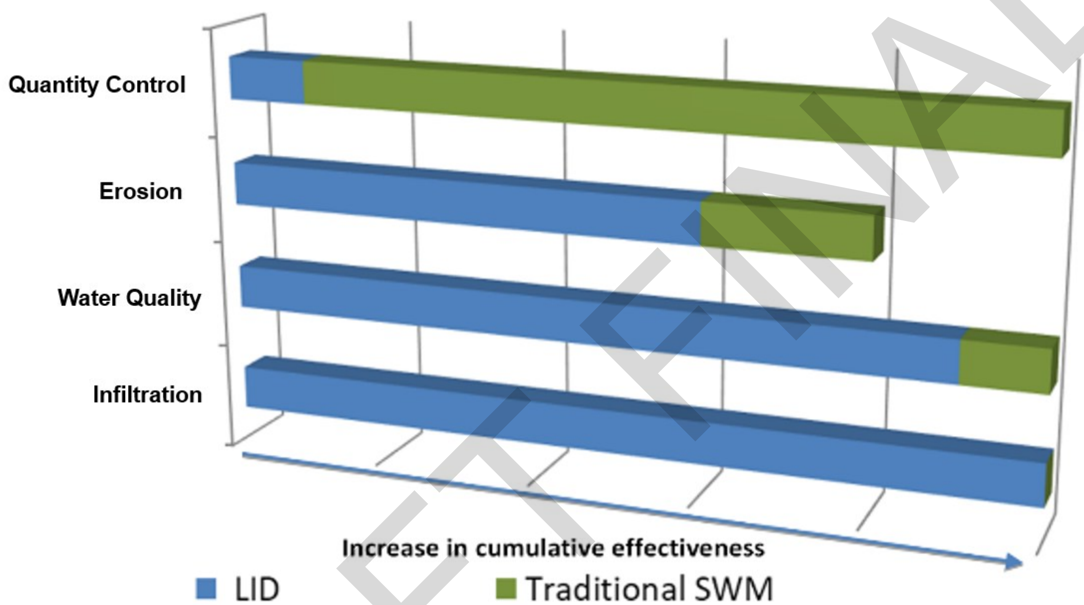

Figure 5.5**Figure 5.5** illustrates the generalized impact of a holistic approach to stormwater management on the four (4) primary and most common stormwater management objectives

when LID and conventional stormwater management solutions are used.

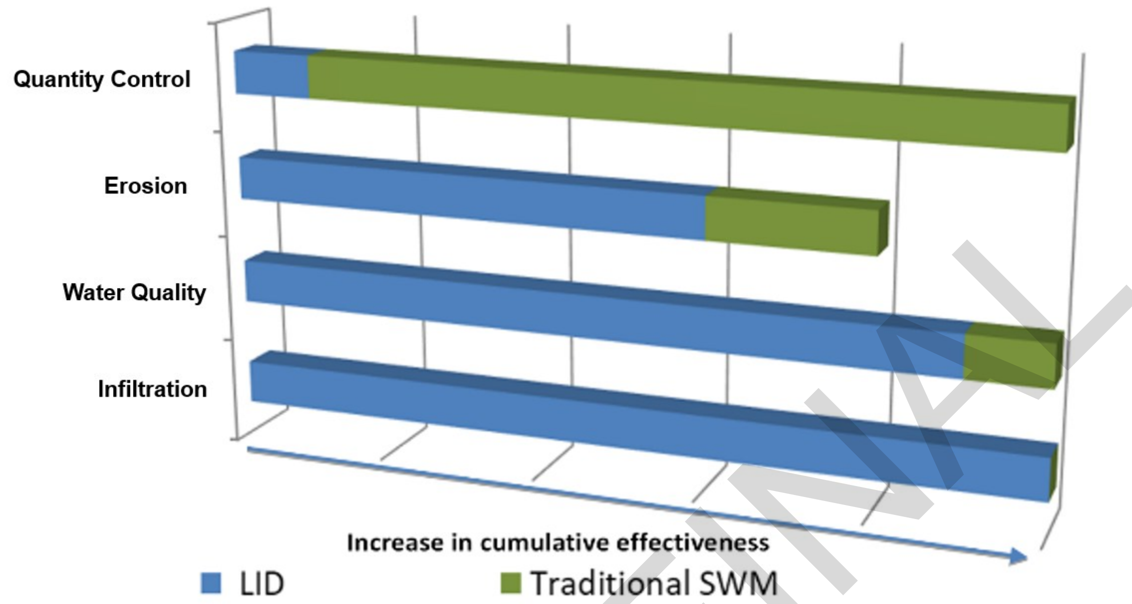

Figure 5.5: The Rationale for the Traditional Stormwater Management and LID Approach

Quantity control volume reductions for LID measures will not be accepted, per CLOCA's requirements, so all conventional SWM ponds must be sized for the full quantity control volume. However, the permanent pool and extended detention volumes may be reduced based on the implementation of LIDs throughout the catchment.

As discussed previously, LID is a green infrastructure approach to stormwater management that uses simple, distributed and cost-effective engineered landscaped features and other techniques to infiltrate, store, filter, evaporate and detain rainfall where it falls. The principles of LID are part of the evolution of stormwater management whereby rainwater is managed as a resource. The conventional stormwater management and LID approach uses both end-of-pipe facilities and LID stormwater management practices in the form of source and conveyance controls, including:

- Bioretention;
- Bioswales;
- Perforated pipe / Exfiltration trenches;
- Soakaway Pits;
- Rain water harvesting; and
- Permeable pavements.

The LIDs are incorporated into new development areas to provide water quality control via runoff volume reductions and filtration. Where these LIDs can treat the runoff generated from the 90th percentile event, the end of pipe facilities can be designed to provide water quantity control only. For these catchment scenarios, a dry stormwater management pond and/or multi-use flood storage facility may be feasible. In new development areas where LIDs can treat only a portion of the runoff, the end-of-pipe facilities will need to provide a volume of water quality storage. In this situation, the water quality volume can be reduced by reducing the calculated imperviousness of the catchment based on the impervious area fully controlled by LIDs. For example, if LIDs control 3.6 ha out of 10 ha of impervious area in an 18-ha catchment, the percent imperviousness for sizing the wet pond can be reduced from 55% to 35%.

The traditional (conventional) stormwater management and LID approach can be developed in a way that fosters complete corridors wherever possible throughout the study subwatersheds, whereby stormwater management features are integrated with natural heritage, open space and recreational opportunities. This involves properly integrating green infrastructure with consideration for passive, ecologically supportive land uses adjacent to creek and tributary corridors. The complete corridor approach is a proactive way to protect, maintain, rehabilitate and/or restore critical ecological function. Properly implemented, a complete corridor provides continuous natural area and enhanced ecological connectivity for the movement of water, wildlife and people.

Cost estimates for maintenance activities associated with wet and dry pond SWM facilities are summarized below in **Table 5.3**. Maintenance activities associated with both types of facilities such as fence replacement, headwall repair etc., have not been included. Cost estimates are preliminary and subject to change given facility specifications, construction timing and other variable factors.

Table 5.3: Maintenance Cost Estimates

Maintenance Activities	Total Cost ($)		Cost/ha	
	Wet Pond	Dry Pond	Wet Pond	Dry Pond
Sediment Removal	95,000-919,000	91,000-94,000	5,600-68,000	5,200-5,800
Dewatering and Water Management	20,000-25,000	N/A	-	N/A
Vegetation Clearing and Grubbing	2,500	N/A	-	N/A
Grass Cutting and Weed Control (2x year)	N/A	N/A	N/A	2,750

6 Modeling of the Stormwater Strategy

Four alternative stormwater strategies were identified in **Section 5** to address the potential impacts associated with future development (**Section 4.2**). **Section 6** will describe the criteria used to evaluate these strategies, followed by the evaluation and selection of the preferred alternative. An assessment of the effects of climate change is also provided.

6.1 Criteria Description

Five criteria have been identified that must be met through the preferred stormwater strategy. These criteria include:

- **SWM Quantity Control:** Potential to reduce the impact of new development on peak flows associated with both urban and riverine flooding, such that the 2-year through 100-year post-development flows are less than or equal to the predevelopment flows, and that the post-development uncontrolled flows are less than the existing regulatory flows.
- **Water quality:** Potential to improve water quality based on existing water quality conditions and ability to provide Enhanced water quality as per the MECP requirements.
- **Water balance:** Potential to meet a water balance within the subwatershed area that is consistent with a natural catchment area lacking anthropogenic impervious surfaces (i.e., meet pre-development water balance). High Volume Recharge Areas (HVRAs) and Ecologically Significant Groundwater Recharge Areas (ESGRAs) will require a site-specific water balance to be completed as a component of the stormwater management submission.
- **Erosion control:** Potential to maintain existing fluvial geomorphic regime or improve erosion conditions within Soper Creek and associated tributaries. The reestablishment of a natural erosion and sediment deposition regime is closely tied to matching the runoff responses associated with pre-development conditions.
- **Thermal impacts:** Potential to maintain cooler water temperatures discharged into streams to sustain coolwater habitat. Impervious surfaces, such as roads and rooftops, can reach very high temperatures, especially during the summer months, and this heat is transferred to stormwater running over it.

6.2 SWM Quantity Control

Since LID measures will not be accepted for SWM Quantity Control purposes, only traditional stormwater management was considered in addition to the do-nothing approach for the purpose of quantity control.

A Visual Otthymo 6.2 model (VO6) provided by CLOCA was updated to account for any changes within each subwatershed. **Appendix B** describes the model updates.

For the Soper Creek watershed, two distinct VO6 models have been created:

- A Watershed Scale VO6 model was created based on the original catchment areas provided by CLOCA with refinements to drainage area boundaries within reaches SM10 and SE1. This model has been modified with updated rainfall data, land use and revised hydrologic parameters including CN, Ia and Tp. The intent of the Watershed Scale model is to identify peak flow rates at key flow nodes with larger catchment areas for inclusion direct comparison to the original CLOCA VO model and potential inclusion in the HEC-RAS hydraulic floodplain model;
- A Tributary / Detailed Scale VO6 model was also created. This model has used the original catchment areas provided by CLOCA and further discretized theses catchments within the Secondary Plan areas to provide a higher level of detail. This model has been modified with updated rainfall data, land use and revised hydrologic parameters including CN, Ia and Tp. The intent of the Detailed Scale model is to refine existing and proposed condition peak flows at smaller catchment footprints which will aid in the development and sizing of stormwater management attenuation volumes and LID volumes.

Based on discussions with the Municipality and CLOCA, the 24hr SCS Type II and 12hr Chicago storm distributions have been ran within the VO modelling environment. The 12hr Chicago Storm distribution produces higher peak flows than the 24hr SCS Type II storm distribution. Therefore, the 12hr Chicago storm distribution has been carried forward for further analysis and discussion. Hurricane Hazel has been selected as the Regional Storm with a 94.8% reduction factor applied as directed by CLOCA. CN values have been adjusted to AMC III conditions for Regional Storm runs.

Detailed commentary on both Watershed and Detailed Scale hydrologic models has been provided in **Sections 6.3** and **6.4**.

6.3 Watershed Level Hydrologic Modelling Discussion

Figure 6.1 illustrates the Watershed level catchments while **Table 6.1** and **Table 6.2** illustrate the peak flow comparison between the Existing CLOCA model and the refined Existing Conditions Model completed by Aquafor. The Existing peak flow rates are associated with VO Modelling Scenario 2000.

Table 6.1: Summary of Estimated Flood Flows (Watershed Scale) – Ex. 100-Year Event

	NHYD	Location	Existing CLOCA (m^3/s)	Existing Aquafor (m^3/s)	Difference (m^3/s)
Soper Creek	68	Con Rd 3	113.5	92.3	-21.2
	100	Highway 2	137.2	117.3	-19.9
	104	D/S Hwy 2	141.3	123.0	-18.3
	106	Highway 401	141.6	123.9	-17.7
	109	D/S West Beach	141.8	124.2	-17.6

Table 6.2: Summary of Estimated Flood Flows (Watershed Scale) – Ex. Regional Event

	NHYD	Location	Existing CLOCA (m^3/s)	Existing Aquafor (m^3/s)	Difference (m^3/s)
Soper Creek	68	Con Rd 3	368.6	363.7	-4.9
	100	Highway 2	510.9	478.1	-32.8
	104	D/S Hwy 2	516.3	492.5	-23.8
	106	Highway 401	522.1	495.5	-26.6
	109	D/S West Beach	522.8	496.1	-26.7

Table 6.3: Summary of Estimated Flood Flows (Watershed Scale) – Pr Uncontrolled - 100-year

	NHYD	Location	Existing CLOCA (m^3/s)	Future Un-Controlled Aquafor (m^3/s)	Difference (m^3/s)
Soper Creek	68	Con Rd 3	113.5	102.48	-11.02
	100	Highway 2	137.2	116.07	-21.13
	104	D/S Hwy 2	141.3	120.38	-20.92
	106	Highway 401	141.6	121.72	-19.88
	109	D/S West Beach	141.8	121.97	-19.83

Table 6.4: Summary of Estimated Flood Flows (Watershed Scale) – Pr Uncontrolled - Regional

	NHYD	Location	Existing CLOCA (m^3/s)	Future Un-Controlled Aquafor (m^3/s)	Difference (m^3/s)
Soper Creek	68	Con Rd 3	368.6	387.35	18.75
	100	Highway 2	510.9	506.02	-4.88
	104	D/S Hwy 2	516.3	516.2	-0.1
	106	Highway 401	522.1	521.46	-0.64
	109	D/S West Beach	522.8	522.28	-0.52

A direct comparison of Existing Condition Peak flow rates between Existing Condition models reveals a peak flow reduction with the revised Aquafor VO model in direct comparison to the existing CLOCA model. A desk top comparison of hydrologic parameters between both models found that catchment areas, CN and Ia values are comparable between hydrologic models. However, the revised Aquafor VO model produces Time to Peak (Tp) values less than that of the existing CLOCA model. This reduced peak flow timing allows the downstream portion of the watershed to drain before the peak of the upper portion of the watershed arrives. While peak flow timing reduces peak flows at the Watershed Scale, flow nodes at the watershed level scale are located at major roadway crossings only and may not reflect localized flow conditions within the smaller tributaries. Accordingly, based on the above, peak flow timing is an important aspect of the watershed that must be addressed when considering smaller catchment footprints, proposed stormwater management facilities and individual reach hydraulic characteristics.

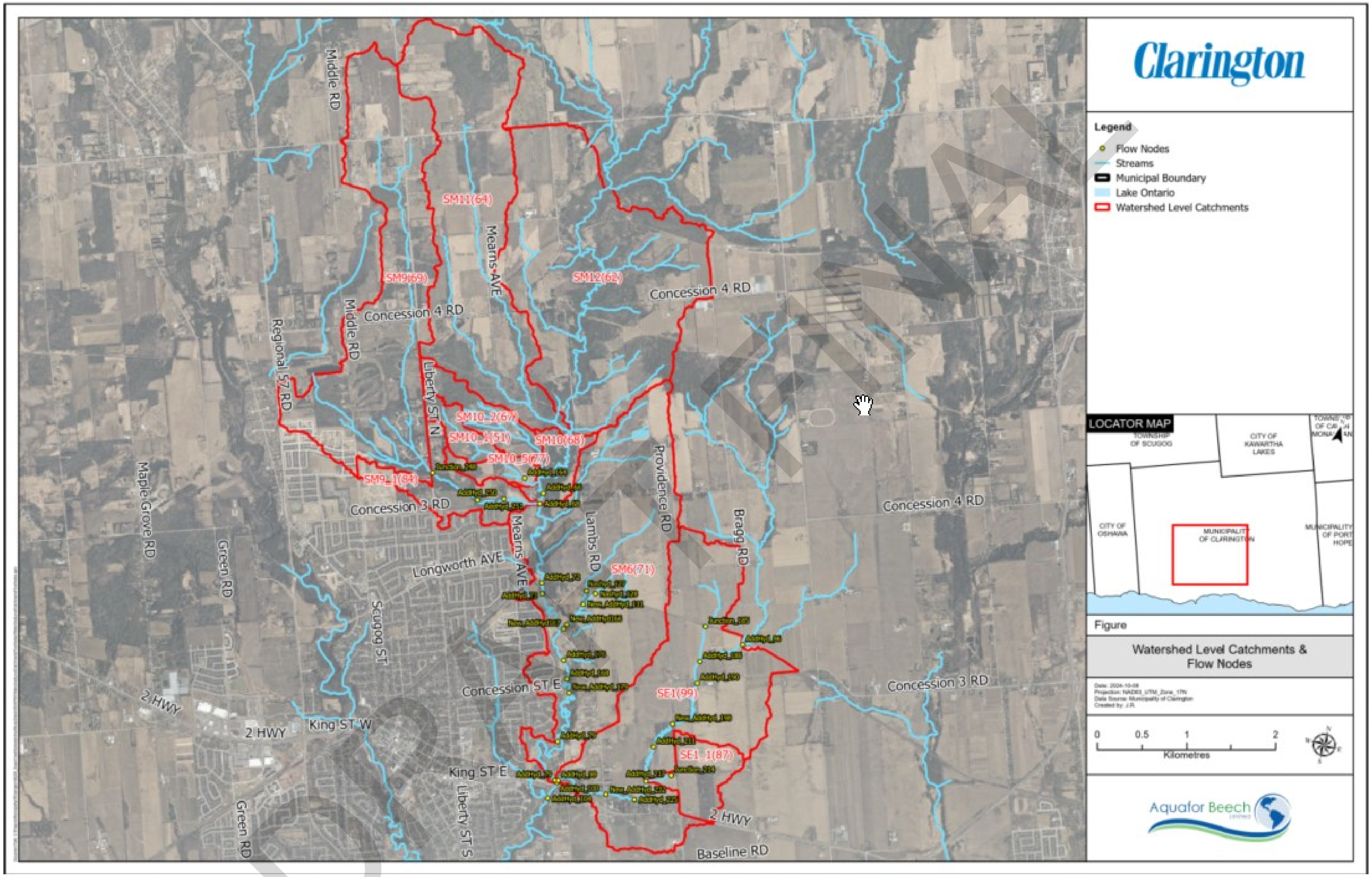

Figure 6.1: Watershed Scale Subdivided Subcatchments

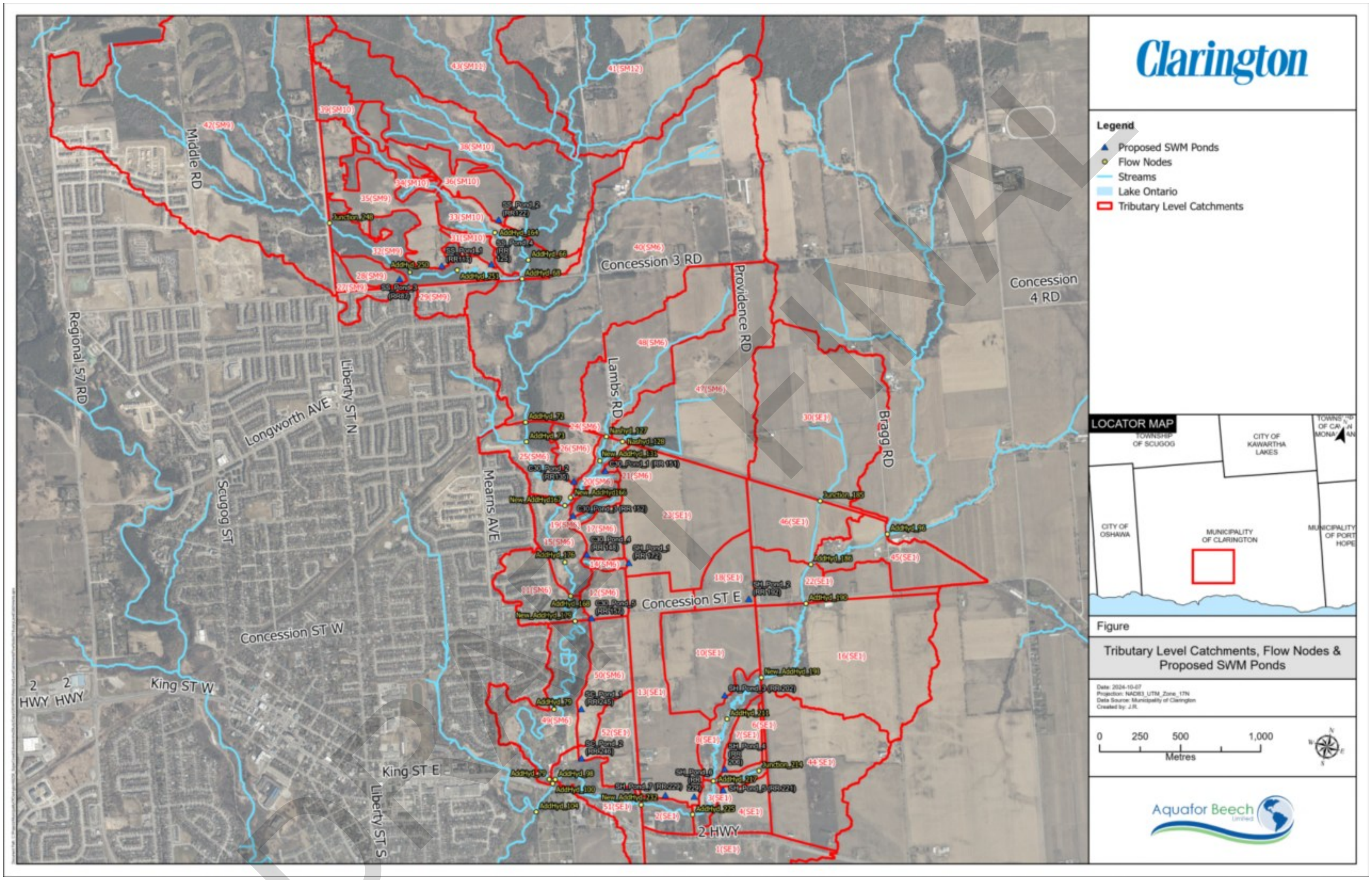

Figure 6.2: Tributary/Detailed Scale Subdivided Subcatchments with Flow Nodes

6.4 Detailed Hydrologic Modelling Discussion

Using the watershed level catchment area boundaries within the Soper Creek Watershed as a reference, further catchment discretization was completed to provide an enhanced level of modelling resolution. For ease of reference, this enhanced level of detail is referred to as the "Tributary Level" of detail for the remainder of the report. The intent of the increased level of detail has been provided to address the following:

1) Isolate development area footprints to assess peak flows and stormwater quality and quantity control requirements;
2) Increase the level of flow nodes for additional reference points within the watershed;
3) Refine the extent of flow routing within the model; and
4) Create a best-efforts modelling approach to replicate field conditions in absence of formal calibrated/validated hydrologic model.

Modelling Run 4000 details the Tributary Level Existing Conditions peak flows for the 2-100-year and Regional events, at key locations (**Figure 6.2**) and are presented in **Table 6.5** for reference.

Table 6.5: Flow Node Summary - Tributary Level - Existing Conditions Peak Flow Summary (m^3/s)

Modelling Run 4000 Tributary Level Existing Conditions			Peak Flow (m3/s)						
Reach	HYD	Location	2	5	10	25	50	100	Reg.
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	29.11
SM19	250	Soper Springs - DS of SWM SS Pond 3	1.64	3.02	4.10	5.61	6.84	8.11	30.92
SM19	251	Soper Springs - DS of SWM SS Pond 1	1.75	3.20	4.33	5.91	7.19	8.51	32.59
SM10	241	Soper Springs - DS of SWM SS Pond 2	0.08	0.15	0.21	0.30	0.38	0.46	1.57
SM6	66	Soper Springs	60.50	69.08	76.16	81.40	86.69	85.02	331.12
SM6	68	Concession Road 3	62.26	72.21	80.29	86.83	93.11	92.35	363.66
SM6	72	Rail Line	39.76	48.44	56.07	63.63	76.90	91.23	372.56
SM6	73	Downstream of Rail Line	39.07	48.22	55.74	63.92	77.77	92.22	376.85
SM6	131	Camp 30	0.87	1.59	2.14	2.90	3.51	4.13	10.33
SM6	166	Camp 30	0.95	1.74	2.34	3.18	3.85	4.54	11.57
SM6	167	Camp 30	35.62	45.40	54.06	65.08	78.88	93.24	382.07
SM6	176	Camp 30	35.41	45.51	54.36	65.48	79.33	93.67	383.51
SM6	168	Camp 30	34.42	44.74	53.54	65.56	79.39	93.83	382.58
SM6	179	Concession Street	25.58	35.89	46.05	61.93	74.86	88.27	365.59
SM6	79	Camp 30	25.18	35.79	45.98	61.78	74.54	87.89	363.66

Modelling Run 4000 Tributary Level Existing Conditions			**Peak Flow (m3/s)**						
Reach	**HYD**	**Location**	**2**	**5**	**10**	**25**	**50**	**100**	**Reg.**
SE1	**185**	**Rail Line**	0.78	1.40	1.86	2.48	2.97	3.47	7.36
SE2	**96**	**Bragg Road**	5.68	10.12	13.49	18.12	21.82	25.60	75.63
SE1	**186**	**Reach Confluence Upstream of Concession St**	7.23	13.06	17.49	23.60	28.52	33.62	95.01
SE1	**190**	**Concession St East**	7.74	14.00	18.80	25.30	30.65	36.09	101.58
SE1	**198**	**Soper Hills East Development Limit**	8.40	15.15	20.30	27.29	32.95	38.73	110.68
SE1	**211**	**Soper Hills**	8.39	15.10	20.22	27.14	32.75	38.50	110.89
SE1a	**214**	**Soper Hills**	1.49	2.64	3.51	4.69	5.62	6.57	13.10
SE1	**217**	**Soper Hills**	9.23	16.58	22.15	29.68	35.78	42.03	121.61
SE1	**225**	**Soper Hills**	9.19	16.48	22.01	29.48	35.51	41.75	121.37
SE1	**232**	**Soper Hills West Development Limit**	9.49	16.95	22.60	30.26	36.39	42.75	125.18
SM6	**100**	**King Street East**	32.22	49.73	63.55	83.40	100.04	117.31	478.07
SM7	**104**	**Bowmanville Cemetery**	33.41	52.71	67.37	88.03	105.30	123.01	492.49
SM1	**106**	**Highway 401**	31.95	53.14	67.94	88.85	106.27	123.92	495.54
SM1	**109**	**D/S West Beach Road**	32.02	53.28	68.12	89.09	106.51	124.18	496.10

As directed by CLOCA, AMC III conditions and a 94.8% reduction factor has been applied to the Hurricane Hazel Regional Event. Based on the flow values illustrated in **Table 6.5**, the Regional Peak flows are higher than the 100-year peak flows in all cases. Therefore, the Hurricane Hazel Regional event is the Regulatory storm event for the Soper Creek Watershed. The above noted flows are used as a benchmark run to which all modelling runs associated with Future Development conditions are compared.

Using the Secondary Plan Areas identified for future development and future development hydrologic parameters approved by the Municipality and CLOCA, a Future Un-Controlled hydrologic model was completed, Modelling Run 5000. This modelling run contains the same catchment boundaries and flow node locations as Modelling Run 4000 to ensure a like-for-like comparison between peak flows may be obtained and assessed. **Table 6.6** illustrates the 100-year and Regional peak flows for Modelling Run 5000 and the direct comparison to existing conditions. A detailed comparison of all storm events has been included in **Appendix B.**

Table 6.6: Flow Node Summary - Proposed Uncontrolled vs Existing Conditions – 100-year and Regional (m^3/s)

Modelling Run 5000 Tributary Level Proposed Un-Controlled Conditions			Peak Flow (m^3/s)		Proposed Conditions vs Existing Conditions (m^3/s)		Proposed Conditions vs Existing Conditions (%)	
Reach	**HYD**	**Location**	**100**	**Reg.**	**100**	**Reg.**	**100**	**Reg.**
SM19	**248**	**Liberty Street**	7.69	29.11	0.00	0.00	0.00%	0.00%
SM19	**250**	**Soper Spring - DS of SWM SS Pond 3**	8.11	30.87	0.00	-0.05	0.01%	-0.17%
SM19	**251**	**Soper Spring - DS of SWM SS Pond 1**	15.47	32.27	6.96	-0.32	81.88%	-0.99%
SM6	**66**	**Soper Springs**	103.62	330.81	18.60	-0.31	21.88%	-0.10%
SM6	**68**	**Concession Road 3**	110.54	362.82	18.19	-0.84	19.70%	-0.23%
SM6	**72**	**Rail Line**	97.36	371.52	6.13	-1.04	6.72%	-0.28%
SM6	**73**	**Downstream of Rail Line**	98.33	375.74	6.11	-1.11	6.63%	-0.29%
SM6	**131**	**Camp 30**	4.13	10.33	0.00	0.00	0.00%	0.00%
SM6	**166**	**Camp 30**	4.49	11.55	-0.04	-0.02	-0.97%	-0.20%
SM6	**167**	**Camp 30**	99.76	380.74	6.52	-1.33	6.99%	-0.35%
SM6	**176**	**Camp 30**	100.15	380.63	6.47	-2.88	6.91%	-0.75%
SM6	**168**	**Camp 30**	100.35	379.45	6.53	-3.13	6.96%	-0.82%
SM6	**179**	**Concession Street**	94.85	362.51	6.58	-3.08	7.45%	-0.84%
SM6	**79**	**Camp 30**	94.51	360.92	6.62	-2.74	7.53%	-0.75%
SE1	**185**	**Rail Line**	3.47	7.36	0.00	0.00	0.00%	0.00%
SE2	**96**	**Bragg Road**	25.60	75.63	0.00	0.00	0.00%	0.00%
SE1	**186**	**Reach Confluence Upstream of Concession St**	33.62	95.01	0.00	0.00	0.00%	0.00%
SE1	**190**	**Concession St East**	36.13	101.55	0.05	-0.02	0.13%	-0.02%
SE1	**198**	**Soper Hills East Development Limit**	38.77	110.73	0.05	0.05	0.12%	0.05%
SE1	**211**	**Soper Hills**	38.65	111.04	0.14	0.15	0.37%	0.13%
SE1a	**214**	**Soper Hills**	6.57	13.10	0.00	0.00	0.00%	0.00%
SE1	**217**	**Soper Hills**	42.17	121.71	0.14	0.11	0.35%	0.09%
SE1	**225**	**Soper Hills**	41.90	121.47	0.15	0.09	0.36%	0.08%
SE1	**232**	**Soper Hills West Development Limit**	42.88	125.00	0.13	-0.17	0.30%	-0.14%
SM6	**100**	**King Street East**	126.34	474.02	9.03	-4.05	7.69%	-0.85%
SM7	**104**	**Bowmanville Cemetery**	132.22	487.63	9.22	-4.86	7.49%	-0.99%
SM1	**106**	**Highway 401**	133.22	490.34	9.30	-5.20	7.51%	-1.05%
SM1	**109**	**D/S West Beach Road**	133.51	490.83	9.34	-5.27	7.52%	-1.06%

The direct comparison of Future Un-Controlled flows to existing conditions provides three key insights, including:

1) The first, future un-controlled peak flows exceed existing conditions flow rates at several key locations within the Soper Springs area upstream of Concession Road 3 and

the main branch of Soper Creek, as far downstream as West Beach Road. This indicates the Stormwater Quantity Controls will be required within the Secondary Plan areas. The magnitude and extents of attenuation will be explored through further analysis as detailed in this report;

2) Future un-controlled peak flows at Flow Node 232 (Western Limit of the Soper Hills Development) are only marginally higher than Existing Conditions. This may indicate that stormwater quantity controls may not be required in this area. Additional commentary has been provided in **Section 6.4.1.**
3) The second observation is that Regional Peak flows, in the Un-Controlled Condition, are generally less than existing conditions. This condition indicates that Regional Flow Controls are not required.

6.4.1 Stormwater Quantity Control

In light of the observations obtained by comparing future un-controlled flow rates to existing conditions, modelling iterations were completed to assess the impacts of Stormwater Quantity Controls within the watershed. A total of 17 end-of-pipe SWM facilities were modelled wherever development is proposed. Pond locations proposed by the Secondary Plan land use for Soper Hills, Soper Springs, Camp 30 and Timber Trails lands were accepted and used by this study, and placed near the outlets of subcatchments (**Figure 3.1** and **Figure 3.2**). The drainage area for each facility was defined based on the Secondary Plans provided by the Municipality, while pond sizing was obtained by varying the storage volumes per hectare until each of the following conditions were met:

1. Condition #1 - Post-development flows **per catchment** throughout the watershed from the 2-year through 100-year events were less than or equal to the 2-100 year existing flows;
2. Condition #2 - Post-development flows **at key nodes** throughout the watershed from the 2-year through 100-year events were less than or equal to the 2-100 year existing flows; and
3. Condition #3 - Uncontrolled flows were less than the existing regulatory flows, where the regulatory flow is defined as the larger of the 100-year or Regional flow.

6.4.1.1 Future Controlled Scenarios

The Existing peak flow rates are associated with VO Modelling Scenario 4000 while the Future (Uncontrolled) scenario is associated with VO Modelling Scenario 5000 and finally, the Future (Controlled) scenarios are associated with VO Modelling Scenario 6000 series. VO Modelling Scenario 5050 provides a proposed Un-Controlled Regional Scenario and the only Tributary Level Regional modelling run for the Soper Creek SWS.

Table 6.7 provides a peak flow summary comparison between Existing and Future Controlled Peak Flow rates for each proposed development area for the 100-year and Regional Events.

Detailed for comparisons for all other storm events, including the 2, 5, 10, 25 and 50-year events, have been provided in **Appendix B**.

Table 6.7: Catchment Level - Proposed Controlled vs Existing Conditions - 100-year (m^3/s)

Drainage Area	HYD	Pond Name	Route Reservoir HYD	Existing Conditions Modelling Run 4000 100-year (m3/s)	Proposed Conditions Modelling Run 6000 100-year (m3/s)	Difference 100-year (m3/s)
SM9_35	80	SS_Pond_1	117	1.77	1.64	-0.13
SM10_36	67	SS_Pond_2	122	0.95	0.89	-0.05
SM9_28	76	SS_Pond_3	87	0.42	0.40	-0.02
SM10_31	195	SS_Pond_4	125	0.18	0.18	0.00
SM6_21	130	C30_Pond_1	151	0.07	0.06	-0.01
SM6_26	134	C30_Pond_2	135	0.54	0.51	-0.03
SM6_20	140	C30_Pond_3	152	0.21	0.18	-0.03
SM6_17	142	C30_Pond_4	148	0.57	0.57	0.00
SM6_12	146	C30_Pond_5	157	0.44	0.44	0.00
SM6_50	242	SC_Pond_1	245	0.62	0.60	-0.02
SM6_52	243	SC_Pond_2	246	0.84	0.79	-0.04
SE1_23	171	SH_Pond_1	172	3.79	3.79	0.00
SE1_18	191	SH_Pond_2	192	1.47	1.37	-0.10
SE1_10	201	SH_Pond_3	202	3.72	3.36	-0.36
SE1_7	205	SH_Pond_4	206	2.36	2.32	-0.04
SE1_4	220	SH_Pond_5	221	1.57	1.47	-0.11
SE1_13	228	SH_Pond_6_7	229	4.31	3.93	-0.38

As illustrated above, a total of 17 development areas are proposed within the Secondary Plan areas.

Table 6.7 illustrates the results of Condition #1 whereby attenuating post development flows on a catchment-by-catchment basis to existing condition flow rates up to the 100-year event. **Table 6.8** illustrates the results of attenuation Condition #1 at the various flow nodes within the study area.

Table 6.8: Flow Node Peak Flow Summary - Proposed Controlled vs Existing Conditions - 100-year (m^3/s)

Modelling Run 6000 Proposed Controlled Post to Pre- Conditions			Peak Flow (m^3/s)	Proposed Conditions vs Existing Conditions (m^3/s)	Proposed Conditions vs Existing Conditions (%)
Reach	**HYD**	**Location**	**100**	**100**	**100**
SM6	**66**	**Soper Springs**	85.23	0.21	0.25%
SM6	**68**	**Concession Road 3**	93.07	0.72	0.78%
SM6	**72**	**Rail Line**	91.79	0.56	0.61%
SM6	**73**	**Downstream of Rail Line**	92.78	0.56	0.60%
SM6	**131**	**Camp 30**	4.13	0	0.00%
SM6	**166**	**Camp 30**	4.71	0.17	3.75%
SM6	**167**	**Camp 30**	93.92	0.68	0.73%
SM6	**176**	**Camp 30**	94.71	1.04	1.11%
SM6	**168**	**Camp 30**	94.95	1.12	1.20%
SM6	**179**	**Concession Street**	89.34	1.07	1.21%
SM6	**79**	**Camp 30**	88.93	1.04	1.18%
SE1	**185**	**Rail Line**	3.47	0	0.00%
SE2	**96**	**Bragg Road**	25.6	0	0.00%
SE1	**186**	**Reach Confluence Upstream of Concession St**	33.62	0	0.00%
SE1	**190**	**Concession St East**	36.38	0.3	0.82%
SE1	**198**	**Soper Hills East Development Limit**	39.03	0.3	0.78%
SE1	**211**	**Soper Hills**	39.21	0.71	1.84%
SE1a	**214**	**Soper Hills**	6.57	0	0.00%
SE1	**217**	**Soper Hills**	42.92	0.89	2.13%
SE1	**225**	**Soper Hills**	42.74	0.99	2.36%
SE1	**232**	**Soper Hills West Development Limit**	44.15	1.39	3.26%
SM6	**100**	**King Street East**	119.39	2.08	1.77%
SM7	**104**	**Bowmanville Cemetery**	125.12	2.11	1.72%
SM1	**106**	**Highway 401**	126.24	2.32	1.87%
SM1	**109**	**D/S West Beach Road**	126.49	2.31	1.86%

While peak flow attenuation on a catchment-by-catchment basis has been achieved, peak flow increases throughout the watershed within have been observed. Specifically, 100-year peak flows downstream of Concession Road 3 and downstream of the Soper Springs Area, at Flow

Nodes 167 and 79 have been observed to increase by up to 1.12m^3/s (1.22%). At the downstream limits of the project area, between Flow Nodes 100 to 109, 100-year peak flows have been observed to increase by up to 2.31m^3/s (1.86%). At the western limits of the Soper Hills development area at Flow Node 232, 100-year peak flows have been observed to increase by 1.39m3/s or 3.26%. While peak flow attenuation from post to pre-development conditions has resulted in a flow reduction, the timing of release rates from the proposed SWM facilities has resulted in notable flow increases throughout the watershed. Accordingly, in an attempt to reduce future condition peak flows to existing condition peak flows, additional attenuation modelling scenarios were required.

6.4.1.2 Additional Attenuation Scenarios

In total, 11 modelling runs have been completed to assess various attenuation scenarios within the watershed. Generally, the attenuation modelling runs can be grouped into the following categories:

- Post to Pre-Controls on All Catchments;
- Minor System Controls on All Catchments (2, 5, 10yr);
- Over-Control on All Catchments (25%, 50%, 100%);
- Under-Control on All Catchments (25%, 50%);
- Proposed SWM Facilities within the Soper Springs Area Only;

Table 6.9 provides an overview of all modelling runs within the Soper Creek Subwatershed Study VO model. Modelling Runs associated with stormwater quantity control (i.e. attenuation) are presented in the 6000 series. Additional commentary detailing key observations at selected flow nodes has been provided in the following sections of the report. Detailed flow comparisons for all storm events have been provided in **Appendix B** for reference.

Table 6.9: Modelling Run Scenario Summary

Run ID	Land Use	Level	Attenuation Provided? (Y/N)	Description
1000_Ex_CLOCA_Re Storms	Existing	Watershed	**N**	Original CLOCA VO Model with revised storm files. The 2 to 100-year storm files have been updated based on current day IDF information.
1050_Ex_CLOCA Regional	Existing	Watershed	**N**	Original CLOCA VO Model with revised Regional Storm. A 94.8% reduction factor has applied to Hurricane Hazel. AMC III conditions have been applied.
The following hydrologic models have been developed using the Municipality of Clarington's current and future land use planning scenarios and hydrologic parameters approved by both Clarington and CLOCA.				
2000_Ex_ABL	Existing	Watershed	**N**	Aquafor Modified VO Existing Condition Model (2-100yr).
2000_Ex_ABL_Regional	Existing	Watershed	**N**	Aquafor Modified VO Existing Condition Regional Model. A 94.8% reduction factor has been applied to Hurricane Hazel. AMC III conditions have been applied.
4000_Ex Tributary Level ABL	Existing	Tributary	**N**	Aquafor Modified VO Existing Condition Model (2-100yr).
4001_Ex Tributary Level ABL _27mm LID Run	Existing	Tributary	**N**	Aquafor Modified VO Existing Condition Model (27mm LID Quality Control Run Only).
4050_Ex_Tributary Level ABL_Regional	Existing	Tributary	**N**	Aquafor Modified VO Existing Condition Regional Model. A 94.8% reduction factor has been applied to Hurricane Hazel. AMC III conditions have been applied.
5000_Pr Tributary Level ABL	Future	Tributary	**N**	Aquafor Future Condition Un-Controlled Model (2-100yr).
5050_Pr Tributary Level ABL_Regional	Future	Tributary	**N**	Aquafor Future Condition Un-Controlled Regional Model. A 94.8% reduction factor has been applied to Hurricane Hazel. AMC III conditions have been applied.
6005_Pr Tributary Level ABL Controlled_wOverflows	Future	Tributary	**Y**	Aquafor Future Condition Post to Pre Controlled Model (2-100yr).

Run ID	Land Use	Level	Attenuation Provided? (Y/N)	Description
6010_Pr Tributary Level ABL Controlled_wOverflows_Minor System Only	Future	Tributary	Y	Aquafor Future Condition Minor System Controlled Model (2-10yr). Peak flows including the 25,50 and 100-year events are un-controlled.
6015_Pr Tributary Level ABL_Soper Springs Control Only	Future	Tributary	Y	Aquafor Future Condition Post to Pre Controlled Model within the Soper Springs Secondary Plan Only (2-100yr).
6110_Pr Tributary Level ABL OverControlled_wOverflows_25%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. The Post to Pre attenuation scenario has been used as a benchmark for this modelling run. This modelling run has used a 1.25x the Post to Pre attenuation volumes. This model provides a 25% Overcontrol Scenario.
6115_Pr Tributary Level ABL OverControlled_wOverflows_50%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. The Post to Pre attenuation scenario has been used as a benchmark for this modelling run. This modelling run has used a 1.50x the Post to Pre attenuation volumes. This model provides a 50% Overcontrol Scenario.
6116_Pr Tributary Level ABL_Soper Springs Over Control Only_50%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. Modelling Run 6015 has been used as a benchmark for this modelling run. This modelling run has used a 1.5x the Post to Pre attenuation volumes. This model provides a 50% Overcontrol Scenario within the Soper Springs Secondary Development plan area only. All other development areas are un-controlled.
6120_Pr Tributary Level ABL OverControlled_wOverflows_100%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. The Post to Pre attenuation scenario has been used as a benchmark for this modelling run. This modelling run has used a 2.0x the Post to Pre attenuation volumes. This model provides a 100% Overcontrol Scenario.

Run ID	Land Use	Level	Attenuation Provided? (Y/N)	Description
6121_Pr Tributary Level ABL_Soper Springs Over Control Only_100%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. Modelling Run 6015 has been used as a benchmark for this modelling run. This modelling run has used a 2.0x the Post to Pre attenuation volumes. This model provides a 100% Overcontrol Scenario within the Soper Springs Secondary Development plan area only. All other development areas are un-controlled.
6210_Pr Tributary Level ABL UnderControlled_wOverflows_25%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. The Post to Pre attenuation scenario has been used as a benchmark for this modelling run. This modelling run has used a 0.75x the Post to Pre attenuation volumes. This model provides a 25% Under Control Scenario.
6215_Pr Tributary Level ABL UnderControlled_wOverflows_50%	Future	Tributary	Y	Aquafor Future Condition Controlled Model. The Post to Pre attenuation scenario has been used as a benchmark for this modelling run. This modelling run has used a 0.50x the Post to Pre attenuation volumes. This model provides a 50% Under Control Scenario.
7005_Ex Tributary Level ABL_wCC	Future	Tributary	N	Aquafor Modified VO Existing Condition Model (2-100yr) with Climate Change Rainfall Data
7010_Pr Tributary Level ABL UnControlled_wCC	Future	Tributary	N	Aquafor Future Condition Un-Controlled Model (2-100yr) with Climate Change Rainfall Data
8000_Pr Tributary Level ABL_LID Sizing	Future	Tributary	Y	Aquafor Future Conditions model. Proposed bioretention cells have been sized for all Proposed Development areas to maintain post to pre 27mm runoff volume targets. Bioretention was used for modeling purposes; **Table 8.2** outlines permitted LID types based on land use.

Run ID	Land Use	Level	Attenuation Provided? (Y/N)	Description
8001_Pr Tributary Level ABL_Soper Springs Over Control Only_50%+LID	Future	Tributary	Y	This modelling run has combined the attenuation scenario of Modelling Run 6116 and the LID features of Modelling Run 8000. This modelling run has been completed for the 2-100year events.

To illustrate the peak flow impacts associated with the various stormwater quantity control modelling runs, we have selected three flow nodes within the study area as reference points. The most upstream flow node is Flow Node 179, located downstream of the Soper Springs Secondary Plan Area at Concession Street on the Main branch of Soper Creek, Reach SM6. The second flow node is Flow Node 232 located at the western limits of the Soper Hills Secondary Plan Area on Reach SE1. The third flow node is Flow Node 100, located at the downstream limits of the project area at King Street East on Reach SM6. **Figure 6.3** illustrates an absolute comparison of 100-year peak flow rates of all attenuation modelling runs vs existing conditions.

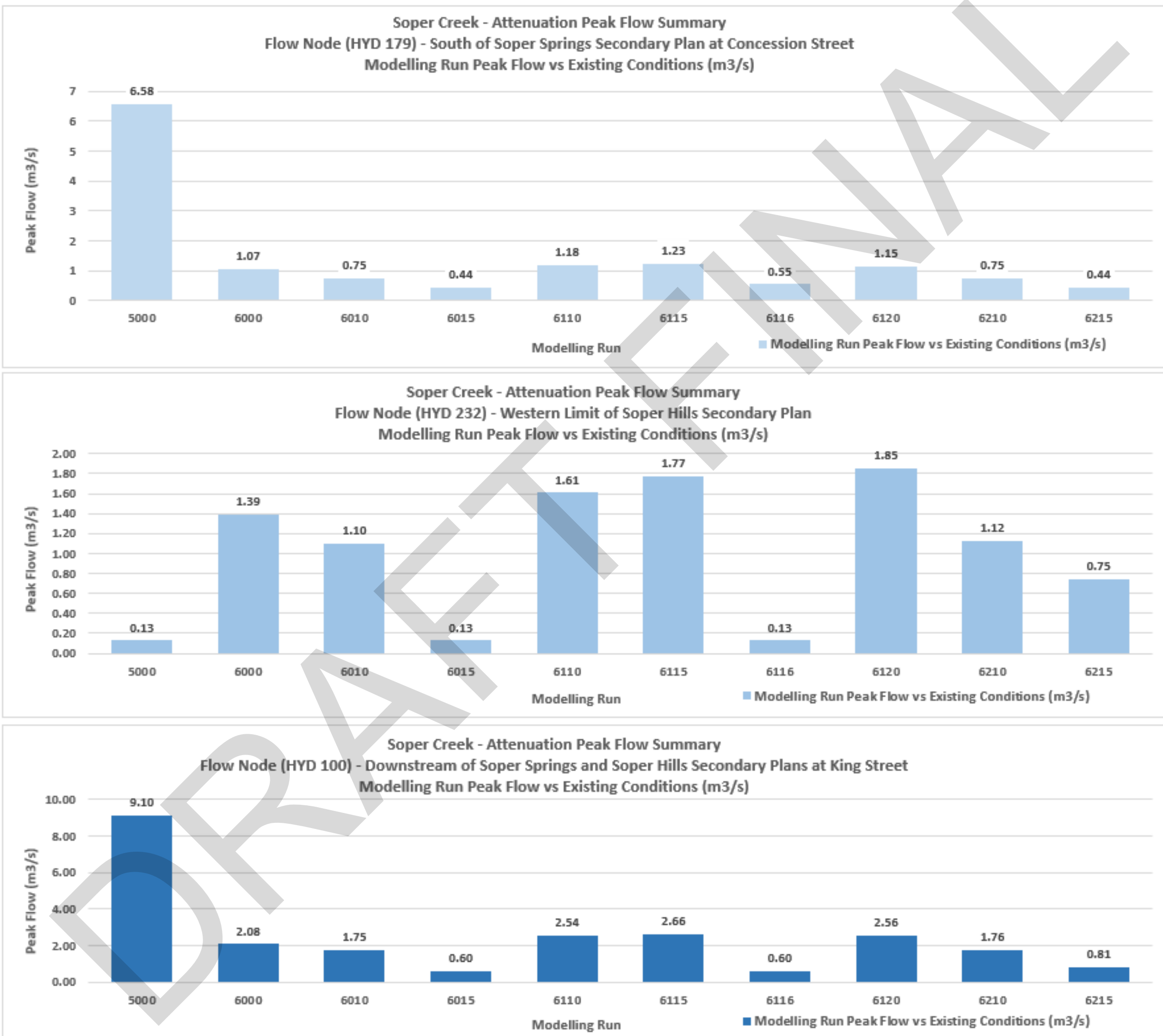

Figure 6.3: 100-year - Attenuation Modelling Runs vs Existing Conditions (m^3/s)

Despite the wide range of modelling scenarios undertaken in attempt to reduce future condition peak flows to existing condition flow rates, all attenuation scenarios undertaken for this analysis have resulted in peak flow increases throughout the watershed. While some peak flow increases are significantly more than others, the un-controlled scenario (5000) and Post to

Pre-Controls in the Soper Springs Secondary Plan Only (6015) provide the highest flow increases across all three flow nodes referenced. Accordingly, both of these modelling scenarios have not been carried forward for further consideration.

When comparing the peak flow comparisons of the Over Controlled Modelling Runs 6110, 6115, 6120, despite the wide range of attenuation volumes within the scenarios, there are minor differences between modelling scenarios through the three flow nodes of reference. For example, Flow Node 100 shows future condition peak flows of 2.54m^3/s, 2.66m^3/s, and 2.56m^3/s above Existing Conditions at the three flow nodes. This indicates that over-controls on all future development areas increases peak flows within the watershed due to peak flow timing. Providing only Minor System attenuation of the 2, 5, and 10-year peak flows associated with Modelling Run 6010, also increases peak flows within the watershed by 1.75m^3/s at Flow Node 100.

Under-Controlled Modelling Runs 6210 and 6215 provide a net reduction in quantity control volumes across all future development areas. A 50% reduction in post to pre attenuation volumes associated with modelling run 6215 produces lower peak flow increases than directly compared to all of the Over Control scenarios. While Modelling Run 6215 does illustrate peak flow increases throughout the watershed, this scenario provides the best attenuation scenario discussed to this point.

Based on the above observations, peak flow attenuation within the Soper Hills Secondary Plan increases peak flows to Reach SE1 (Eastern Tributary of Soper Creek) above the Future Un-Controlled condition. While the Future Un-Controlled condition does in-fact increase peak flow rates within Reach SE1, on a relative basis, peak flow increases are relatively muted in the Un-Controlled Scenario at 0.3% for the 100-year event at the western limit of the Soper Hills Secondary Plan Area. Therefore, based on the above analyses and direct comparison to existing conditions, an absence of stormwater quantity controls in the Soper Hills Secondary plan area provides the least impact to peak flows with Reach SE1. This is largely attributed to peak flow timing within the watershed as peak flows within the Soper Hills Secondary Plan areas are permitted to leave the system prior to peak flows upstream of the Secondary Plan area arriving at the same location. As such, subsequent modelling runs were focused on attenuation within the Soper Springs area only.

Figure 6.3 has been repeated below as **Figure 6.4** with an emphasis on Modelling Run 6015 – Soper Springs Post to Pre-Attenuation Only (green boxes) and Modelling Run 6116 – Soper Springs 50% Over-Control (red boxes).

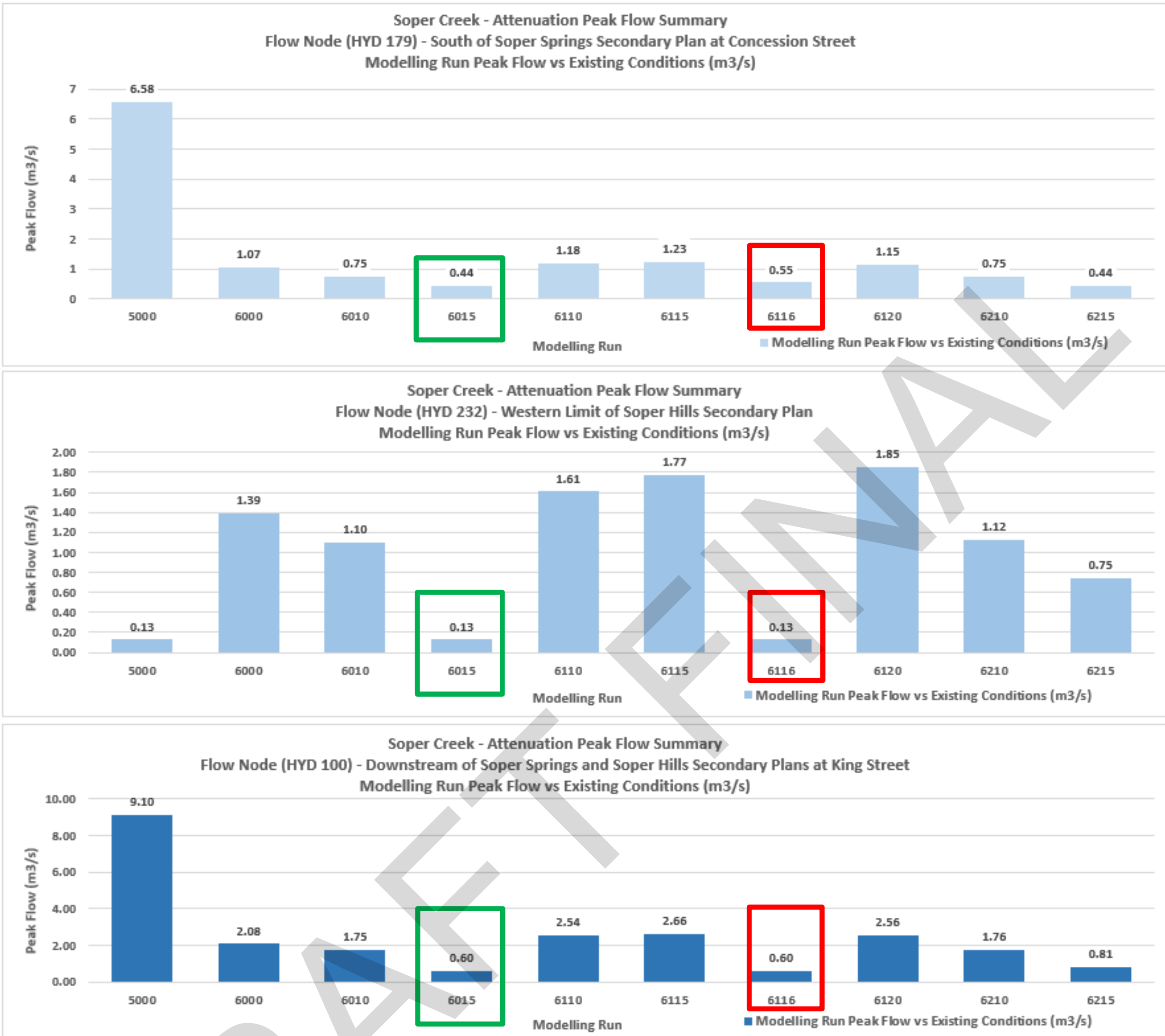

Figure 6.4: 100-year - Attenuation Modelling Runs vs Existing Conditions (m3/s) – Focus on Soper Springs

Reach SM6 (Main Reach of Soper Creek), which accepts direct runoff from the Soper Springs Secondary Plans and Camp 30 Lands, shows increases in peak flows on Modelling Run 6015 and 6116 for all flow nodes. However, peak flow increases between both modelling runs are identical at Flow Nodes 232 and 100. Similar to previous discussions on the Soper Hills Secondary Plan area, Flow Node 232 shows minimal increases. This again supports the previous statement regarding the importance of an absence of quantity controls within the Soper Hills Secondary Plan area.

However, there is a marginal difference in 100-year peak flows at Flow Node 179. Modelling Run 6116 – Soper Springs 50% Over-Control (red boxes) shows a slightly higher peak flow rate of 0.55m^3/s vs Modelling Run 6015 – Soper Springs Post to Pre-Control Only (green boxes) of 0.44m^3/s.

A direct comparison of peak flows in the 100-year event for all attenuation scenarios has been provided in **Table 6.10**. Modelling Runs 6015 and 6116 have been identified in **BOLD** for reference**.** A detailed view of flow comparisons at all flow node locations for the 2, 5, 10, 25, 50, 100-year and Regional Events for Modelling Run 6015 has been provided in **Table 6.11**. Additional commentary between Modelling Run's 6015 and 6116 has been provided in the following sections of this report.

Table 6.10: 100-year Attenuation Modelling Runs vs Existing Conditions (m^3/s) – All Scenarios - Focus on Soper Springs Post to Pre-Control in Bold (6015,6116)

Proposed SWM Pond Scenario Comparison Matrix Flow Nodes

Peak Flow (m3/s)

Reach	HYD	Location	Existing 4000 100yr	UnControlled 5000 100yr	Controlled Post to Pre 6000 100yr	Controlled Post to Pre Minor System Control Only 6010 100yr	Soper Springs Post to Pre Only 6015 100yr	25% OverControl 6110 100yr	50% OverControl 6115 100yr	Soper Springs 50% OverControl Only 6116 100yr	100% OverControl 6120 100yr	25% Under Control 6210 100yr	50% UnderControl 6215 100yr
SM19	248	Liberty Street	7.69	7.69			**7.69**			**7.69**			
SM19	250	Soper Springs - DS of SWM SS Pond 3	8.11	8.11			**8.17**			**8.19**			
SM19	251	Soper Springs - DS of SWM SS Pond 1	8.51	15.47			**8.90**			**8.93**			
SM6	66	Soper Springs	85.02	103.62	85.23	84.99	**85.21**	85.15	85.08	**85.08**	84.96	85.15	85.06
SM6	68	Concession Road 3	92.35	110.54	93.07	92.32	**93.05**	92.86	92.66	**92.66**	92.28	92.91	92.54
SM6	72	Rail Line	91.23	97.36	91.79	91.61	**91.78**	91.84	91.85	**91.85**	91.79	91.63	91.46
SM6	73	Downstream of Rail Line	92.22	98.33	92.78	92.61	**92.77**	92.83	92.85	**92.85**	92.78	92.62	92.45
SM6	131	Camp 30	4.13	4.13	4.13	4.13	**4.13**	4.13	4.13	**4.13**	4.13	4.13	4.13
SM6	166	Camp 30	4.54	4.49	4.71	4.57	**4.49**	4.66	4.61	**4.49**	4.54	4.66	4.61
SM6	167	Camp 30	93.24	99.76	93.92	93.71	**93.81**	93.98	94.00	**93.88**	93.92	93.72	93.53
SM6	176	Camp 30	93.67	100.15	94.71	94.44	**94.18**	94.85	94.94	**94.24**	94.92	94.41	94.10
SM6	168	Camp 30	93.83	100.35	94.95	94.65	**94.32**	95.09	95.18	**94.39**	95.15	94.62	94.27
SM6	179	Concession Street	88.27	94.85	89.34	89.02	**88.71**	89.45	89.50	**88.82**	89.42	89.02	88.71
SM6	79	Camp 30	87.89	94.51	88.93	88.63	**88.32**	89.05	89.10	**88.36**	89.02	88.63	88.33
SE1	185	Rail Line	3.47	3.47	3.47	3.47	**3.47**	3.47	3.47	**3.47**	3.47	3.47	3.47
SE2	96	Bragg Road	25.60	25.60	25.60	25.60	**25.60**	25.60	25.60	**25.60**	25.60	25.60	25.60
SE1	186	Reach Confluence Upstream of Concession St	33.62	33.62	33.62	33.62	**33.62**	33.62	33.62	**33.62**	33.62	33.62	33.62
SE1	190	Concession St East	36.09	36.13	36.38	36.32	**36.13**	36.41	36.42	**36.13**	36.39	36.32	36.24
SE1	198	Soper Hills East Development Limit	38.73	38.77	39.03	38.96	**38.77**	39.05	39.03	**38.77**	39.00	38.97	38.90
SE1	211	Soper Hills	38.50	38.65	39.21	39.11	**38.65**	39.32	39.37	**38.65**	39.38	39.10	38.96
SE1a	214	Soper Hills	6.57	6.57	6.57	6.57	**6.57**	6.57	6.57	**6.57**	6.57	6.57	6.57
SE1	217	Soper Hills	42.03	42.17	42.92	42.77	**42.17**	43.12	43.20	**42.17**	43.24	42.78	42.57
SE1	225	Soper Hills	41.75	41.90	42.74	42.51	**41.90**	42.92	43.01	**41.90**	42.97	42.60	42.31
SE1	232	Soper Hills West Development Limit	42.75	42.88	44.15	43.85	**42.88**	44.36	44.53	**42.88**	44.60	43.88	43.50
SM6	100	King Street East	117.31	126.41	119.39	119.05	**117.91**	119.85	119.97	**117.91**	119.87	119.07	118.12
SM7	104	Bowmanville Cemetary	123.01	132.31	125.12	124.79	**123.62**	125.60	125.71	**123.42**	125.58	124.83	123.80
SM1	106	Highway 401	123.92	133.29	126.24	125.90	**124.52**	126.72	126.81	**124.41**	126.49	125.95	124.61
SM1	109	D/S West Beach Road	124.18	133.59	126.49	126.15	**124.78**	126.96	127.06	**124.66**	126.76	126.18	124.85

Scenario Peak Flow vs Existing Conditions (m3/s)

Reach	HYD	Location	UnControlled 5000 100yr	Controlled Post to Pre 6000 100yr	Controlled Post to Pre Minor System Control Only 6010 100yr	Soper Springs Post to Pre Only 6015 100yr	25% OverControl 6110 100yr	50% OverControl 6115 100yr	Soper Springs 50% OverControl Only 6116 100yr	100% OverControl 6120 100yr	25% Under Control 6210 100yr	50% UnderControl 6215 100yr
SM19	248	Liberty Street	0.00			**0.00**			**0.00**			
SM19	250	Soper Springs - DS of SWM SS Pond 3	0.00			**0.06**			**0.07**			
SM19	251	Soper Springs - DS of SWM SS Pond 1	6.96			**0.40**			**0.43**			
SM6	66	Soper Springs	18.60	0.21	-0.03	**0.19**	0.14	0.06	**0.06**	-0.06	0.13	0.04
SM6	68	Concession Road 3	18.19	0.72	-0.03	**0.70**	0.51	0.31	**0.31**	-0.07	0.56	0.19
SM6	72	Rail Line	6.13	0.56	0.38	**0.55**	0.61	0.62	**0.62**	0.56	0.40	0.23
SM6	73	Downstream of Rail Line	6.11	0.56	0.38	**0.55**	0.61	0.63	**0.63**	0.56	0.40	0.23
SM6	131	Camp 30	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00
SM6	166	Camp 30	-0.04	0.17	0.03	**-0.04**	0.12	0.08	**-0.04**	0.01	0.13	0.07
SM6	167	Camp 30	6.52	0.68	0.47	**0.57**	0.74	0.76	**0.63**	0.68	0.48	0.29
SM6	176	Camp 30	6.47	1.04	0.77	**0.50**	1.17	1.26	**0.57**	1.25	0.73	0.42
SM6	168	Camp 30	6.53	1.12	0.82	**0.50**	1.27	1.35	**0.56**	1.32	0.79	0.45
SM6	179	Concession Street	6.58	1.07	0.75	**0.44**	1.18	1.23	**0.55**	1.15	0.75	0.44
SM6	79	Camp 30	6.62	1.04	0.73	**0.42**	1.16	1.20	**0.47**	1.13	0.74	0.43
SE1	185	Rail Line	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00
SE2	96	Bragg Road	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00
SE1	186	Reach Confluence Upstream of Concession St	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00
SE1	190	Concession St East	0.05	0.30	0.23	**0.05**	0.32	0.33	**0.05**	0.30	0.23	0.15
SE1	198	Soper Hills East Development Limit	0.05	0.30	0.23	**0.05**	0.32	0.30	**0.05**	0.27	0.24	0.18
SE1	211	Soper Hills	0.14	0.71	0.61	**0.14**	0.82	0.87	**0.14**	0.88	0.60	0.45
SE1a	214	Soper Hills	0.00	0.00	0.00	**0.00**	0.00	0.00	**0.00**	0.00	0.00	0.00
SE1	217	Soper Hills	0.14	0.89	0.74	**0.14**	1.09	1.18	**0.14**	1.21	0.75	0.54
SE1	225	Soper Hills	0.15	0.99	0.76	**0.15**	1.17	1.26	**0.15**	1.22	0.85	0.56
SE1	232	Soper Hills West Development Limit	0.13	1.39	1.10	**0.13**	1.61	1.77	**0.13**	1.85	1.12	0.75
SM6	100	King Street East	9.10	2.08	1.75	**0.60**	2.54	2.66	**0.60**	2.56	1.76	0.81
SM7	104	Bowmanville Cemetary	9.30	2.11	1.79	**0.61**	2.59	2.71	**0.41**	2.57	1.82	0.80
SM1	106	Highway 401	9.38	2.32	1.98	**0.60**	2.80	2.89	**0.49**	2.57	2.04	0.70
SM1	109	D/S West Beach Road	9.42	2.31	1.97	**0.60**	2.78	2.88	**0.48**	2.58	2.00	0.67

Scenario Peak Flow vs Existing Conditions (%)

Reach	HYD	Location	UnControlled 5000 100yr	Controlled Post to Pre 6000 100yr	Controlled Post to Pre Minor System Control Only 6010 100yr	Soper Springs Post to Pre Only 6015 100yr	25% OverControl 6110 100yr	50% OverControl 6115 100yr	Soper Springs 50% OverControl Only 6116 100yr	100% OverControl 6120 100yr	25% Under Control 6210 100yr	50% UnderControl 6215 100yr
SM19	248	Liberty Street	0.0%			**0.0%**			**0.0%**			
SM19	250	Soper Springs - DS of SWM SS Pond 3	0.0%			**0.7%**			**0.9%**			
SM19	251	Soper Springs - DS of SWM SS Pond 1	81.9%			**4.7%**			**5.0%**			
SM6	66	Soper Springs	21.9%	0.2%	0.0%	**0.2%**	0.2%	0.1%	**0.1%**	-0.1%	0.2%	0.0%
SM6	68	Concession Road 3	19.7%	0.8%	0.0%	**0.8%**	0.6%	0.3%	**0.3%**	-0.1%	0.6%	0.2%
SM6	72	Rail Line	6.7%	0.6%	0.4%	**0.6%**	0.7%	0.7%	**0.7%**	0.6%	0.4%	0.2%
SM6	73	Downstream of Rail Line	6.6%	0.6%	0.4%	**0.6%**	0.7%	0.7%	**0.7%**	0.6%	0.4%	0.2%
SM6	131	Camp 30	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%
SM6	166	Camp 30	-1.0%	3.7%	0.7%	**-1.0%**	2.7%	1.7%	**-1.0%**	0.2%	2.8%	1.6%
SM6	167	Camp 30	7.0%	0.7%	0.5%	**0.6%**	0.8%	0.8%	**0.7%**	0.7%	0.5%	0.3%
SM6	176	Camp 30	6.9%	1.1%	0.8%	**0.5%**	1.3%	1.3%	**0.6%**	1.3%	0.8%	0.4%
SM6	168	Camp 30	7.0%	1.2%	0.9%	**0.5%**	1.4%	1.4%	**0.6%**	1.4%	0.8%	0.5%
SM6	179	Concession Street	7.5%	1.2%	0.8%	**0.5%**	1.3%	1.4%	**0.63%**	1.3%	0.9%	0.5%
SM6	79	Camp 30	7.5%	1.2%	0.8%	**0.5%**	1.3%	1.4%	**0.5%**	1.3%	0.8%	0.5%
SE1	185	Rail Line	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%
SE2	96	Bragg Road	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%
SE1	186	Reach Confluence Upstream of Concession St	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%
SE1	190	Concession St East	0.1%	0.8%	0.6%	**0.1%**	0.9%	0.9%	**0.1%**	0.8%	0.6%	0.4%
SE1	198	Soper Hills East Development Limit	0.1%	0.8%	0.6%	**0.1%**	0.8%	0.8%	**0.1%**	0.7%	0.6%	0.5%
SE1	211	Soper Hills	0.4%	1.8%	1.6%	**0.4%**	2.1%	2.3%	**0.4%**	2.3%	1.6%	1.2%
SE1a	214	Soper Hills	0.0%	0.0%	0.0%	**0.0%**	0.0%	0.0%	**0.0%**	0.0%	0.0%	0.0%
SE1	217	Soper Hills	0.3%	2.1%	1.8%	**0.3%**	2.6%	2.8%	**0.3%**	2.9%	1.8%	1.3%
SE1	225	Soper Hills	0.4%	2.4%	1.8%	**0.4%**	2.8%	3.0%	**0.4%**	2.9%	2.0%	1.3%
SE1	232	Soper Hills West Development Limit	0.3%	3.3%	2.6%	**0.3%**	3.8%	4.1%	**0.3%**	4.3%	2.6%	1.7%
SM6	100	King Street East	7.8%	1.8%	1.5%	**0.5%**	2.2%	2.3%	**0.51%**	2.2%	1.5%	0.7%
SM7	104	Bowmanville Cemetary	7.6%	1.7%	1.5%	**0.5%**	2.1%	2.2%	**0.3%**	2.1%	1.5%	0.6%
SM1	106	Highway 401	7.6%	1.9%	1.6%	**0.5%**	2.3%	2.3%	**0.4%**	2.1%	1.6%	0.6%
SM1	109	D/S West Beach Road	7.6%	1.9%	1.6%	**0.5%**	2.2%	2.3%	**0.4%**	2.1%	1.6%	0.5%

Table 6.11: Modelling Run 6015 - Soper Springs Post to Pre-Control vs Existing Conditions (m^3/s) – All Flows (2 to100yr)

Modelling Run 6015 Proposed Soper Springs Only - Post to Pre Control Conditions			Peak Flow (m3/s)						Proposed Conditions vs Existing Conditions (m3/s)						Proposed Conditions vs Existing Conditions (%)					
Reach	HYD	Location	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM19	250	Soper Spring - DS of SWM SS Pond 3	1.68	3.07	4.15	5.66	6.90	8.17	0.04	0.05	0.05	0.05	0.05	0.06	2.44%	1.62%	1.24%	0.89%	0.79%	0.71%
SM19	251	Soper Spring - DS of SWM SS Pond 1	1.99	3.47	4.62	6.24	7.55	8.90	0.23	0.27	0.29	0.33	0.36	0.40	13.36%	8.38%	6.77%	5.65%	5.02%	4.68%
SM6	66	Soper Springs	60.61	69.22	76.32	81.58	86.88	85.21	0.10	0.13	0.16	0.18	0.19	0.19	0.17%	0.19%	0.22%	0.23%	0.22%	0.23%
SM6	68	Concession Road 3	62.60	72.67	80.85	87.48	93.78	93.05	0.35	0.46	0.56	0.64	0.68	0.70	0.56%	0.63%	0.70%	0.74%	0.73%	0.76%
SM6	72	Rail Line	40.13	48.92	56.57	64.20	77.41	91.78	0.37	0.47	0.50	0.57	0.52	0.55	0.92%	0.97%	0.90%	0.90%	0.67%	0.61%
SM6	73	Downstream of Rail Line	39.44	48.67	56.24	64.49	78.29	92.77	0.38	0.45	0.49	0.57	0.52	0.55	0.97%	0.94%	0.89%	0.89%	0.67%	0.60%
SM6	131	Camp 30	0.87	1.59	2.14	2.90	3.51	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM6	166	Camp 30	1.27	1.96	2.42	3.16	3.82	4.49	0.33	0.22	0.08	-0.01	-0.03	-0.04	34.28%	12.90%	3.46%	-0.44%	-0.75%	-0.97%
SM6	167	Camp 30	36.07	45.87	54.60	65.59	79.45	93.81	0.45	0.46	0.53	0.52	0.56	0.57	1.26%	1.02%	0.99%	0.79%	0.71%	0.61%
SM6	176	Camp 30	35.84	45.95	54.82	65.97	79.86	94.18	0.43	0.44	0.47	0.49	0.54	0.50	1.21%	0.96%	0.86%	0.76%	0.68%	0.54%
SM6	168	Camp 30	34.86	45.18	53.99	66.06	79.99	94.32	0.44	0.43	0.45	0.50	0.60	0.50	1.28%	0.97%	0.84%	0.76%	0.76%	0.53%
SM6	179	Concession Street	25.99	36.31	46.45	62.36	75.20	88.71	0.41	0.42	0.40	0.43	0.34	0.44	1.61%	1.16%	0.86%	0.70%	0.46%	0.50%
SM6	79	Camp 30	25.65	36.19	46.38	62.17	74.93	88.32	0.47	0.41	0.40	0.40	0.38	0.42	1.86%	1.13%	0.86%	0.64%	0.52%	0.48%
SE1	185	Rail Line	0.78	1.40	1.86	2.48	2.97	3.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE2	96	Bragg Road	5.68	10.12	13.49	18.12	21.82	25.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	186	Reach Confluence Upstream of Concession St	7.23	13.06	17.49	23.60	28.52	33.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	190	Concession St East	7.79	14.05	18.85	25.35	30.70	36.13	0.04	0.05	0.05	0.05	0.05	0.05	0.58%	0.34%	0.25%	0.18%	0.16%	0.13%
SE1	198	Soper Hills East Development Limit	8.45	15.20	20.35	27.34	33.00	38.77	0.05	0.05	0.05	0.05	0.05	0.05	0.56%	0.33%	0.25%	0.19%	0.16%	0.12%
SE1	211	Soper Hills	8.51	15.25	20.37	27.29	32.89	38.65	0.13	0.15	0.15	0.15	0.14	0.14	1.51%	0.99%	0.73%	0.56%	0.43%	0.37%
SE1a	214	Soper Hills	1.49	2.64	3.51	4.69	5.62	6.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	217	Soper Hills	9.39	16.75	22.31	29.84	35.93	42.17	0.16	0.17	0.17	0.16	0.15	0.14	1.73%	1.03%	0.75%	0.55%	0.42%	0.35%
SE1	225	Soper Hills	9.35	16.65	22.18	29.64	35.67	41.90	0.16	0.18	0.17	0.17	0.16	0.15	1.72%	1.07%	0.78%	0.57%	0.45%	0.36%
SE1	232	Soper Hills West Development Limit	9.70	17.16	22.79	30.43	36.54	42.88	0.22	0.21	0.20	0.17	0.15	0.13	2.29%	1.23%	0.86%	0.56%	0.41%	0.30%
SM6	100	King Street East	32.96	50.30	64.17	83.95	100.74	117.91	0.74	0.58	0.63	0.55	0.70	0.60	2.29%	1.16%	0.99%	0.66%	0.70%	0.51%
SM7	104	Bowmanville Cemetary	34.27	53.28	67.98	88.65	106.01	123.62	0.86	0.57	0.61	0.62	0.71	0.61	2.58%	1.09%	0.91%	0.71%	0.67%	0.49%

Table 6.12: Modelling Run 6116 - Soper Springs Post to Pre-Control vs Existing Conditions (m^3/s) – All Flows (2 to100yr)

Modelling Run 6116 Proposed Soper Springs ONLY - 50% OverControlled Conditions			Peak Flow (m3/s)						Proposed Conditions vs Existing Conditions (m3/s)						Proposed Conditions vs Existing Conditions (%)					
Reach	HYD	Location	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM19	250	Soper Spring - DS of SWM SS Pond 3	1.67	3.07	4.15	5.66	6.91	8.19	0.04	0.05	0.05	0.05	0.06	0.07	2.20%	1.62%	1.29%	0.98%	0.94%	0.89%
SM19	251	Soper Spring - DS of SWM SS Pond 1	1.94	3.45	4.61	6.25	7.57	8.93	0.19	0.25	0.28	0.34	0.38	0.43	10.96%	7.91%	6.47%	5.81%	5.34%	5.02%
SM6	66	Soper Springs	60.58	69.18	76.27	81.52	86.80	85.08	0.08	0.09	0.11	0.12	0.11	0.06	0.13%	0.14%	0.15%	0.15%	0.12%	0.07%
SM6	68	Concession Road 3	62.54	72.57	80.71	87.29	93.53	92.66	0.29	0.35	0.41	0.45	0.42	0.31	0.46%	0.49%	0.52%	0.52%	0.46%	0.33%
SM6	72	Rail Line	40.06	48.80	56.43	64.05	77.46	91.85	0.30	0.35	0.36	0.42	0.57	0.62	0.74%	0.73%	0.64%	0.66%	0.74%	0.68%
SM6	73	Downstream of Rail Line	39.37	48.55	56.11	64.41	78.34	92.85	0.30	0.33	0.37	0.49	0.57	0.63	0.77%	0.69%	0.65%	0.76%	0.74%	0.68%
SM6	131	Camp 30	0.87	1.59	2.14	2.90	3.51	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM6	166	Camp 30	1.27	1.96	2.42	3.16	3.82	4.49	0.33	0.22	0.08	-0.01	-0.03	-0.04	34.28%	12.90%	3.46%	-0.44%	-0.75%	-0.97%
SM6	167	Camp 30	35.99	45.77	54.46	65.59	79.50	93.88	0.37	0.37	0.40	0.51	0.61	0.63	1.05%	0.81%	0.73%	0.78%	0.78%	0.68%
SM6	176	Camp 30	35.77	45.85	54.66	66.00	79.89	94.24	0.36	0.33	0.31	0.52	0.57	0.57	1.01%	0.73%	0.56%	0.79%	0.72%	0.61%
SM6	168	Camp 30	34.78	45.07	53.84	66.09	80.00	94.39	0.37	0.33	0.30	0.53	0.61	0.56	1.06%	0.74%	0.55%	0.80%	0.77%	0.60%
SM6	179	Concession Street	25.92	36.24	46.41	62.35	75.28	88.82	0.34	0.35	0.36	0.43	0.42	0.55	1.34%	0.98%	0.79%	0.69%	0.56%	0.63%
SM6	79	Camp 30	25.57	36.14	46.34	62.14	74.96	88.36	0.39	0.35	0.36	0.37	0.41	0.47	1.54%	0.98%	0.79%	0.59%	0.56%	0.53%
SE1	185	Rail Line	0.78	1.40	1.86	2.48	2.97	3.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE2	96	Bragg Road	5.68	10.12	13.49	18.12	21.82	25.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	186	Reach Confluence Upstream of Concession St	7.23	13.06	17.49	23.60	28.52	33.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	190	Concession Street East	7.79	14.05	18.85	25.35	30.70	36.13	0.04	0.05	0.05	0.05	0.05	0.05	0.58%	0.34%	0.25%	0.18%	0.16%	0.13%
SE1	198	Soper Hills East Development Limit	8.45	15.20	20.35	27.34	33.00	38.77	0.05	0.05	0.05	0.05	0.05	0.05	0.56%	0.33%	0.25%	0.19%	0.16%	0.12%
SE1	211	Soper Hills	8.51	15.25	20.37	27.29	32.89	38.65	0.13	0.15	0.15	0.15	0.14	0.14	1.51%	0.99%	0.73%	0.56%	0.43%	0.37%
SE1a	214	Soper Hills	1.49	2.64	3.51	4.69	5.62	6.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	217	Soper Hills	9.39	16.75	22.31	29.84	35.93	42.17	0.16	0.17	0.17	0.16	0.15	0.14	1.73%	1.03%	0.75%	0.55%	0.42%	0.35%
SE1	225	Soper Hills	9.35	16.65	22.18	29.64	35.67	41.90	0.16	0.18	0.17	0.17	0.16	0.15	1.72%	1.07%	0.78%	0.57%	0.45%	0.36%
SE1	232	Soper Hills West Development Limit	9.70	17.16	22.79	30.43	36.54	42.88	0.22	0.21	0.20	0.17	0.15	0.13	2.29%	1.23%	0.86%	0.56%	0.41%	0.30%
SM6	100	King Street East	32.90	50.22	64.06	83.86	100.66	117.91	0.68	0.49	0.52	0.46	0.62	0.60	2.11%	0.99%	0.81%	0.55%	0.62%	0.51%
SM7	104	Bowmanville Cemetary	34.22	53.19	67.88	88.48	105.91	123.42	0.81	0.49	0.51	0.45	0.61	0.41	2.42%	0.92%	0.76%	0.51%	0.58%	0.34%
SM1	106	Highway 401	32.72	53.65	68.45	89.27	106.86	124.41	0.77	0.51	0.51	0.42	0.59	0.49	2.42%	0.96%	0.76%	0.47%	0.56%	0.40%
SM1	109	D/S West Beach Road	32.78	53.79	68.63	89.53	107.10	124.66	0.76	0.51	0.51	0.43	0.60	0.48	2.38%	0.96%	0.75%	0.49%	0.56%	0.39%

Following the observations as noted above, an additional three flow nodes were added to the VO model, including Flow Nodes 248, 250 and 251 as illustrated in **Figure 6.5**.

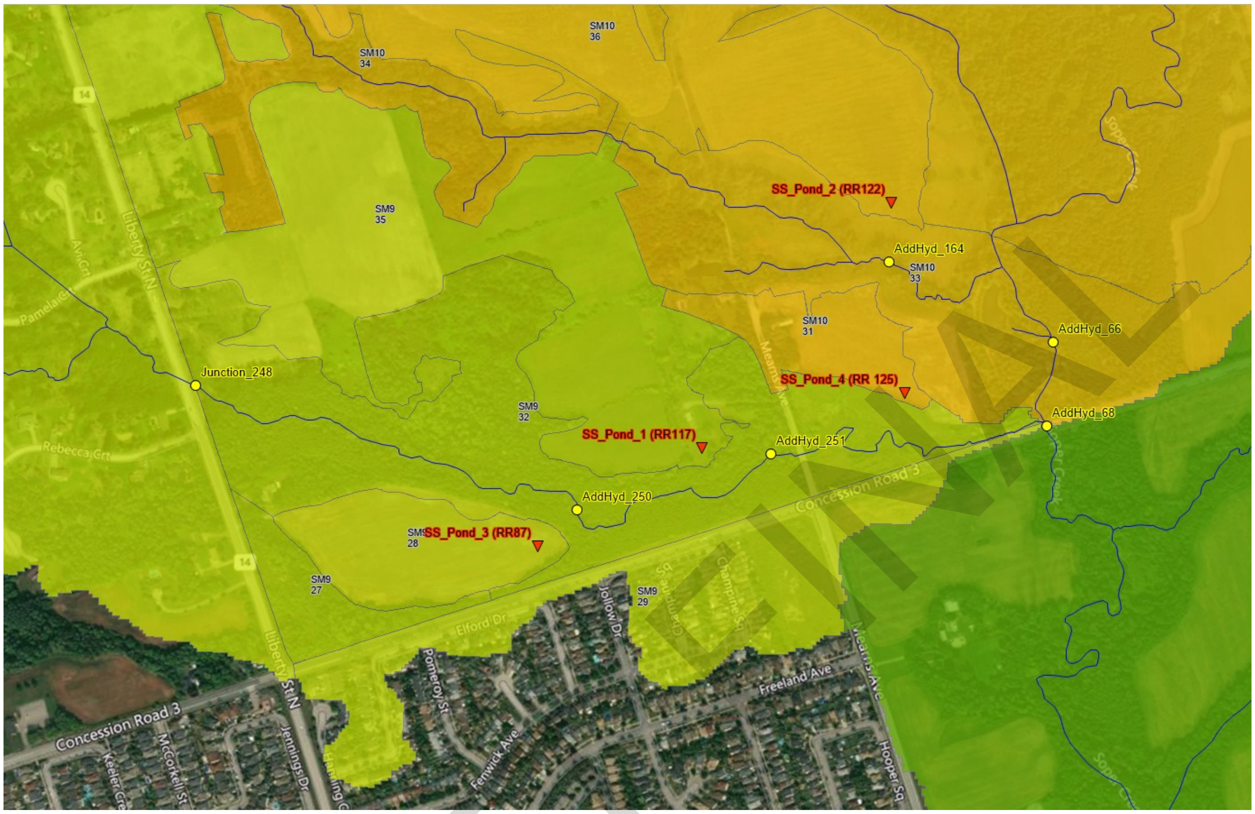

Figure 6.5: Soper Springs Secondary Plan – Additional Flow Nodes

The intent of placing these three additional flow nodes in the model was to observe the progression of associated impacts of peak flows within Reach SM19 of the Soper Springs secondary plan area. **Table 6.13** illustrates a side by side comparison between Modelling Runs 6015 and 6116 at Flow Nodes 248, 250 and 251.

Table 6.13: Modelling Scenarios 6015 and 6116 vs Existing Conditions

Modelling Run 6015 Proposed Soper Springs Only - Post to Pre Control Conditions			Peak Flow (m3/s)						Proposed Conditions vs Existing Conditions (m3/s)						Proposed Conditions vs Existing Conditions (%)					
Reach	HYD	Location	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM19	250	Soper Spring - DS of SWM SS Pond 3	1.68	3.07	4.15	5.66	6.90	8.17	0.04	0.05	0.05	0.05	0.05	0.06	2.44%	1.62%	1.24%	0.89%	0.79%	0.71%
SM19	251	Soper Spring - DS of SWM SS Pond 1	1.99	3.47	4.62	6.24	7.55	8.90	0.23	0.27	0.29	0.33	0.36	0.40	13.36%	8.38%	6.77%	5.65%	5.02%	4.68%

Modelling Run 6116 Proposed Soper Springs ONLY - 50% OverControlled Conditions			Peak Flow (m3/s)						Proposed Conditions vs Existing Conditions (m3/s)						Proposed Conditions vs Existing Conditions (%)					
Reach	HYD	Location	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM19	250	Soper Spring - DS of SWM SS Pond 3	1.67	3.07	4.15	5.66	6.91	8.19	0.04	0.05	0.05	0.05	0.06	0.07	2.20%	1.62%	1.29%	0.98%	0.94%	0.89%
SM19	251	Soper Spring - DS of SWM SS Pond 1	1.94	3.45	4.61	6.25	7.57	8.93	0.19	0.25	0.28	0.34	0.38	0.43	10.96%	7.91%	6.47%	5.81%	5.34%	5.02%

In comparing both modelling runs at Flow Node 251, when looking at Major System peak flows, Modelling Run 6015 produces lower peak flows in the 100-year event. Modelling Run 6116 produces lower peak flows in the 2, 5 and 10-year events than Modelling Run 6015. A transition between both modelling runs occur at the 25-year event.

While there are peak flow differences between Modelling Runs 6015 and 6116, differences are minor. As Reach SM19, located between Liberty Street North and Concession Road 3, does contain Species at Risk and contains locations of stable slope risk, we have carried Modelling Run 6116 forward for further analysis and consideration. However, we would recommend further analysis at the detailed design stage with regards to peak flow timing and impervious levels within the Soper Springs area.

A 50% increase in Post to Pre Attenuation Volumes in the Soper Springs Secondary Plan area has resulted in the most favorable Stormwater Quantity Control strategy explored to this point in this report. This scenario does still show a net flow increase at all Flow Node locations above Existing Conditions, including a small increase of 0.56m^3/s (0.63%) at Flow Node 179 and 0.60m^3/s (0.51%) at Flow Node 100.

The proposed Secondary Plans for the Soper Springs development areas identify a total of four (4) proposed stormwater management facilities. The quantity and locations of these proposed SWM facilities to identify attenuation volumes required for each SWM facility based on a m^3/ha basis in accordance with Modelling Run 6116. The results of the attenuation analysis have been provided in **Table 6.14**.

Table 6.14: Future Conditions (Detailed Scale) Attenuation Summary – 100-yr Event (m^3/s)

NHYD	Secondary Plan Dev. Area (ha)	Existing	Future (Controlled)	Difference (m^3/s)	# Ponds	Storage per Pond (m^3)	Storage Provided (m^3/ha)
SM9_35	28.21	1.774	1.16	-0.614	1	14,874.93	527.29
SM10_36	19.08	0.948	0.602	-0.346	1	7,802.97	408.96
SM9_28	4.9	0.421	0.261	-0.16	1	2,742.31	559.66
SM10_31	3.46	0.175	0.104	-0.071	1	1,897.35	548.37

Based on the total attenuation volume required per catchment, the total volume was divided by the number of ponds within the catchment to provide a total storage volume per pond required. The provided the required storage volume on a m^3/ha basis within the Secondary Plan areas.

The Future Overcontrolled peak flows are below the Existing Peak flow rates by up to 0.61m^3/s as shown in **Table 6.14**. The importance of this overcontrol of peak flows in the Secondary Plan areas is evident when looking outside the Secondary Plan areas and observing peak flow comparisons at the various flow nodes within the watershed. The comparison of controlled Future peak flows vs existing conditions is provided in **Figure 6.6.**

The objective of defining stormwater quantity control is to define storage volumes for proposed development such that peak flows within Soper Creek do not increase as a result of development. A total of 10 attenuation scenarios were analyzed within the Soper Creek watershed and included in this report using land use information which was available at the time of undertaking the study. Through this analysis, it was found that all 10 stormwater quantity control scenarios resulted in increases in peak flows at various flow nodes within the watershed. The storage volumes will need to be updated once further detailed work is completed, which will modify parameters such as percent impervious, drainage area and patterns, location of SWMF are updated through the Draft Plan phases. LID SWM facility locations will be identified during the site plan phase.

Figure 6.6: Regional Event - Modelling Runs 5000, 6015 and 6116 vs Existing Conditions (m³/s)

6.5 Hydraulic Analysis

Updated watershed level modelling has been completed as a part of the Soper Creek Subwatershed Study. Based on the results of **Section 6.3**, both the Watershed and Tributary level peak flows completed in this Subwatershed Study are lower than the original CLOCA peak flows. Accordingly, based on detailed discussions with both the Town and CLOCA, updated floodlines of the currently mapped reaches have not been reproduced within this report. However, new floodlines have been generated for Reaches SE1_1 and SM10_1, which were not previously mapped. Detailed mapping of these reaches is provided in **Appendix C**, along with the hydraulic structure summary sheets for the crossings on these reaches not previously surveyed.

6.5.1 Tributary Level Analysis

As detailed in **Section 6.3**, despite the attenuation alternatives considered, Future Condition peak flows are higher than Existing Conditions. However, while greater than Existing Conditions, 100-year Future Condition Peak flows of Modelling Run 6116 (Soper Springs 50% Over Control) are generally only up to 0.7% higher. This scenario best represents the proposed conditions within the subwatershed, and was therefore used to quantify the hydraulic impact of the of increase in peak flows on the various reaches within the subwatershed study. As such, the flow files in the original CLOCA HEC-RAS model were replaced with Tributary Level Existing (VO Modelling Run 4000) peak flows, Tributary Level Future Conditions (VO Modelling Run 6116) for the 2-100 year peak flows and finally, Tributary Level Future Conditions (VO Modelling Run 5050) for the Un-Controlled Regional Event.

While noting that proposed condition peak flows are higher than existing conditions, we would expect proposed water surface elevations to be higher than of existing conditions. However, nominal increases in water surface elevations (i.e., less than 0.04m) would be classified within the realm of standard modelling error and therefore not of significance for further analysis. Accordingly, to assess the potential hydraulic impacts of the preferred VO modelling Run 6116, a comparison of direct flow, water surface, shear and velocity was completed for all cross sections within the SWS where proposed water surface elevation differences are greater than 0.04m when compared to existing conditions. Three (3) reaches were identified which contain water surface elevations of 0.04m or greater including:

- Reach: SE1_Lower - located immediately downstream of the Soper Hills Secondary Plan area;
- Reach: SM19 – located at the southern limits of the Soper Springs Secondary Plan area and immediately upstream of Concession Road 3; and
- Reach: SM6 – main reach of Soper Creek between Concession Road 3 and King Street East.

Additional Hydraulic comparisons for all other flow events have been provided in **Appendix B**.

6.5.2 Reach: SE1_Lower

Within Reach SE_1 Lower, Cross Section 1519.615 shows a 5-year flood elevation increase of 0.19m. The commentary and Figure 6.7 that follows examines the flood elevation increase in additional detail.

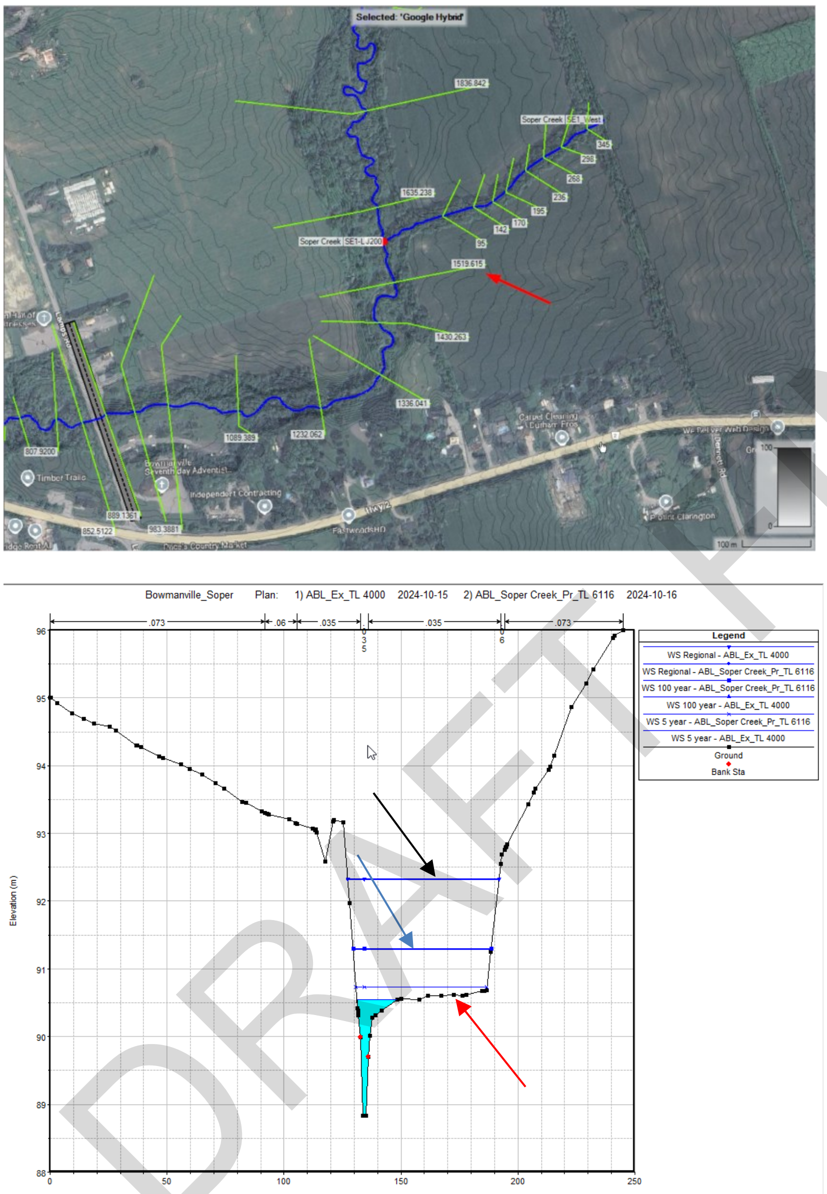

Figure 6.7: Reach SE1_Lower – Cross Section 1519.615 Plan View (Top) and Cross Section View (Bottom)

Cross Section 1519.615 is located immediately downstream of the Soper Hills Secondary Plan and also immediately downstream of Junction J200. Under existing conditions, the 5-year peak flow of 16.95m^3/s resides at bankfull capacity.

Under proposed conditions, peak flows increase by $0.21 m^3/s$ to $17.16 m^3/s$. As a result, the proposed 5-year peak flow is no longer contained within the low flow banks of the watercourse and spreads into the bottom of the valley corridor (red arrow in Figure 6.7).

As a result, the increased wetter perimeter and associated added surface area is directly attributed to the increase in water surface elevations at this cross section. We note however, despite the increase in the 5-year event we note that there are no impacts to the 100-year (blue arrow) or Regional Elevations (black arrow). We also note that both 100-year and Regional Flood Elevations are fully contained within the valley corridor in this location. Further, we note that the 5-year elevation increase is an isolated increase within this reach and is not experienced upstream or downstream of this cross section.

6.5.3 Reach: SM19

Within Reach SM19, Cross Section 482.8841 shows a flood elevation increases of 0.05-0.06m between the 2-100-year storm events. The commentary and Figure 6.8 that follows examines the flood elevation increase in additional detail.

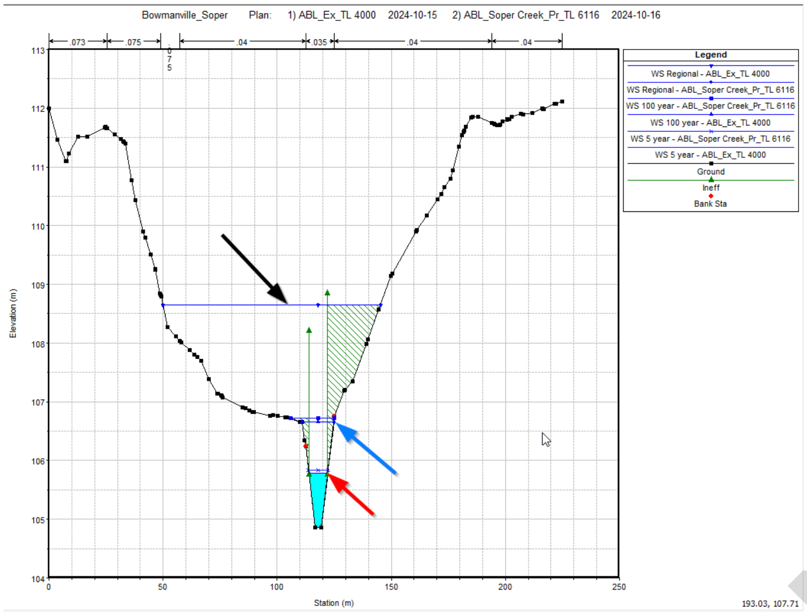

Figure 6.8: Reach SM19 – Cross Section 482.8841 Plan View (Top) and Cross Section View (Bottom)

Reach SM19 under future conditions is subjected to flow increases of 11% (+0.19m^3/s) in the 2-year event to 4.94% (+0.42m^3/s) in the 100-year event. Cross Section 482.8841 resides immediately upstream of the Mearns Ave roadway crossing.

Accordingly, as existing flows are restricted through this roadway crossing, it would stand to reason that flow increases associated with future conditions would be further restricted under future conditions. We note however, despite the increases in the 5-year event (red arrow) and 100-year (blue arrow), flows are contained within the valley corridor of the reach. We note that there are no impacts to the Regional Elevations (black arrow).

The increase in flood elevations associated with future conditions is limited to less than 20m upstream of the Mearns Ave roadway crossing.

6.5.4 Reach SM6

Within Reach SM6 there are 18 locations where future water surface elevations have observed to reside at 0.04m above existing conditions. A total of 9 locations have been observed where future water surface elevations have observed to reside in excess of 0.04m above existing conditions.

Cross Section 4945.543 is one of the cross-section locations within Reach SM6 that exhibits a flood elevation increase of 0.04m. We note that the flood elevation increase in most cases resides at the 50-year or 100-year level.

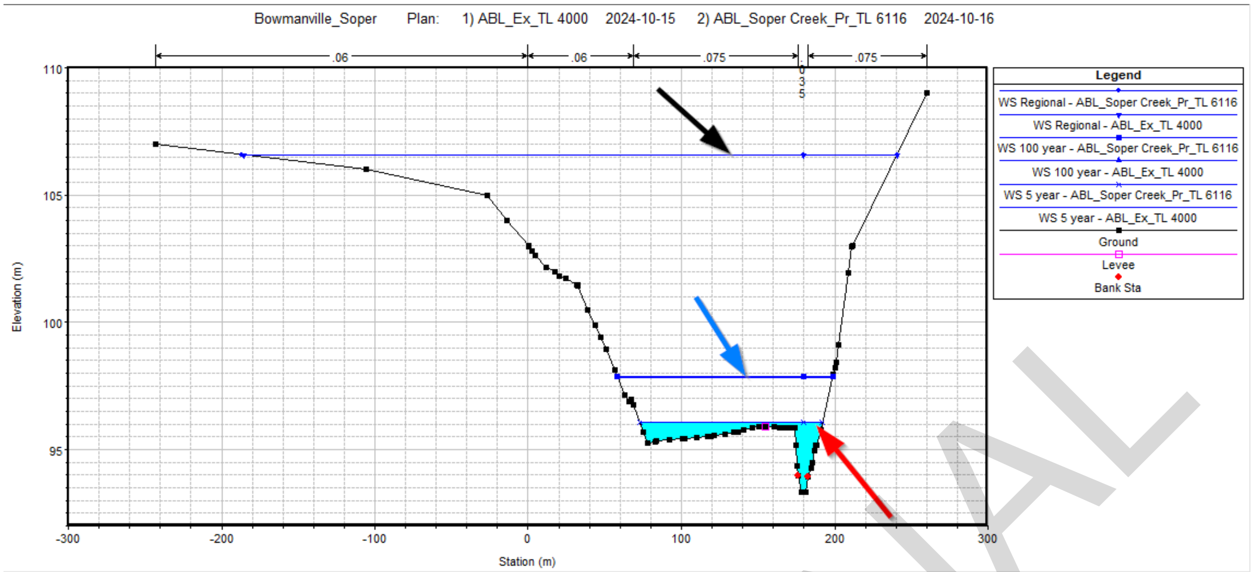

Figure 6.9: Reach SM6 – Cross Section 4945.543

As illustrated in Figure 6.9, above the 100-year flood elevation, the increase of 0.04m is attributed to a 0.34% (0.31m^3/s) flow increase at this location. While the flow increase does produce a flood elevation increase, we note that the flow increase is fully contained within the valley corridor. This observation is similar to other cross sections exhibiting the same elevation increase.

Cross Section 3737.857 is subject to a 0.74% (0.57m^3/s) flow increase in future conditions over existing conditions in the 50-year event. While less than a 1% flow increase is present at this location, the 50-year flood elevation increase has been observed at 0.26m and visually illustrated in Figure 6.10 below.

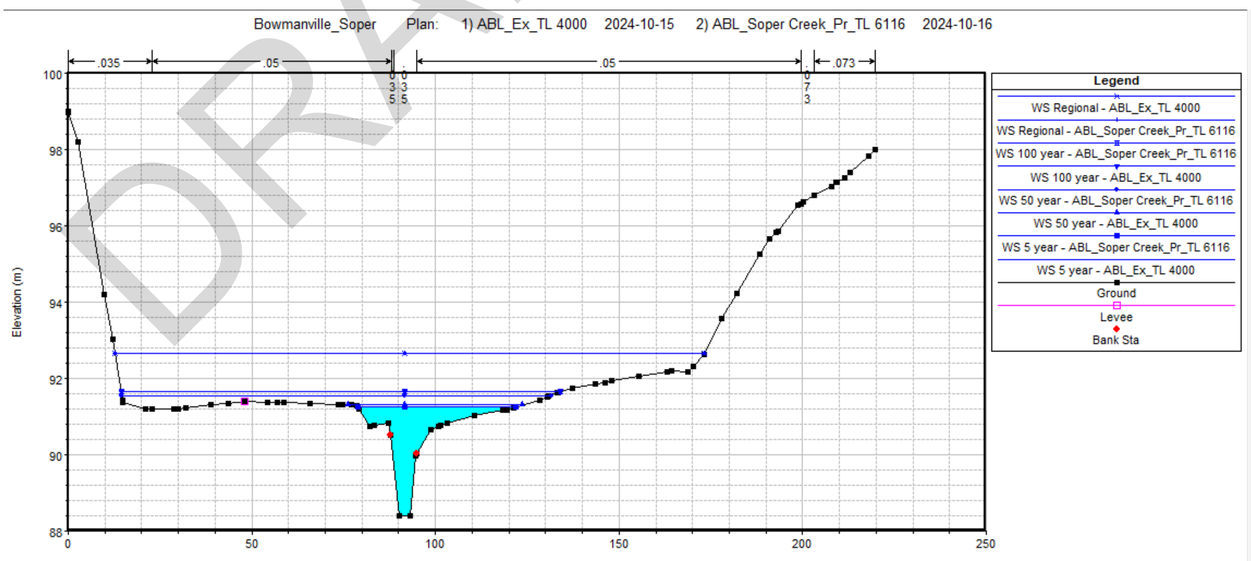

Figure 6.10: Reach SM6 – Cross Section 3737.857

For further discussion purposes we have also provided a section view of Cross Section 3871.795 located immediately upstream of Cross Section 3737.857 and a flow summary comparison illustrated in **Table 6.15** of other cross sections in the direct vicinity.

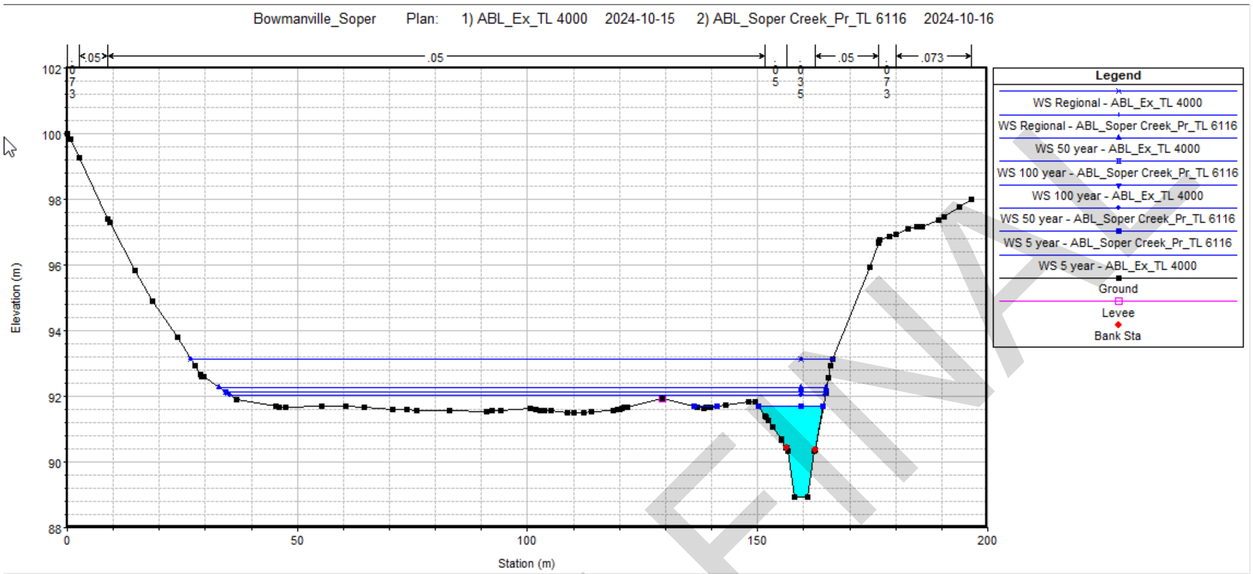

Figure 6.11: Reach SM6 – Cross Section 3871.795

A direct comparison of cross sections 3871.795 and 3737.857 reveals key differences in valley corridor topography which influence flood elevation differences. From a flow distribution perspective, at Cross Section 3737.857, visually, 60% of flows reside over the channel of the floodplain while visually 40% reside over the overbank areas. At cross section 3871.795, visually, 20% of flows reside over the channel of the floodplain while visually 80% reside over the overbank areas. Said another way, the way to which flow interact with the floodplain in this area is quite variable in the 50-year event. We note however, that at cross sections 3595.88 and 4029.458, the 50-year flood elevation differences between existing and proposed conditions is relatively muted at 0.04m or less.

Within the flood elevation differences noted to this stage in the report, we note that while the flood elevations are elevated above existing conditions, both shear stress and velocity are lower than existing conditions.

Table 6.15: Reach SM6, Cross Sections 4029.458 to 3595.98

Reach	River Sta	Profile	Existing Q Total (m3/s)	Proposed Q Total (m3/s)	Q Diff (m3/s)	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	W.S. Elev Diff. (m)	Existing Shear Chan (N/m2)	Proposed Shear Chan (N/m2)	Shear Chan Diff (N/m s)	Existing Vel Chnl (m/s)	Proposed Vel Chnl (m/s)	Vel Chnl Diff (m/s)
SM6	4029.458	25 year	63.63	64.05	0.42	92.39	92.39	0	47.95	48.2	0.25	2.240	2.25	0.010
SM6	4029.458	50 year	76.89	77.46	0.57	92.5	92.54	0.04	50.06	44.73	-5.33	2.31	2.19	-0.12
SM6	4029.458	100 year	91.23	91.85	0.62	92.62	92.62	0	49.76	50.2	0.44	2.320	2.33	0.010
SM6	3871.795	25 year	63.63	64.05	0.42	92.03	92.04	0.01	44.61	44.41	-0.2	2.210	2.2	-0.010
SM6	3871.795	50 year	76.89	77.46	0.57	92.26	92.03	-0.23	31.6	66.31	34.71	1.880	2.69	0.810
SM6	3871.795	100 year	91.23	91.85	0.62	92.13	92.13	0	67.12	66.46	-0.66	2.720	2.71	-0.010
SM6	3737.857	25 year	63.63	64.05	0.42	91.35	91.35	0	97.78	97.7	-0.08	3.120	3.12	0.000
SM6	3737.857	50 year	76.89	77.46	0.57	91.3	91.56	0.26	151.55	74.84	-76.71	3.87	2.77	-1.10
SM6	3737.857	100 year	91.23	91.85	0.62	91.64	91.64	0	78.68	79.72	1.04	2.850	2.87	0.020
SM6	3677.983	25 year	63.63	64.05	0.42	91.44	91.45	0.01	28.06	27.57	-0.49	1.720	1.7	-0.020
SM6	3677.983	50 year	76.89	77.46	0.57	91.3	91.2	-0.1	67.5	97.76	30.26	2.640	3.16	0.520
SM6	3677.983	100 year	91.23	91.85	0.62	91.41	91.42	0.01	62.77	61.5	-1.27	2.570	2.54	-0.030
SM6	3595.88	25 year	63.63	64.05	0.42	90.65	90.65	0	130.8	132.77	1.97	3.630	3.65	0.020
SM6	3595.88	50 year	76.89	77.46	0.57	91.11	91.13	0.02	40.02	39.16	-0.86	2.070	2.05	-0.020
SM6	3595.88	100 year	91.23	91.85	0.62	91.35	91.36	0.01	26.44	26.06	-0.38	1.710	1.7	-0.010

Table 6.16: Future Conditions (Detailed Scale) Attenuation Summary – 100-yr Event (m^3/s)

River	Reach	River Sta	Profile	Existing Q Total (m3/s)	Proposed Q Total (m3/s)	Q Diff (m3/s)	Existing W.S. Elev (m)	Proposed W.S. Elev (m)	W.S. Elev Diff. (m)	Existing Shear Chan (N/m2)	Proposed Shear Chan (N/m2)	Shear Chan Diff (N/m s)	Existing Vel Chnl (m/s)	Proposed Vel Chnl (m/s)	Vel Chnl Diff (m/s)	% Flow Difference	% Shear Difference	% Velocity Difference
Soper Creek	SE1_Lower	1519.615	5 year	16.95	17.16	0.21	90.54	90.73	0.19	103.52	45.87	-57.65	3.00	2.04	-0.96	1.24%	-55.69%	-32.00%
Soper Creek	SM19	482.8841	2 year	1.75	1.94	0.19	105.47	105.52	0.05	6.04	5.97	-0.07	0.62	0.62	0.00	10.86%	-1.16%	0.00%
Soper Creek	SM19	482.8841	5 year	3.2	3.45	0.25	105.79	105.84	0.05	5.4	5.28	-0.12	0.62	0.62	0.00	7.81%	-2.22%	0.00%
Soper Creek	SM19	482.8841	10 year	4.33	4.61	0.28	106	106.05	0.05	5.05	5.01	-0.04	0.63	0.63	0.00	6.47%	-0.79%	0.00%
Soper Creek	SM19	482.8841	25 year	5.91	6.25	0.34	106.27	106.32	0.05	4.97	4.97	0	0.65	0.66	0.01	5.75%	0.00%	1.54%
Soper Creek	SM19	482.8841	50 year	7.19	7.57	0.38	106.47	106.52	0.05	5.02	5.04	0.02	0.67	0.68	0.01	5.29%	0.40%	1.49%
Soper Creek	SM19	482.8841	100 year	8.51	8.93	0.42	106.66	106.72	0.06	5.1	5.14	0.04	0.69	0.70	0.01	4.94%	0.78%	1.45%
Soper Creek	SM6	5479.409	100 year	92.35	92.66	0.31	97.96	98	0.04	81.18	73.08	-8.1	2.95	2.81	-0.14	0.34%	-9.98%	-4.75%
Soper Creek	SM6	5398.18	100 year	92.35	92.66	0.31	97.97	98.01	0.04	19.48	18.2	-1.28	1.50	1.45	-0.05	0.34%	-6.57%	-3.33%
Soper Creek	SM6	5267.811	100 year	92.35	92.66	0.31	97.89	97.93	0.04	15.37	14.36	-1.01	1.34	1.30	-0.04	0.34%	-6.57%	-2.99%
Soper Creek	SM6	5015.943	100 year	92.35	92.66	0.31	97.86	97.9	0.04	4.94	4.73	-0.21	0.80	0.78	-0.02	0.34%	-4.25%	-2.50%
Soper Creek	SM6	4945.543	50 year	93.11	93.53	0.42	96.94	96.98	0.04	17.24	16.48	-0.76	1.46	1.43	-0.03	0.45%	-4.41%	-2.05%
Soper Creek	SM6	4945.543	100 year	92.35	92.66	0.31	97.85	97.89	0.04	5.11	4.91	-0.2	0.83	0.81	-0.02	0.34%	-3.91%	-2.41%
Soper Creek	SM6	4873.544	100 year	92.35	92.66	0.31	97.83	97.88	0.05	5.51	5.33	-0.18	0.87	0.85	-0.02	0.34%	-3.27%	-2.30%
Soper Creek	SM6	4774.082	50 year	93.11	93.53	0.42	96.89	96.93	0.04	7.8	7.56	-0.24	1.02	1.00	-0.02	0.45%	-3.08%	-1.96%
Soper Creek	SM6	4774.082	100 year	92.35	92.66	0.31	97.83	97.87	0.04	3.06	2.97	-0.09	0.66	0.65	-0.01	0.34%	-2.94%	-1.52%
Soper Creek	SM6	4678.019	100 year	92.35	92.66	0.31	97.83	97.87	0.04	3.11	3.03	-0.08	0.67	0.66	-0.01	0.34%	-2.57%	-1.49%
Soper Creek	SM6	4558.51	50 year	93.11	93.53	0.42	96.86	96.9	0.04	4.92	4.8	-0.12	0.82	0.81	-0.01	0.45%	-2.44%	-1.22%
Soper Creek	SM6	4558.51	100 year	92.35	92.66	0.31	97.82	97.86	0.04	2.25	2.19	-0.06	0.57	0.56	-0.01	0.34%	-2.67%	-1.75%
Soper Creek	SM6	4459.789	50 year	76.89	77.46	0.57	96.86	96.9	0.04	1.59	1.56	-0.03	0.47	0.47	0.00	0.74%	-1.89%	0.00%
Soper Creek	SM6	4459.789	100 year	91.23	91.85	0.62	97.82	97.86	0.04	1.08	1.06	-0.02	0.40	0.40	0.00	0.68%	-1.85%	0.00%
Soper Creek	SM6	4427.738	50 year	76.89	77.46	0.57	96.86	96.9	0.04	1.51	1.49	-0.02	0.46	0.46	0.00	0.74%	-1.32%	0.00%
Soper Creek	SM6	4427.738	100 year	91.23	91.85	0.62	97.82	97.86	0.04	1.11	1.09	-0.02	0.41	0.40	-0.01	0.68%	-1.80%	-2.44%
Soper Creek	SM6	4398.671	50 year	76.89	77.46	0.57	96.39	96.43	0.04	48.54	48.53	-0.01	2.67	2.68	0.01	0.74%	-0.02%	0.37%
Soper Creek	SM6	4029.458	50 year	76.89	77.46	0.57	92.5	92.54	0.04	50.06	44.73	-5.33	2.31	2.19	-0.12	0.74%	-10.65%	-5.19%
Soper Creek	SM6	3737.857	50 year	76.89	77.46	0.57	91.3	91.56	0.26	151.55	74.84	-76.71	3.87	2.77	-1.10	0.74%	-50.62%	-28.42%
Soper Creek	SM6	3113.564	5 year	45.4	45.77	0.37	88.74	88.88	0.14	57.89	35.49	-22.4	2.41	1.91	-0.50	0.81%	-38.69%	-20.75%
Soper Creek	SM6	2876.1	25 year	65.08	65.59	0.51	88.32	88.38	0.06	14.09	11.95	-2.14	1.21	1.12	-0.09	0.78%	-15.19%	-7.44%
Soper Creek	SM6	2772.416	25 year	65.08	65.59	0.51	88.24	88.31	0.07	14.73	12.18	-2.55	1.24	1.13	-0.11	0.78%	-17.31%	-8.87%
Soper Creek	SM6	2692.408	25 year	65.08	65.59	0.51	88.24	88.31	0.07	3.61	3.1	-0.51	0.63	0.58	-0.05	0.78%	-14.13%	-7.94%
Soper Creek	SM6	2611.559	2 year	35.62	35.99	0.37	87.52	87.56	0.04	22.42	12.77	-9.65	1.47	1.11	-0.36	1.04%	-43.04%	-24.49%
Soper Creek	SM6	2611.559	25 year	65.08	65.59	0.51	88.22	88.29	0.07	4.4	3.74	-0.66	0.69	0.64	-0.05	0.78%	-15.00%	-7.25%
Soper Creek	SM6	2586.727	25 year	65.08	65.59	0.51	88.21	88.29	0.08	3.99	3.43	-0.56	0.66	0.61	-0.05	0.78%	-14.04%	-7.58%
Soper Creek	SM6	2543.888	25 year	61.93	62.35	0.42	88.08	88.27	0.19	21.93	5.59	-16.34	1.54	0.79	-0.75	0.68%	-74.51%	-48.70%

The last cross section of note where future condition water surface elevations are elevated above existing conditions is cross section 2543.888. This cross section is located immediately upstream of the King Street East Roadway Crossing. Figure 6.12 below illustrates the 25-year water surface.

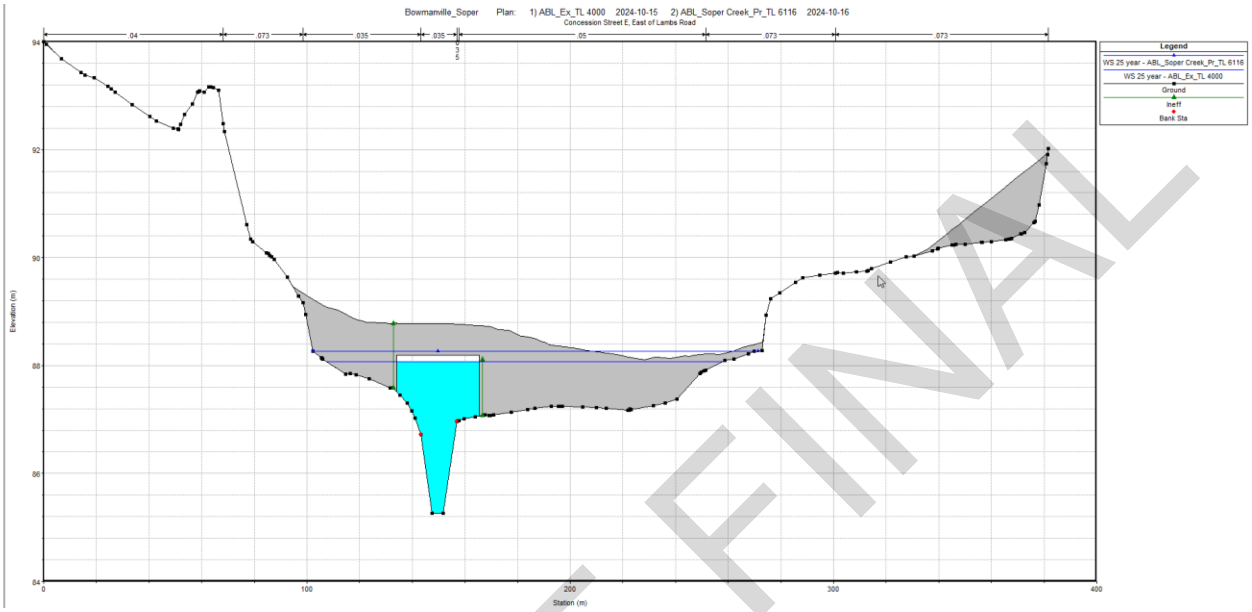

Figure 6.12: Reach SM6 – Bridge Internal Cross Section 2528.5458BR (Cross Section 2543.888)

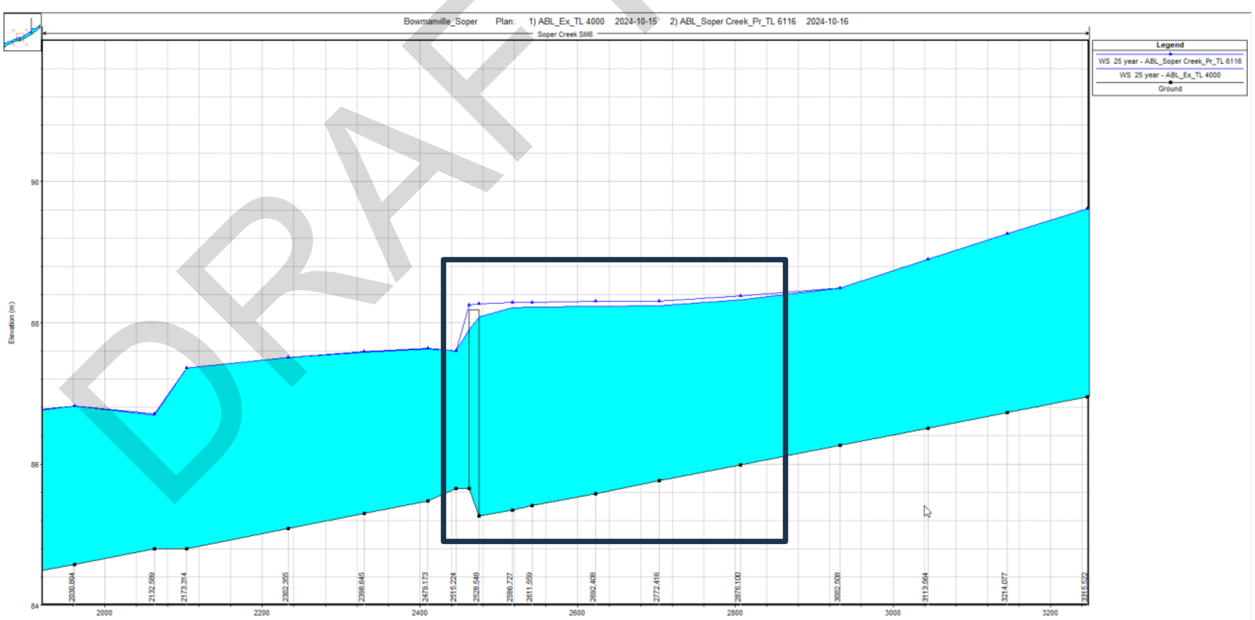

Figure 6.13: Reach SM6 – HEC-Ras Profile View at King Street East

As illustrated, under existing conditions the 25-year water surface elevation resides at the edge of roadway (88.08m) of King Street East but does not overtop the roadway. We note that the low point on the roadway at this crossing resides at 88.11m. The proposed future 25-year flood elevation resides at 88.27m, overtopping the roadway by 0.16m (88.27m – 88.11m). The 25-year head pond between future conditions and existing conditions at this location extends approximately 450m upstream of the crossing. However, larger or smaller return events are largely unimpacted. The Regional water surface elevation (existing and proposed conditions) at this location has been observed at 89.40m, exceeding the safe 0.3m emergency vehicle depth threshold at this crossing. As detailed in **Table 6.17**, the existing King Street East Crossing does not meet the 25-year conveyance design criteria at this crossing. While the future condition peak flows are higher than existing conditions, conveyance improvements at this location to meet design standards would reduce or eliminate flood elevation differences.

6.5.5 Roadway Crossing Analysis

Map J3 of the Official Plan for the Municipality of Clarington (**Figure 6.14**), identifies the majority of roadway crossings within the Secondary Plan Areas as being Arterial Roadways. Accordingly, based on the municipal roadway classification we have completed a detailed hydraulic analysis on a total of 13 crossings (10 culverts and 3 bridges) within the direct vicinity of the Secondary Plan Areas. The hydraulic analysis has been carried out in accordance with the Ministry of Transportation Highway Drainage Design Standards, January 2008. The crossings within the study area reside within the framework of sections WC-1, WC-2 and WC-7.

To complete the above analysis, the existing CLOCA Bomanville_Soper Creek HEC-RAS hydraulic model has been updated with peak flow rates derived from both the Watershed Level Existing and Future (Uncontrolled) watershed scale models (VO Models 2000 and 3000 respectively). Ineffective flow areas and High Flow Computational methods were also adjusted, where required. Based on the revised flow rates and applicable design criteria, capacity, freeboard and clearance requirements for each crossing were assessed. The results of the existing condition analysis have been provided in **Table 6.17** and **Table 6.18**.

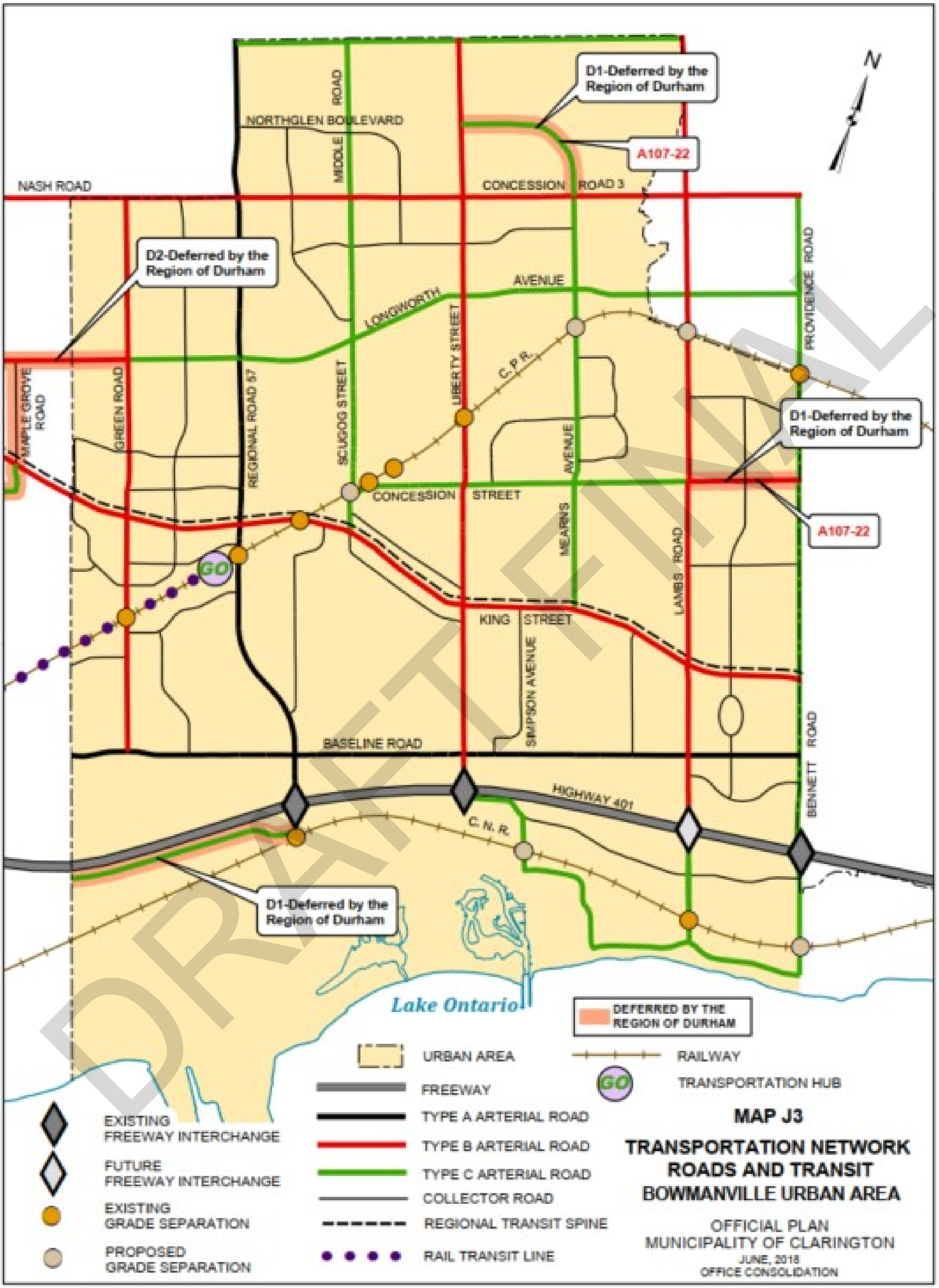

Figure 6.14: Map J3 Official Plan for the Municipality of Clarington

Table 6.17: Existing Roadway Crossing Design Criteria

River	Reach	River Station	Location	Description	Road Classification	Span < 6m?	MTO Design Criteria	MTO Standard
Soper Creek	SE2	1242.044	Arlington-Clarke Townline Road, North of Concession Street	2.9m x 2.05m Ellipse Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SE2	127.9769	CN Rail, East of Bragg Road, North of Concession Street E.	3m x 2.35m Arch Culvert	N/A	Y	25-year	WC-1, WC-7
Soper Creek	SE3	2602.968	Concession Road 3, East of Bragg Road (Structure 115 & 116)	Two Cells - Max 1.35m x 0.885m Ellipse Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SE3	99.98821	CN Rail, East of Bragg Road, North of Concession Street E	2.1m x 1.98m Conc Arch Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SM19	1534.643	Liberty Street N, North of Rebecca Court	2.75m dia CSP Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SM19	475.5821	Mearns Avenue, North of Concession Road 3	2.15m dia CSP Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SE1	4675.454	Bragg Road, North of Concession Street E	3.6m span x 2.05m rise Conc Box Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SE1	3863.974	Concession Street E, West of Bragg Road	3.7m x 1.58m CSP Ellipse Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SE1	873.1224	Lambs Road, North of Regional Highway 2	4.95m x 1.965m Rise Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SM6	4374.132	CN Railway, between Meams Ave and Lambs Road	5.2m x 4.03m Conc Arch Culvert	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SM6	2528.548	Concession Street E, East of Lambs Road	3.8m span x 2.9m rise Bridge	Rural Arterial	Y	25-year	WC-1, WC-7
Soper Creek	SM12	589.4403	Lambs Road, South of Concession Road 4	13.80m Span Bridge	Rural Arterial	N	50-year	WC-1, WC-2
Soper Creek	SM6	5719.686	Concession Road 3, West of Lambs Road	10.28m Span Bridge	Rural Arterial	N	50-year	WC-1, WC-2

Table 6.18: Existing Roadway Crossing Hydraulic Analysis

River	Reach	River Station	Location	Description	Freeboard (m)	Crossing Meets Design Criteria?	Overtopped?
Soper Creek	SE2	1242.044	Arlington-Clarke Townline Road, North of Concession Street	2.9m x 2.05m Ellipse Culvert	0.37	No	No
Soper Creek	SE2	127.9769	CN Rail, East of Bragg Road, North of Concession Street E.	3m x 2.35m Arch Culvert	3.91	Yes	No
Soper Creek	SE3	2602.968	Concession Road 3, East of Bragg Road (Structure 115 & 116)	Two Cells - Max 1.35m x 0.885m Ellipse Culvert	-0.17	No	Yes
Soper Creek	SE3	99.98821	CN Rail, East of Bragg Road, North of Concession Street E	2.1m x 1.98m Conc Arch Culvert	4.32	Yes	No
Soper Creek	SM19	1534.643	Liberty Street N, North of Rebecca Court	2.75m dia CSP Culvert	2.57	Yes	No
Soper Creek	SM19	475.5821	Mearns Avenue, North of Concession Road 3	2.15m dia CSP Culvert	0.95	No	No
Soper Creek	SE1	4675.454	Bragg Road, North of Concession Street E	3.6m span x 2.05m rise Conc Box Culvert	-0.33	No	Yes
Soper Creek	SE1	3863.974	Concession Street E, West of Bragg Road	3.7m x 1.58m CSP Ellipse Culvert	-0.45	No	Yes
Soper Creek	SE1	873.1224	Lambs Road, North of Regional Highway 2	4.95m x 1.965m Rise Culvert	0.18	No	No
Soper Creek	SM6	4374.132	CN Railway, between Meams Ave and Lambs Road	5.2m x 4.03m Conc Arch Culvert	9.38	Yes	No
Soper Creek	SM6	2528.548	Concession Street E, East of Lambs Road	3.8m span x 2.9m rise Bridge	-0.78	No	Yes
Soper Creek	SM12	589.4403	Lambs Road, South of Concession Road 4	13.80m Span Bridge	-0.04	No	No
Soper Creek	SM6	5719.686	Concession Road 3, West of Lambs Road	10.28m Span Bridge	-0.58	No	Yes

For the purposes of this report, a Rural Arterial roadway classification was assumed, which carries a 25-year design flow requirement for crossings with spans less than 6m. Crossings in excess of a 6m span are subject to a 50-year design flow requirement. Based on the results of this analysis, only four (4) of the 13 existing crossings meet the applicable Rural Arterial roadway design criteria. For crossings that have not met the applicable design criteria, an iterative hydraulic analysis has been completed in attempt to provide additional capacity at the required crossings. Results of the Proposed Culvert Replacement Summary has been provided in **Table 6.19** and discussed in further detail below.

Generally, 25-year peak flows reside at normal depth conditions within their respective reaches within the study area and reside at or close to the edge of travelled lanes of many roadways. This unique flow characteristic provides challenges for conveyance improvements without raising the roadway profile. While raising a roadway profile may be possible, the following challenges pertain to the overall hydraulics of the crossing:

- Roadway profile modifications would need to be modified to suit the roadway classification and designed to the posted speed limit;
- Raising the roadway profile may increase major system flood elevation increases (i.e. 100yr or Regional);
- Raising the roadway profile will result in additional fill placement within the floodplain that will require compensation;
- Guardrails, if a new requirement or extension required based on current design standards, may also increase major system flood elevation increases (i.e. 100yr or Regional).

Based on the above, crossing upgrades have been provided to achieve free flowing conditions for the 25-year or 50-year event at the roadway as applicable. However, to provide the level of freeboard required, roadway profiles would been to be provided. Based on the above commentary, additional analysis is required to assess both opportunities and challenges associated with specific replacement alternatives.

Table 6.19: Proposed Culvert Replacement Summary

No	River	Reach	River Station		Proposed Replacement Description	Freeboard (m)	Culvert Meets Design Criteria?	Roadway Overtopped?	Comments
1	**Soper Creek**	**SE2**	**1242.044**	Alington-Clarke Townline Road, North of Concession Street	6m span x 2.4m box	1.43	**Yes**	**No**	Design Criteria achieved. Roadway profile to remain.
2	**Soper Creek**	**SE3**	**2602.968**	Concession Road 3, East of Bragg Road (Structure 115 & 116)	2 - 2.4m span x 1.2m rise box	0.59	**No**	**No**	*Normal Depth Reached through culvert. Roadway must be elevated to meet design criteria.
3	**Soper Creek**	**SM19**	**475.5821**	Mearns Avenue, North of Concession Road 3	3m span x 1.8m rise	1.52	**Yes**	**No**	Design Criteria achieved. Roadway profile to remain.
4	**Soper Creek**	**SE1**	**4675.454**	Bragg Road, North of Concession Street E	9m span x 2.05m rise conc box	0.32	**No**	**No**	*Normal Depth Reached through culvert. Roadway must be elevated to meet design criteria.
5	**Soper Creek**	**SE1**	**3863.974**	Concession Street E, West of Bragg Road	9m span x 1.8m rise conc box	0.85	**No**	**No**	*Normal Depth Reached through culvert. Roadway must be elevated to meet design criteria.
6	**Soper Creek**	**SE1**	**873.1224**	Lambs Road, North of Regional Highway 2	9m span x 2.05m rise conc box	0.89	**No**	**No**	*Normal Depth Reached through culvert. Roadway must be elevated to meet design criteria.
7	**Soper Creek**	**SM6**	**2528.548**	Concession Street E, East of Lambs Road	32m span bridge	-0.31	**No**	**Yes**	**32m span bridge does not meet design criteria which is 10x the existing size.
8	**Soper Creek**	**SM12**	**589.4403**	Lambs Road, South of Concession Road 4	25m span bridge	0	**No**	**No**	**25m span bridge does not meet design criteria which is 2X the existing size.
9	**Soper Creek**	**SM6**	**5719.686**	Concession Road 3, West of Lambs Road	30m span bridge	0.14	**No**	**No**	*Normal Depth Reached through culvert. Roadway must be elevated to meet design criteria.

* Crossings have been sized to provide free flowing conditions through the roadway. While free flowing conditions are provided, the roadway profile is required to be elevated to meet freeboard requirements. Additional analysis is required to determine the impacts of raising the roadway profile on major system storm events.

** Tailwater conditions at these crossings prevent improved conveyance with a larger structure. Crossings 7 and 8 illustrate spans in excess of 2x existing conditions which do not meet the proposed design criteria of the crossing. Like for like or nominally larger replacement structures are recommended for both crossings. Additional analysis is required to determine the impacts of raising the roadway profile on major system storm events.

6.6 Water Quality

An Enhanced level of protection is required for Soper Creek Subwatershed. To achieve this level of control, LID measures are prioritized for achieving the water quality criteria, followed by stormwater management facilities and then manufactured treatment devices (CLOCA, 2020). The MECP's Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA) accepts control of the 90th percentile storm event (27 mm) to achieve Enhanced water quality treatment, as presented in **Figure 6.15**, where the Runoff Volume Control Target (RVC_T) corresponds to the runoff generated from the regionally specific 90th percentile rainfall event.

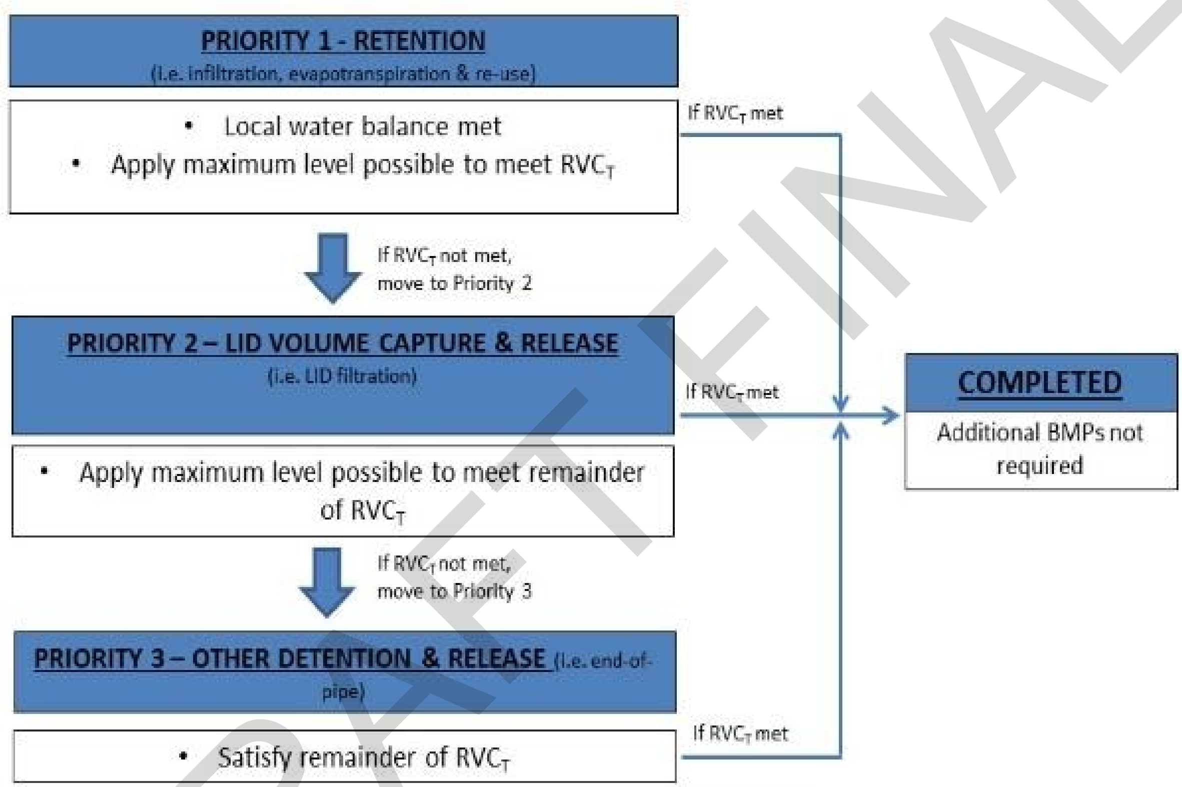

Figure 6.15: Runoff Control Hierarchy from the MECP's LID Stormwater Management Guidance Manual

LID measures were therefore modeled throughout the new developments in the Secondary Plan areas. For modeling purposes, the VO6.2 model assumed a bioretention system is implemented for all proposed land uses. Treatment of the 27 mm event throughout both subwatersheds was feasible using LIDs, so the use of stormwater management facilities or manufactured treatment devices was not necessary to achieve an Enhanced level of treatment. For this analysis we have conservatively sized the bioretention facilities to maintain existing 27mm runoff volumes, although the ultimate installed type of LID features is dependent on land use (**Table 5.2** and **Table 8.2**). This analysis has been completed to provide footprint and volumetric details surrounding an optimal scenario infiltration and treatment scenario. It is understood that technical constraints identified during detailed design may reduce the footprint and volume reduction capabilities.

Table 6.20 illustrates the standard default parameters used in the preparation of the LID analysis. Detailed hydrology surrounding the proposed LID modelling has been provided within the VO model under scenario 8000. Surface ponding has been limited to 0.15m and assumed to reside over the entire footprint of the LID. The depth and length of each bioretention cell have been iterated to provide the required LID footprint to maintain existing 27mm runoff volumes the future development scenarios.

Table 6.20: Default Bioretention Parameters

Engineered Soil Layer					Water Quality	
Depth (m)	**Porosity**	**Infiltration (mm/hr)**	**Seepage (m/hr)**	**Soil Moisture**	**TSS (%)**	**TP (%)**
1	0.467	0.009	0.055	0.3	75	25
Mulch Layer		**Storage Layer**			**Native Soil**	
Mulch Depth (m)	**Mulch Porosity**	**Stor. Height (m)**	**Stor. Porosity**	**Min. Drawdown Time (hr)**	**Soil Texture**	**Infiltration Rate (m/hr)**
0.3	0.4	1	0.4	24	Loam	0.008

LIDs have been included within all catchments within the Soper Springs and Soper Hills Secondary Plans, Camp 30 lands and the Timber Trail Development via Bioretention (for modeling purposes). The sizing of the Bioretention facilities has been completed via an iterative process based on 27mm Runoff Volumes (RV). To size the LIDs, we have calculated both the Existing and Proposed Condition Runoff Volumes. The 27mm volumes have been determined through an analysis of Runoff Volumes directly obtained from the VO Hydrograph Results. Specifically, we have calculated both the Existing and Proposed Condition 27mm Runoff Volume (RV) for each catchment. As expected, the proposed RV (un-treated) values are higher than Existing Conditions. While holding a number of key modelling parameters constant (i.e. Max Ponding Depth, Infiltration, Seepage, Porosity, Moisture, Infiltration, etc.) we have determined a generic footprint (m^2) and volume (m^3) of proposed storage required to meet or be below the existing 27mm runoff volume under proposed land use conditions.

We note that while the LID volume provided exceeds the required 27mm runoff volume targets, we do believe, based on historical experience with LID model calibration, the function of the LIDs in VO may be under-represented. It is therefore likely that the LIDs will attenuate and infiltrate more than what is shown within Visual Otthymo. The outputs and sizing have been based on LID modelling limitations within Visual Otthymo. We note that additional iterations and/or a sensitivity analysis has not been completed within this SWS. However, we would recommend refinements to the hydrology model at the detailed design stage to account for revisions to impervious areas and site-specific soils opportunities/constraints.

Table 6.21 below illustrates key information pertaining to the sizing of the bioretention facilities for the Secondary Plan areas including LID Area (m^2), LID% of Total Drainage Area, and LID Total Storage Provided (m^3). All bioretention facilities have been sized to maintain or improve the 27mm runoff volume of the future development condition over Existing Conditions. In all cases, the future/proposed runoff volumes reside less than runoff volumes under existing conditions.

Table 6.21: Soper Creek – Secondary Development Plan - LID Sizing Table

Name	HYD	Area (ha)	Ex_27mm (m3/s)	Ex_27mm RV (mm)	Ex_27mm RV (m3)	27mm Tot Vol (m3)	Ex_27mm Infil. (m3)	Pr_27mm RV (mm)	Pr_27mm RV (m3)	Ext Det 40m3/ha	Storage (Req'd) m3	LID % of Total Area	LID Total Area (m2)	LID HYD	LID Junction HYD	Pr wLID 27mm (m3/s)	Pr wLID 27mm RV (mm)	Q Diff (m3/s)	RV Diff (mm)	LID Total Storage Provided (m^3)	Storage Provided vs Storage Required (m3)
SM9_35	80	28.21	0.13	3.08	868.30	7616.7	6748.40	12.85	3624.14	1128.40	3624.14	4.40%	12412.4	348	449	0.22	2.92	0.092	-0.162	13175.98	9551.84
SM10_36	67	19.08	0.07	2.44	464.79	5151.6	4686.81	11.12	2121.12	763.20	2121.12	3.00%	5724.0	350	451	0.10	2.01	0.034	-0.425	6582.91	4461.79
SM9_28	76	4.9	0.03	4.06	198.79	1323	1124.21	16.40	803.50	196.00	803.50	4.50%	2205.0	352	453	0.04	3.08	0.005	-0.981	2502.04	1698.54
SM10_31	195	3.46	0.01	2.09	72.35	934.2	861.85	12.90	446.34	138.40	446.34	3.80%	1314.8	354	455	0.01	1.19	0.003	-0.904	1578.83	1132.49
SM6_21	130	0.51	0.00	3.13	15.97	137.7	121.73	14.82	75.57	20.40	75.57	3.90%	198.9	356	457	0.00	3.20	0	0.068	227.22	151.65
SM6_26	134	7.45	0.04	2.65	197.35	2011.5	1814.15	15.39	1146.41	298.00	1146.41	4.25%	3166.3	358	459	0.05	2.65	0.017	0.001	3633.14	2486.73
SM6_20	140	3.02	0.02	4.38	132.40	815.4	683.00	17.87	539.76	120.80	539.76	4.75%	1434.5	360	461	0.03	3.88	0.013	-0.508	1596.90	1057.14
SM6_17	142	7.24	0.06	4.42	319.79	1954.8	1635.01	9.19	665.14	289.60	665.14	1.75%	1267.0	362	463	0.08	3.98	0.023	-0.439	1374.39	709.25
SM6_12	146	7.72	0.04	4.37	337.21	2084.4	1747.19	17.74	1369.84	308.80	1369.84	4.55%	3512.6	364	465	0.09	3.99	0.047	-0.382	4079.91	2710.07
SM6_50	242	16.81	0.06	2.63	441.26	4538.7	4097.44	17.37	2919.06	672.40	2919.06	4.95%	8321.0	366	467	0.11	2.50	0.057	-0.123	9538.52	6619.46
SE1_52	243	10	0.09	5.66	566.10	2700	2133.90	18.33	1832.70	400.00	1832.70	4.50%	4500.0	368	469	0.14	4.72	0.046	-0.942	2148.20	315.50
SE1_23	171	52.33	0.36	4.99	2609.17	14129.1	11519.93	13.79	7216.31	2093.20	7216.31	3.00%	15699.0	370	471	0.70	4.74	0.342	-0.246	17736.00	10519.69
SE1_18	191	12.63	0.09	3.02	381.17	3410.1	3028.93	15.40	1944.39	505.20	1944.39	4.25%	5367.8	372	473	0.09	2.67	-0.005	-0.352	6134.69	4190.30
SE1_10	201	32.67	0.25	3.04	992.19	8820.9	7828.71	13.90	4540.80	1306.80	4540.80	3.75%	12251.3	374	475	0.24	2.65	-0.011	-0.392	13878.46	9337.66
SE1_7	205	7.51	0.42	13.25	994.70	2027.7	1033.00	14.39	1080.69	300.40	1080.69	0.50%	375.5	376	477	0.66	12.81	0.246	-0.436	1136.95	56.26
SE1_4	220	10.72	0.15	5.76	617.69	2894.4	2276.71	16.52	1770.84	428.80	1770.84	3.75%	4020.0	378	479	0.17	5.35	0.023	-0.412	4550.80	2779.96
SE1_13	228	42.56	0.37	4.56	1940.74	11491.2	9550.46	12.59	5358.30	1702.40	5358.30	2.75%	11704.0	380	481	0.53	4.23	0.16	-0.327	13401.61	8043.31

Figure 6.16 illustrates the positive impacts LIDs have on peak flow rates throughout the watershed while using catchment SE1_13 as a comparison. Proposed Un-Controlled Conditions have been based on VO Modelling Run 5000 while the Proposed Conditions with LIDs have been based on VO Modelling Run 8000.

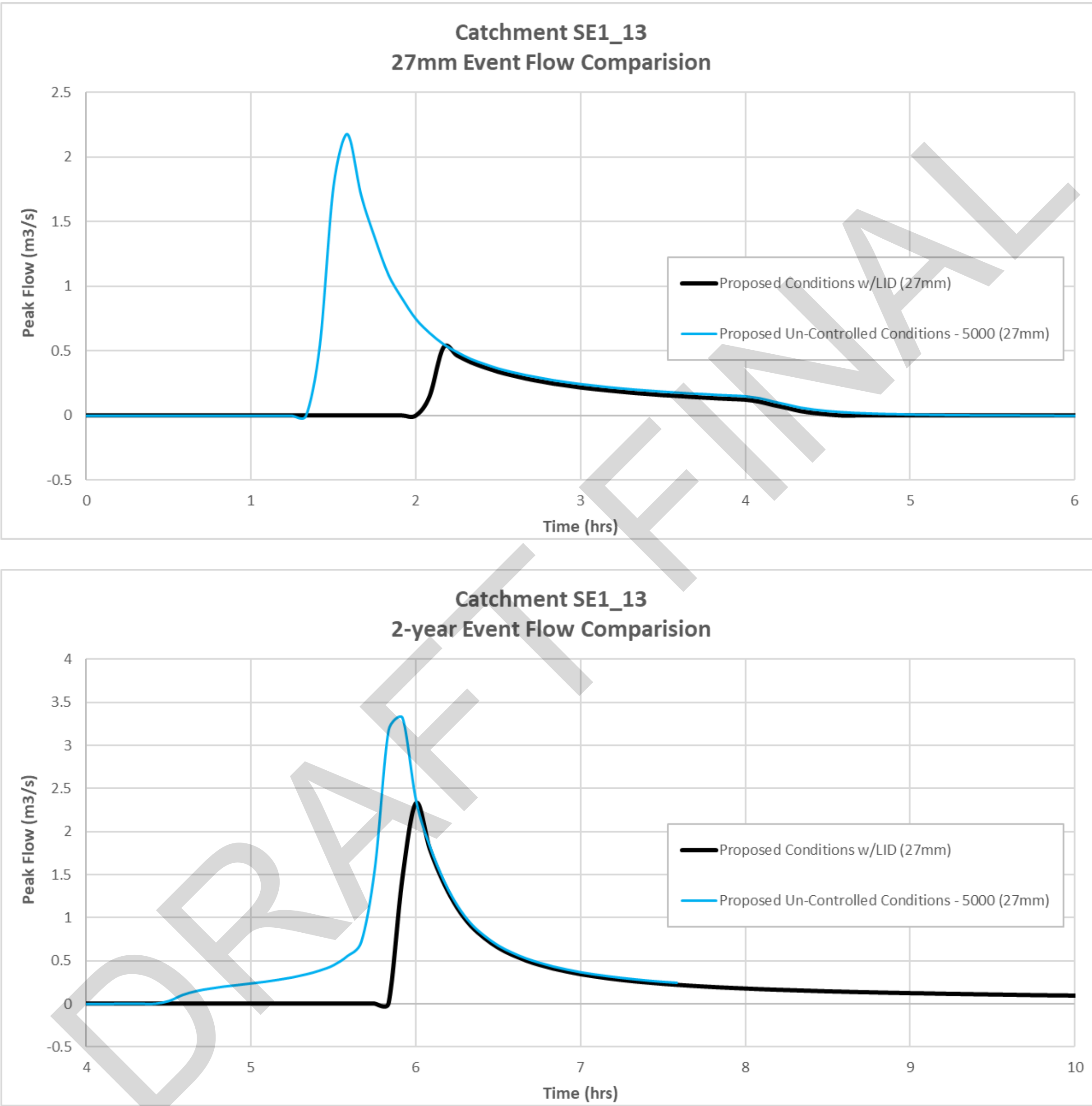

Figure 6.16: LID Performance 27mm and 2-year Flow Comparisons

As illustrated in **Table 6.21** and **Figure 6.16,** the proposed bioretention cells provide a considerable flow reduction for both the 27mm and 2-year events. While proposed condition peak flow rates are higher than existing conditions, we note that proposed runoff volumes in the 27mm event are less than existing conditions whereby achieving the Runoff Volume Targets for the watershed.

VO Modelling Run 8001 contains the 50% Over-Control Volumes within the Soper Springs Secondary Plan Area as well as proposed bioretention cells within all proposed development areas. This modelling scenario has been created for Erosion Analysis purposes only and has not been referenced or analysed elsewhere in the SWS.

6.7 Erosion Control

Erosion potential within Soper Creek was determined to be 15 m/100 years and as high as 37 m/100 years as a part of the geomorphic assessments completed as part of the **Soper Creek Subwatershed Study: Phase 1 Report**. All of the assessed reaches throughout Soper Creek were determined to be in a state of geomorphic transition. In order to protect against increased rates of erosion, and thus unstable channel adjustments, stormwater management facilities, including LIDs, will be a necessary part of future development to prevent increased peak flow rates and increased durations of critical discharge exceedance.

A minimum of a 27 mm rainfall event is required to be captured, retained, or detained from all new and/or fully reconstructed impervious surfaces. The first priority is retention of the full volume from the 27 mm event through infiltration, evapotranspiration, reuse, bioretention, etc. If this is not feasible, then volume reduction to the maximum extent practical, as demonstrated through supporting documentation, is required with a minimum of 5 mm. The remaining runoff volume must then be detained on site and released over 24 to 48 hours. This requirement from CLOCA has been adopted as part of this Subwatershed Study.

As presented in **Section 6.6,** control of the runoff from the 27 mm event and portion of the 2-year peak flow is possible using LID measures. The LID measures were able to reduce the Future Uncontrolled peak flow to be equivalent or below the Existing peak flow at most node locations (**Table 6.21**).

In addition, based on the results of the tractive force analysis (**Appendix D**), erosion is a natural process within the Soper Creek Subwatershed and should be maintained at existing rates as much as possible. This would set flow targets to existing conditions if the geomorphic stability of the system is to remain consistent.

6.8 Water Balance

The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead. For the Soper Creek Subwatershed, the Thornthwaite and Mather method was used to estimate existing and future infiltration values on a yearly basis.

The hydrologic cycle is a complex process and its natural components are dependent on many factors (e.g., soils, topography, vegetation, geology, climate). Any change to these natural factors will result in a change to the hydrologic cycle. The water budget analysis is a comprehensive examination of the hydrological cycle based on the following expression:

Precipitation (P) = Evapotranspiration (ET) + Runoff (R) + Infiltration (I)

Evapotranspiration (ET) was calculated according to the Thornthwaite and Mather model (Thornthwaite and Mather, 1957) which uses an accounting procedure to analyze the allocation of water among various components of hydrologic system. This was completed based on weather data from 2013-2023 using the Oshawa weather station. Years with data gaps were supplemented by the nearest Environment Canada weather station in Tapley. Other assumptions are summarized in **Table 6.22.**

Table 6.22: Thornthwaite and Mather Inputs

	Soper Hills		Soper Springs	
	Existing	**Future**	**Existing**	**Future**
Runoff Factor	0.49	0.49	0.23	0.25
Soil-Moisture-Storage-Capacity	164	85	250	219
Percent Impervious	2%	54%	0%	19%
Direct Runoff Factor	5%		5%	
Latitude	44°		44°	
Rain Temperature Threshold	3.3°C		3.3°C	
Snow Temperature Threshold	-10°C		-10°C	
Maximum Melt Rate	0.5		0.5	

The computed evapotranspiration values were then used to estimate annual and monthly water surplus. The results of the water budget analysis highlight the importance of infiltration and evapotranspiration in the natural hydrological cycle (i.e., predevelopment) of the study area (**Table 6.23**).

Table 6.23: Water Budget

	Soper Hills		Soper Springs	
Water Budget Component	**Existing**	**Future**	**Existing**	**Future**
Annual Precipitation (mm/yr)	710			
Actual ET (mm/yr)	527	270	548	454
Water Surplus (mm/yr)	183	440	163	256
Runoff (mm/yr)	95	397	39	156
Infiltration (mm/yr)	88	43	124	100

6.8.1 Annual Infiltration

The Thornthwaite and Mather calculations estimate an annual pre-development infiltration rate of between 88 and 124 mm/year for Soper Hills and Soper Springs, respectively. Given that there are approximately 40 rainfall events per year the average infiltration rate per event is relatively modest (approximately 2 mm per event in Hills and 3 mm in Springs). The actual values on a site-by-site basis will vary depending on soil type, slopes, vegetation cover and depth to water table.

The above recharge targets can be achieved by incorporating appropriate LID source and conveyance control measures as outlined in **Section 5** together with the requirements to meet the Water Quality targets as noted in **Section 6.6**. Collectively the LID measures should ensure that post-development infiltration rates equal or exceed pre-development levels. Monitoring has shown that, for soils of a similar nature, infiltration of up to 10 mm per event is possible in Soper Hills, with higher rates expected in Soper Springs.

High Volume Recharge Areas (HVRAs) and Ecologically Significant Groundwater Recharge Areas (ESGRAs) will require additional attention to ensure pre-development recharge rates are maintained (**Section 7.4**).

6.9 Thermal Mitigation

Soper Creek was characterized as a cold/coolwater stream by CLOCA (2011). Aquatic investigations by Aquafor Beech as part of the **Soper Creek Subwatershed Study: Phase 1 Report** confirmed the presence of coldwater species. As the use of LID measures reduces stormwater temperature, it is expected that the implementation of the proposed stormwater strategy will adequately cool stormwater temperatures when combined with best management practices for the SWM facilities. Since the preferred alternative is for dry facilities will be implemented, there is less of an opportunity for standing water to increase in temperature as exists with wet facilities.

6.10 Preferred Stormwater Management Alternative

Based on the above evaluation, the Preferred Alternative is **Traditional (Conventional) Stormwater Management and LID Approach.** Quantity control is represented by **Model Run 6116**, applying overcontrol for the Soper Springs SWM facilities, and providing no quantity control in Soper Hills, Camp 30 Lands or Timber Trails Development. This approach best meets the required SWM Quantity Control criteria using dry stormwater facilities. Results of this model scenario are presented in Table 6.24.

Table 6.24: Modelling Run 6116 - Soper Springs Over-Control vs Existing Conditions (m3/s) – All Flows (2 to 100-year)

Modelling Run 6116 Proposed Soper Springs ONLY - 50% OverControlled Conditions			Peak Flow (m3/s)						Proposed Conditions vs Existing Conditions (m3/s)						Proposed Conditions vs Existing Conditions (%)					
Reach	HYD	Location	2	5	10	25	50	100	2	5	10	25	50	100	2	5	10	25	50	100
SM19	248	Liberty Street	1.55	2.86	3.88	5.31	6.48	7.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM19	250	Soper Spring - DS of SWM SS Pond 3	1.67	3.07	4.15	5.66	6.91	8.19	0.04	0.05	0.05	0.05	0.06	0.07	2.20%	1.62%	1.29%	0.98%	0.94%	0.89%
SM19	251	Soper Spring - DS of SWM SS Pond 1	1.94	3.45	4.61	6.25	7.57	8.93	0.19	0.25	0.28	0.34	0.38	0.43	10.96%	7.91%	6.47%	5.81%	5.34%	5.02%
SM6	66	Soper Springs	60.58	69.18	76.27	81.52	86.80	85.08	0.08	0.09	0.11	0.12	0.11	0.06	0.13%	0.14%	0.15%	0.15%	0.12%	0.07%
SM6	68	Concession Road 3	62.54	72.57	80.71	87.29	93.53	92.66	0.29	0.35	0.41	0.45	0.42	0.31	0.46%	0.49%	0.52%	0.52%	0.46%	0.33%
SM6	72	Rail Line	40.06	48.80	56.43	64.05	77.46	91.85	0.30	0.35	0.36	0.42	0.57	0.62	0.74%	0.73%	0.64%	0.66%	0.74%	0.68%
SM6	73	Downstream of Rail Line	39.37	48.55	56.11	64.41	78.34	92.85	0.30	0.33	0.37	0.49	0.57	0.63	0.77%	0.69%	0.65%	0.76%	0.74%	0.68%
SM6	131	Camp 30	0.87	1.59	2.14	2.90	3.51	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SM6	166	Camp 30	1.27	1.96	2.42	3.16	3.82	4.49	0.33	0.22	0.08	-0.01	-0.03	-0.04	34.28%	12.90%	3.46%	-0.44%	-0.75%	-0.97%
SM6	167	Camp 30	35.99	45.77	54.46	65.59	79.50	93.88	0.37	0.37	0.40	0.51	0.61	0.63	1.05%	0.81%	0.73%	0.78%	0.78%	0.68%
SM6	176	Camp 30	35.77	45.85	54.66	66.00	79.89	94.24	0.36	0.33	0.31	0.52	0.57	0.57	1.01%	0.73%	0.56%	0.79%	0.72%	0.61%
SM6	168	Camp 30	34.78	45.07	53.84	66.09	80.00	94.39	0.37	0.33	0.30	0.53	0.61	0.56	1.06%	0.74%	0.55%	0.80%	0.77%	0.60%
SM6	179	Concession Street	25.92	36.24	46.41	62.35	75.28	88.82	0.34	0.35	0.36	0.43	0.42	0.55	1.34%	0.98%	0.79%	0.69%	0.56%	0.63%
SM6	79	Camp 30	25.57	36.14	46.34	62.14	74.96	88.36	0.39	0.35	0.36	0.37	0.41	0.47	1.54%	0.98%	0.79%	0.59%	0.56%	0.53%
SE1	185	Rail Line	0.78	1.40	1.86	2.48	2.97	3.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE2	96	Bragg Road	5.68	10.12	13.49	18.12	21.82	25.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	186	Reach Confluence Upstream of Concession St	7.23	13.06	17.49	23.60	28.52	33.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	190	Concession Street East	7.79	14.05	18.85	25.35	30.70	36.13	0.04	0.05	0.05	0.05	0.05	0.05	0.58%	0.34%	0.25%	0.18%	0.16%	0.13%
SE1	198	Soper Hills East Development Limit	8.45	15.20	20.35	27.34	33.00	38.77	0.05	0.05	0.05	0.05	0.05	0.05	0.56%	0.33%	0.25%	0.19%	0.16%	0.12%
SE1	211	Soper Hills	8.51	15.25	20.37	27.29	32.89	38.65	0.13	0.15	0.15	0.15	0.14	0.14	1.51%	0.99%	0.73%	0.56%	0.43%	0.37%
SE1a	214	Soper Hills	1.49	2.64	3.51	4.69	5.62	6.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SE1	217	Soper Hills	9.39	16.75	22.31	29.84	35.93	42.17	0.16	0.17	0.17	0.16	0.15	0.14	1.73%	1.03%	0.75%	0.55%	0.42%	0.35%
SE1	225	Soper Hills	9.35	16.65	22.18	29.64	35.67	41.90	0.16	0.18	0.17	0.17	0.16	0.15	1.72%	1.07%	0.78%	0.57%	0.45%	0.36%
SE1	232	Soper Hills West Development Limit	9.70	17.16	22.79	30.43	36.54	42.88	0.22	0.21	0.20	0.17	0.15	0.13	2.29%	1.23%	0.86%	0.56%	0.41%	0.30%
SM6	100	King Street East	32.90	50.22	64.06	83.86	100.66	117.91	0.68	0.49	0.52	0.46	0.62	0.60	2.11%	0.99%	0.81%	0.55%	0.62%	0.51%
SM7	104	Bowmanville Cemetary	34.22	53.19	67.88	88.48	105.91	123.42	0.81	0.49	0.51	0.45	0.61	0.41	2.42%	0.92%	0.76%	0.51%	0.58%	0.34%
SM1	106	Highway 401	32.72	53.65	68.45	89.27	106.86	124.41	0.77	0.51	0.51	0.42	0.59	0.49	2.42%	0.96%	0.76%	0.47%	0.56%	0.40%
SM1	109	D/S West Beach Road	32.78	53.79	68.63	89.53	107.10	124.66	0.76	0.51	0.51	0.43	0.60	0.48	2.38%	0.96%	0.75%	0.49%	0.56%	0.39%

6.10.1 Costs of Preferred Alternative

Unit cost estimates for the preferred alternative were estimated based on implementation of similar projects within the Greater Toronto and Hamilton Area:

- LID: $400 per linear metre
- Dry Ponds: $175 per cubic metre of pond volume

6.10.2 Quantity Control Key Takeaways

6.10.2.1 Model Discretization and Peak Flow Timing

The Tributary level discretization detailed in the VO modelling presented in this report has been completed with anticipation of future development conditions within the Secondary Plan areas. Key flow nodes and catchment outlets have intentionally been located at roadway crossings, catchment outlets, tributary confluences and secondary plan outlet locations. While enhancing modelling resolution may be attributed to higher non-calibrated peak flows, the orientation and presentation of the VO hydrologic model in this SWS has enabled the direct assessment of up to 17 potential SWM facilities with varying degrees of attenuation. The level of discretization presented in this SWS has provided numerous flow node locations to which future development condition peak flows may be compared accurately to existing conditions. A courser level of model resolution would have not permitted the direct comparison of peak flows at key locations within the watershed.

6.10.2.2 Regional Flow Controls

Based on the Watershed Level and Tributary level analysis of peak flows within the watershed, Future Condition Regional peak flows have been observed to be lower than Existing Condition Peak Flows. Therefore, Regional Flow controls are note required within the subject Secondary Plans.

6.10.2.3 Attenuation Alternatives

A total of 10 Future Condition peak flow scenarios have been completed within the Soper Creek SWS. Scenarios for stormwater attenuation have included Post to Pre-Controls, Minor System Controls Only, Over Control and Under-Control. Despite the wide range in attenuation alternatives considered, all future condition scenarios have produced higher peak flows than existing conditions. Through the analysis of these modelling runs, it was confirmed that attenuation within the Soper Hills Secondary Plan, Camp 30 Lands and Timber Trail Developments increase downstream flow rates due to the presence of peak flow timing with external drainage areas.

Out of the 10 future peak flow scenarios completed, two scenarios have produced the lowest peak flow increases, including VO Modelling Run 6015 – Soper Springs Post to Pre-Controls Only and VO Modelling Run 6116 – Soper Springs 50% Overcontrol on Post to Pre-Control Volumes

Only. We note that despite the increase in storage volumes within the Soper Springs Area associated with VO Modelling Run 6116, peak flow comparisons to existing conditions between both VO Modelling Runs 6105 and 6116 are quite close. VO Modelling Run 6116 has been selected as the preferred alternative as this alternative provides the best flow reduction in Reach SM19 for the 2, 5 and 10-year events which is currently experiencing erosion risk. As the peak flow comparisons are relatively close in nature, it is the recommendation of this report to refine the hydrologic model at the detailed design stage to assess the impacts of post to pre or overcontrol in the Soper Springs Area. Changes to pond outlet locations, impervious values, refinement of infiltration characteristics may change the peak flow magnitude and timing and as a result, attenuation volumes.

6.10.2.4 Quality Control and SWM Block Requirements.

The intent of the stormwater management approach is to utilize dry facilities for quantity control purposes. It is now known that quantity control is only required within the Soper Springs Area. The proposed SWM facilities within the Soper Springs Secondary Plan have been intended to be dry facilities with water quality control and erosion control being provided via LIDs.

LIDs have also been sized for all other development areas within the watershed to accommodate both thermal mitigation and quality control volume targets as outlined in this report. However, we note that the LID sizing has been completed on assumed infiltration characteristics of the watershed and absence of other technical constraints. Detailed geotechnical investigations are required on a site-by-site basis to confirm site-specific infiltration characteristics as well as the presence or absence of other technical constraints.

Accordingly, while it has been confirmed that quantity control is a requirement within Soper Springs Area only, therefore requiring SWM pond blocks within the Secondary Plan area, it is unknown at this time whether LIDs may be fully utilised as intended in other proposed development areas. Accordingly, it is recommended that SWM pond blocks in the Soper Hills, Camp 30 and Timber Trail Developments be maintained until it is confirmed through detailed design that LIDs can provide the full extent of water balance, quality and erosion control and thermal mitigation. This will provide the opportunity to utilise wet quality control ponds if needed to address the above should volume control of the 27mm event through LIDs not be feasible.

6.10.2.5 Deterministic Based Flow Regime

The deterministic hydrologic modelling completed for the Soper Creek SWS utilises design based hydrologic parameters and methodology approved for use by both the Municipality of Clarington and CLOCA. Using the approved designed based hydrologic parameters and methodology, the VO hydrologic modelling has been constructed to represent field conditions to the best extent possible in the absence of a formal calibration and validation process.

We note the presence of sandy based soil conditions within the Soper Creek watershed. In our experience, deterministic VO hydrologic modelling tends to over estimate peak flows where sandy based soil conditions are present. To illustrate this point, we have provided a simple comparison of peak flows from VO Modelling Run 4000 – Tributary Level Existing Conditions at Flow Node 68 (located immediately upstream of Concession Road 3) to peak flows derived from the Unified Ontario Flood Index Method (UOFM). We have referenced the following key hydrologic parameters for the UOFM directly from the Ontario Watershed Information Tool (OWIT) for reference. **Table 6.25** below illustrates the basic hydrologic parameters used in the UOFM.

Table 6.25: Flow Node 68 - UOFM Hydrologic Parameters

Parameter	Symbol	Units	Input*
Drainage Area	A	km^2	52.47
Ecozone		Input 1 = Boreal Shield or 2 = Mixed Wood Plains	2.00
Lake/Wetland Areas	WA	km^2	3.39
Lake Attenuation Index	LI (LI = 1+(WA/A))	dimensionless	1.06
Mean Annual Precipitaiton	P	mm	904.00

*Input from OWIT

In using the hydrologic parameters in **Table 6.25**, Lower Limit, Mid Limit and Upper Limit peak flows, using the UOFM method have been calculated at Flow Node 68 for the 2,10,25,50 and 100-year events and detailed in **Table 6.26** below.

Table 6.26: Flow Node 68 – Peak Flow Comparison – VO vs UOFM

T	2	10	25	50	100
Lower Limit UOFM (m3/s)	10.37	18.23	22.12	24.44	27.07
Mid Limit UOFM (m3/s)	**14.61**	**26.81**	**33.02**	**37.60**	**42.30**
Upper Limit UOFM (m3/s)	20.45	39.15	49.53	57.53	66.42
VO - Modelling Run 4000 (m3/s)	**62.26**	**80.29**	**86.83**	**93.11**	**92.35**
Flow Difference (m3/s)	**47.65**	**53.48**	**53.81**	**55.51**	**50.04**
% Flow Difference (m3/s)	**326%**	**199%**	**163%**	**148%**	**118%**

Peak flow values from VO Modelling Run 4000 have also been provided for a direct comparison to flows derived from the UOFM. Specifically, we have provided a direct flow comparison between the Mid Limit UOFM and VO peak flows for further discussion.

As illustrated, the peak flow differences between the UOFM Method and VO modelled flows are quite significant. As an example, the Mid Limit UOFM 2-year flow at Flow Node 68 has been calculated at 14.61m3/s vs the VO modelled flow of 62.26m3/s. The 2-year VO modelled flow is 326% higher (over 3x) that of the UOFM derived flows. While neither the UOFM or VO modelled flows have been calibrated or validated to field-based conditions, we note that difference in not only flow methods but more importantly, peak flow magnitudes will influence a number of key considerations required for the detailed design, build out and future maintenance of key infrastructure within the Soper Creek subwatershed.

We have intentionally selected Flow Node 68 as a reference point in this section of the report for further discussion as:

- This flow node is located with the upper portion of the Soper Creek Watershed;
- Contains a large external drainage area of over 5000ha;
- Contains the Soper Springs Secondary Plan; and
- Directly Impacts Peak Flows downstream of Concession Road 3.

While the external drainage areas upstream and east of the Soper Hills Secondary plan are equally as important and could be compared in a similar fashion, we again note the importance of peak flow timing within the Soper Springs subatershed.

Both timing and magnitude of peak flows associated with external drainage areas directly influence the assessment of peak flows, attenuation requirements, erosion and roadway crossing analysis to name a few. While the Soper Creek SWS VO Hydrologic Model has been constructed to the best extent possible at the time of writing of this report, we note that the model has not been calibrated or validated to replicate field conditions.

Given the presence of sandy based soils with high infiltration rates, we suspect that the peak flows associated with external drainage areas and further throughout the Soper Creek SWS, may be over estimated. As the direct comparison of attenuation alternatives has been provided at key flow nodes throughout the watershed, both the magnitude and timing of external drainage areas is critical to the assessment of attenuation requirements within the Soper Springs, Soper Hills, Camp 30 and Timber Trail Developments.

Accordingly, it is the recommendation of this report to complete a formal calibration and validation of the VO model to confirm field flow conditions. Following a formal model calibration/validation, we would further recommend that all Storm Water Quantity Control alternatives be revisited to properly assess the impacts of attenuation within the Development Areas.

6.10.2.6 Hydraulic Impacts

Section 6.5 of this report provides a detailed comparison of the HEC-Ras hydraulic impacts of hydrological VO Modelling Run 6116 (Preferred Attenuation Alternative for Quantity Control) vs VO Modelling Run 4000 (Existing Conditions). While increases in flood elevations have been noted in several areas of the watershed, we note the following:

- Flood elevation increases are attributed to increases in flow conditions;
- Flood elevation increases are localised and not widespread;
- Flood elevation increases are not consistent between all storm events;
- Flood elevation increases are contained within the valley corridor of Soper Creek and its associated tributaries;

Flood elevation increases are noted in locations where proposed condition peak flows exceed the capacity of low flow channel portion of the valley corridor and enter the overbank areas. From a flood perspective, the noted increases in water level elevations associated with the future preferred modelling VO modelling Run 6116 would be fully contained within the valley corridor of Soper Creek and its associated tributaries. As such, we do not anticipate any adverse flooding impact to private property as a result of the preferred stormwater management approach.

Analysis and recommendations of the impacts of the preferred stormwater management approach from an Erosion Analysis perspective have been provided in **Appendix D.**

6.11 Potential Impacts Associated with Climate Change

Climate change has the potential to alter rainfall patterns in Ontario as more moisture in a warmer atmosphere is expected to cause an increase in extreme weather events and result in less climate predictability from year-to-year. A change in the intensity and/or frequency of rainfall events can have both acute and long-term effects on stream flow and municipal stormwater management. Rainfall events that produce a larger volume of water than the design flow can result in many complications. If a sufficient outlet or emergency overflow is not provided, large volumes of water can cause surcharging of the storm sewer systems, resulting in flooding in upstream urban areas.

The Municipality of Clarington has completed the first three phases of a five-phase corporate Climate Action Plan. Phase 4, Implement, is currently in progress and consists of “a five-year action-specific plan to prioritize action implementation, measure program implementation success, and identify key performance indicators, responsible departments, funding needs, and timelines for implementation” (Clarington, 2020). Simultaneously, Phase 5 is ongoing to monitor/review the effectiveness and success of the plan to prepare for future updates.

The following section quantifies potential changes to extreme rainfall events. These changes are included as a scenario in the model (**Section 6.6**) thereby contributing to the Action Plan by identifying actions for responding to climate change.

6.11.1 Future IDF Projections

Several tools have been developed by climate scientists and statisticians to project future intensity-duration-frequency (IDF) relationships for rainfall events in Ontario. Three of these tools are discussed below:

1) The **Ontario Climate Change Data Portal (Ontario CCDP)** was developed through the University of Regina with funding from the Ontario Ministry of the Environment and Climate Change (now Ministry of Environment, Conservation and Parks - MECP). This tool was launched to ensure technical or non-technical end-users (e.g., municipalities, private sector) have easy and intuitive access to the latest climate data over the Province of Ontario. Climate projections for several parameters are made on a 25 km grid resolution based on regional climate modelling using PRECIS model and the RegCM model under two emissions scenarios.
2) The **IDF_CC Tool 7.0** was developed through the University of Western Ontario and the Institute for Catastrophic Loss Reduction. This tool was designed as a simple and generic decision support system to generate local IDF curve information that accounts for the possible impacts of climate change. It applies a user-friendly GIS interface and provides precipitation accumulation depths for a variety of return periods (1:2, 1:5, 1:10, 1:25, 1:50 and 1:100 years) and durations (5, 10, 15 and 30 minutes and 1, 2, 6, 12 and 24 hours), and allows users to generate IDF curve information based on historical data, as well as future climate conditions that can inform infrastructure decisions. The IDF_CC tool stores data associated with 700 Environment and Climate Change Canada operated rain stations from across Canada. The IDF_CC tool allows users to select multiple future greenhouse gas concentration scenarios and apply results from a selection 24 Global Circulation Models (GCMs) and nine downscaled GCMs that simulate various climate conditions to local rainfall data.
3) The **MTO IDF Curve Lookup** was developed by the Ontario Ministry of Transportation (MTO) to provide a convenient method to interpolate IDF curve parameters between Meteorological Services Canada stations for MTO projects. As part of the tool, a time-trend analysis was conducted on data between 1960 and 2010 to establish trends in IDF parameters. The tool projects data forward to 2069 and 2099 using a linear trend line. It should be noted that this methodology is not based in climate projections but rather historical observations and as such results vary considerably from the two models introduced above which rely on downscaled global climate models.

The Ontario CCDP tool has not been updated since 2018 and the MTO IDF Curve Lookup only uses linear trends, not accounting for future predicted climate change impacts. Therefore, only the IDF_CC model was considered in order to create IDF climate projections for the Soper Creek Subwatershed.

The IDF_CC Tool 7.0 was used to generate IDF curves for the Toronto City station under the climate change scenario from 2070-2099 using the “all models ensemble” raw GCMs model selection default. The projection SSP2.45 was selected, which corresponds to medium climate change severity. This aligns with direction provided by the MECP for climate change impact assessments (Climate Risk Institute, 2023).

6.11.1.1 Existing IDF Curve

After discussion with the Municipality of Clarington and CLOCA, the decision to use the updated Toronto City IDF curves was formed. Short Duration Rainfall IDF Data from Environment and Climate Change Canada was compiled using the Gumbel method on the Toronto City Rain Gauge during the years 1940-2021. **Table 6.27** displays rainfall intensities for each storm event.

Table 6.27: Updated Toronto Return Period Rainfall Intensities (mm/hr)

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	106.9	146.6	172.9	206.1	230.8	255.2
10 min	75.4	99.2	114.9	134.8	149.5	164.2
15 min	60.3	82.0	96.4	114.6	128.1	141.5
30 min	38.6	53.4	63.1	75.4	84.6	93.6
1 h	23.8	32.6	38.4	45.7	51.2	56.6
2 h	14.1	19.5	23.0	27.5	30.9	34.2
6 h	5.8	7.9	9.2	10.9	12.2	13.4
12 h	3.5	4.5	5.2	6.1	6.8	7.4
24 h	2.0	2.5	2.9	3.4	3.7	4.1

In **Table 6.28**, interpolation equation coefficients can be found for the Updated Toronto City IDF curves.

Table 6.28 Interpolation Equation Coefficients - Updated Toronto

T (years)	Coefficient A	Coefficient B
2	21.3	-0.719
5	28.7	-0.727
10	33.6	-0.730
25	39.8	-0.733
50	44.4	-0.734
100	49.0	-0.736

The following interpolation formula can be used to find the interpolated rainfall rate for any given rainfall duration:

Interpolated Rainfall Rate (mm/hr) $R = A \cdot T^B$

Where:

A and B are the coefficients for each return period (T) in years
T is the time (duration) of the precipitation event in hours (h)

6.11.1.2 Projection Results

The following section uses an SSP2.45 climate change projection for the years 2070-2099 from the IDF_CC Tool

Table 6.29 displays rainfall intensities for each storm event for the projected climate change IDF for Toronto City, SSP2.45, for years 2070-2099.

Table 6.29 Projected Climate Change Rainfall Intensities (mm/hr)

	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
5 min	116.29	160.19	192.18	242.33	284.08	336.98
10 min	83.72	110.63	128.94	157.83	181.36	209.84
15 min	65.73	89.9	107.46	134.93	157.85	186.81
30 min	42.21	59.04	70.88	89.21	104.33	122.79
1 h	26.61	36.94	43.92	53.81	61.59	70.07
2 h	15.64	21.63	25.75	31.79	36.66	42.27
6 h	6.41	8.67	10.27	12.76	14.84	17.43
12 h	3.85	5.06	5.89	7.18	8.22	9.45
24 h	2.21	2.88	3.31	3.96	4.42	4.97

Table 6.30 Interpolation Equation Coefficients - Projected Climate Change

T (years)	Coefficient A	Coefficient B	Coefficient t_0
2	27.7	-0.796	0.083
5	38.9	-0.818	0.101
10	46.7	-0.830	0.109
25	58.3	-0.841	0.114
50	67.8	-0.850	0.118
100	81.4	-0.869	0.135

The following interpolation formula can be used to find the precipitation intensity rate for any given rainfall duration:

$$i\left(\frac{mm}{h}\right) = A \cdot (t + t_0)^B$$

Where:

i is the precipitation intensity rate in $\frac{mm}{h}$
A, B and t_0, are the coefficients for each return period (T) in years
t is the time (duration) of the precipitation event in hours (h)

Table 6.31 tabulates the percent increase in rainfall intensity from the Updated Toronto IDF data to the SSP2.45 climate change projection.

Table 6.31 Percent Increase from Updated Toronto IDF Curve to SSP2.45 (IDF-CC, 2070-2099)

	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
5 min	8.8	9.3	11.2	17.6	23.1	32.0
10 min	11.0	11.5	12.2	17.1	21.3	27.8
15 min	9.0	9.6	11.5	17.7	23.2	32.0
30 min	9.4	10.6	12.3	18.3	23.3	31.2
1 h	11.8	13.3	14.4	17.7	20.3	23.8
2 h	10.9	10.9	12.0	15.6	18.6	23.6
6 h	10.5	9.7	11.6	17.1	21.6	30.1
12 h	10.0	12.4	13.3	17.7	20.9	27.7
24 h	10.5	15.2	14.1	16.5	19.5	21.2

As illustrated in **Table 6.32**, the projected climate change IDF SSP2.45 for years 2070-2099 by IDF_CC is more conservative than the updated Toronto IDF Curve. This holds under all scenarios, return periods and duration of precipitation. Generally, the percent increase between the existing and projected data increases as return period increases. It is therefore recommended that the effects of climate change be taken into account by using these IDF projection results as a sensitivity analysis during the design of stormwater infrastructure.

Table 6.32 provides a summary comparison between current rainfall data and climate change rainfall data at various flow nodes within the project area.

Table 6.32: 100-year – Existing Conditions - Standard Rainfall (w/o CC) vs Climate Change (w CC) Peak Flow Summary

Reach	HYD	Location	Ex (w/o CC) Modelling Run 4000 (m3/s)	Ex (w CC) Modelling Run 7005 (m3/s)	Difference (m^3/s)
SM19	248	Liberty Street	7.69	10.61	2.92
SM19	250	Soper Spring - DS of SWM SS Pond 3	8.11	11.18	3.07
SM19	251	Soper Spring - DS of SWM SS Pond 1	8.51	11.64	3.14
SM6	66	Soper Springs	85.02	112.53	27.52
SM6	68	Concession Road 3	92.35	124.03	31.68
SM6	72	Rail Line	91.23	126.28	35.05
SM6	73	Downstream of Rail Line	92.22	127.56	35.33
SM6	131	Camp 30	4.13	5.78	1.65
SM6	166	Camp 30	4.54	6.35	1.82
SM6	167	Camp 30	93.24	128.99	35.75
SM6	176	Camp 30	93.67	129.45	35.78
SM6	168	Camp 30	93.83	129.68	35.85
SM6	179	Concession Street	88.27	121.51	33.24
SM6	79	Camp 30	87.89	120.54	32.65
SE1	185	Rail Line	3.47	4.80	1.34
SE2	96	Bragg Road	25.60	35.52	9.92
SE1	186	Reach Confluence Upstream of Concession St	33.62	46.65	13.04
SE1	190	Concession St East	36.09	50.16	14.07
SE1	198	Soper Hills East Development Limit	38.73	53.76	15.04
SE1	211	Soper Hills	38.50	53.34	14.84
SE1a	214	Soper Hills	6.57	9.16	2.59
SE1	217	Soper Hills	42.03	58.04	16.01
SE1	225	Soper Hills	41.75	57.64	15.89
SE1	232	Soper Hills West Development Limit	42.75	58.83	16.07
SM6	100	King Street East	117.31	158.97	41.66
SM7	104	Bowmanville Cemetery	123.01	165.25	42.25

7 Description of the Recommended Plan

This chapter will summarize the overall Management Strategy for the Secondary Plan lands in consideration of the preceding sections. **Section 4** outlined the proposed land uses, while **Sections 5** and **6** identified alternative stormwater strategies and selected a preferred approach. The discussion in this section will focus on targets and appropriate measures related to stormwater management (surface water), erosion, natural heritage plans and groundwater.

7.1 Stormwater Management (Surface Water)

Changes in land use, including the conversion of rural lands to urban development alters the water balance as pervious surfaces are converted to impervious surfaces, infiltration characteristics of the soils are altered and vegetation is removed. When rural lands are urbanized, porous soils are replaced with impervious materials such as concrete and asphalt which yield high runoff during precipitation events. Consequently, land use change can lead to a significant and sometimes radical alteration in the watershed hydrology and water quality.

In order to mitigate the impact of urbanization of the Soper Creek Subwatershed, stormwater management in the form of source, conveyance and end-of-pipe facilities will need to provide:

- water quality treatment consistent with MECP “enhanced” level quality control;
- infiltration opportunities to maintain pre-development water balance characteristics and support Ecologically Significant Groundwater Recharge Areas (ESGRAs) and High-Volume Recharge Areas (HVRAs);
- detention of peak flows to mitigate flooding in tributaries and critical reaches of Soper Creek; and
- erosion controls to maintain existing erosion rates within Soper Creek.

The Runoff Volume Control Target (RVC_T) corresponds to the runoff generated from the regionally specific 90th percentile rainfall event, which is approximately a 27 mm event in Soper Creek Subwatershed, which is more stringent than CLOCA’s volume control criteria to capture, retain or detain runoff from a 25 mm rain event. To meet the more conservative criteria, new projects in the Soper Creek Subwatershed will therefore have a RVC_T corresponding to the 27 mm event. The runoff generated from a 27 mm rainfall event should be controlled using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are preferred. The control hierarchy is shown below in **Figure 7.1**.

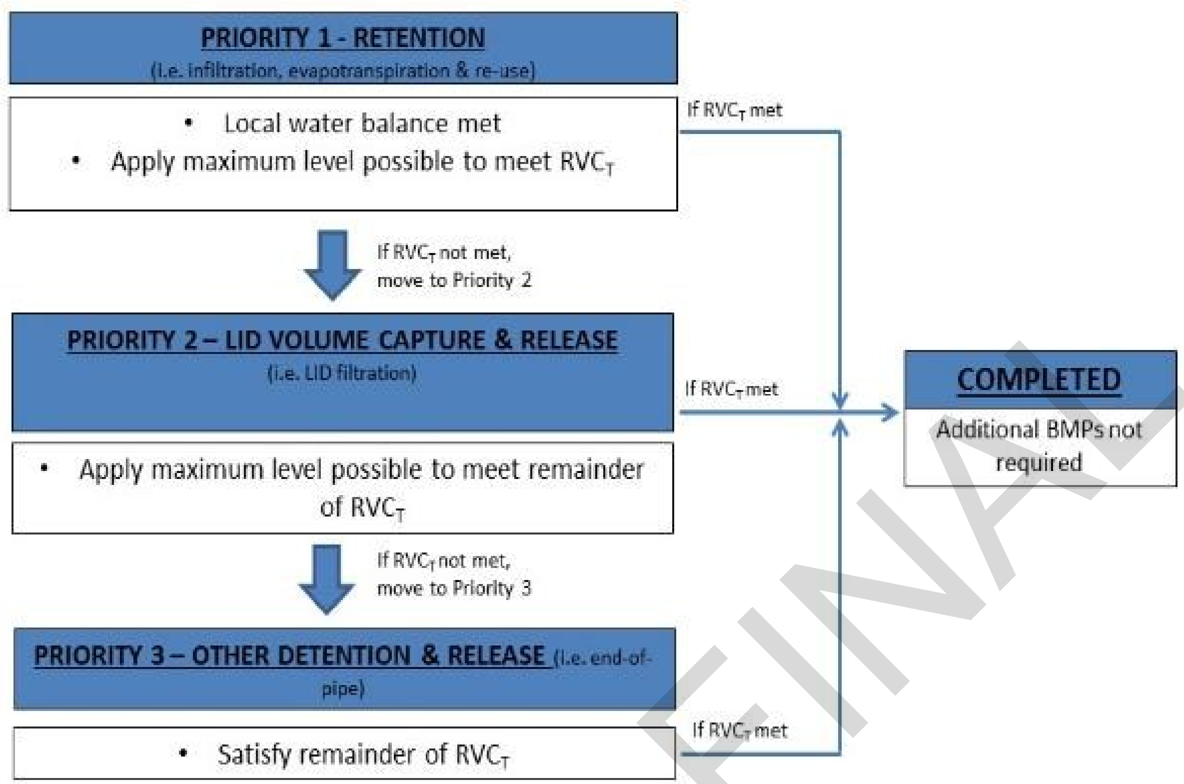

Figure 7.1: The runoff control hierarchy from the MECP's LID Stormwater Management Guidance Manual

7.1.1 SWM Quantity Control

This section will address the SWM Quantity Control strategy for up to the 100-year and Regional storms to ensure that proposed development does not increase flows within the creeks or their tributaries. CLOCA requires the following criteria, also adopted by this study:

1. Post-development flows per catchment throughout the watershed from the 2-year through 100-year events were less than or equal to the 2-100 year existing flows;
2. Post-development flows at key nodes throughout the watershed from the 2-year through 100-year events were less than or equal to the 2-100 year existing flows; and
3. Uncontrolled flows were less than the existing regulatory flows, where the regulatory flow is defined as the larger of the 100-year or Regional flow.

Due to the complex nature of peak flow timing within Soper Creek subwatershed, stormwater detention ponds providing overcontrol are necessary in the Soper Springs Secondary Plan area, to mitigate the increase in post-development flows. The required detention can be provided within the end-of-pipe stormwater ponds as recommended as part of the preferred stormwater strategy. This consists of four (4) municipal ponds which were located within the Soper Springs Secondary Plan, but placed near the outlets of their respective subcatchments.

The list of the proposed ponds and stormwater control facilities and their storage volumes are presented in **Table 7.1** based on the locations identified in **Figure 3.1** and **Figure 3.2**. The assumed footprint of each facility is also provided, using an average facility depth of 2m. The proposed locations, storage volumes and footprints are preliminary and need to be confirmed through the design process. In addition, these ponds must be designed to ensure that the post-development flow rates at key flow nodes (**Figure 6.2**) are controlled to the pre-development flow rates.

Table 7.1: Summary of Conceptual Municipal Stormwater Management Ponds

NHYD	Secondary Plan Dev. Area (ha)	Existing	Future (Controlled)	Difference (m^3/s)	# Ponds	Storage per Pond (m^3)	Storage Provided (m^3/ha)	Assumed Total Pond Footprint (i.e 7% of DA) (ha)
SM9_35	28.21	1.774	1.16	-0.614	1	14874.93	527.29	1.97
SM10_36	19.08	0.948	0.602	-0.346	1	7802.97	408.96	1.34
SM9_28	4.9	0.421	0.261	-0.16	1	2742.31	559.66	0.34
SM10_31	3.46	0.175	0.104	-0.071	1	1897.35	548.37	0.24

7.1.2 Water Quality

Following the approach outlined in **Figure 7.1**, it is recommended that new development areas within the Soper Creek Subwatershed maintain a water quality target that will not vary and will remain as control of the runoff generated from a 27 mm event using infiltration LID measures as a first priority, followed by filtration measures if full infiltration is not feasible. This approach is aligned with the requirements of CLOCA and the MECP CLI ECA, which prioritizes LID measures to achieve an Enhanced level of treatment within the Soper Creek Subwatershed. An Enhanced level of treatment corresponds to a long-term load reduction of total suspended solids of 80%.

Achieving control of the 27 mm event is possible through infiltration, with **Table 7.2** presenting the equivalent runoff volume within each subcatchment. Actual runoff from the 27 mm event must be calculated during detailed design. However, local conditions may indicate that infiltration of the 27 mm event is not feasible (**Section 7.1.2.1** for discussion of site-specific factors). If any of these factors apply to a specific site, then LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes should be considered. If using these techniques to treat the 27 mm event is still not feasible, then the use of stormwater management facilities (e.g. wet ponds, wetlands, or hybrid ponds) or manufactured treatment devices (e.g. oil and grit separators) may be permitted. Regardless of the method used to achieve the water quality criteria, SWM quantity controls to control peak flows will still be required at the end-of-pipe (per **Section 7.1.1**). If wet ponds are installed, the design of these ponds should ensure that they do not increase the erosion potential to the receiving watercourse, and should also include thermal mitigation best practices.

Table 7.2: Runoff Volumes

Name	Ex_27mm Runoff Volume (mm)	Ex_27mm Total Vol (m^3)
SM9_35	3.078	7,616.7
SM10_36	2.436	5,151.6
SM9_28	4.057	1,323
SM10_31	2.091	934.2
SM6_21	3.132	137.7
SM6_26	2.649	2,011.5
SM6_20	4.384	815.4
SM6_17	4.417	1,954.8
SM6_12	4.368	2,084.4
SM6_50	2.625	4,538.7
SE1_52	5.661	2,700
SE1_23	4.986	14,129.1
SE1_18	3.018	3,410.1
SE1_10	3.037	8,820.9
SE1_7	13.245	2,027.7
SE1_4	5.762	2,894.4
SE1_13	4.56	11,491.2

7.1.2.1 Site-Specific Factors Limiting Use of LIDs

The use of infiltration LID measures may be limited by site-specific factors. These factors, as described by Sustainable Technologies Evaluation Program (2019) and MECP (2017), include:

- Shallow bedrock;
- High groundwater;
- Zoning, setbacks or other land-use requirements;
- Property or infrastructure restrictions;
- Poor soils (low infiltration rates, highly compacted, contaminated); or
- Highly vulnerable aquifer.

In addition to these factors, the presence of high-risk site activities within the catchment area may also restrict the use of LIDs. For all sites, infiltration practices should not accept runoff from drainage areas within the site which are associated with higher risks such as fueling stations, waste disposal areas, vehicle washing stations, salt storage areas, stockpiling areas and shipping and receiving areas. A complete list of high-risk site activities based on O.Reg. 153/04 (Records of Site Condition) and O.Reg. 287/07 (Clean Water Act) is provided in **Table 7.3**. These regulations provide guidance for protecting soil and water from contamination. This prohibition includes the use of flexible liners and or gated/ closeable inlets to prevent infiltration of runoff due to the potential for punctures and or winter by-pass, respectively. Should 'permanent' and or 'hardened' impermeable closed bottom structure be used (i.e. plastic or concrete tanks, vaults, or chambers) be proposed, explicit approval from the Municipality of Clarington shall be obtained.

Instead of infiltration-based stormwater practices, pollution prevention practices in the form of administrative and engineering controls should be applied in these areas, followed by treatment using conventional stormwater management controls such as ponds, wetlands and hybrid facilities as well as hydrodynamic separators (OGS units) and/or membrane or media filtration units (e.g. Jellyfish filters, Storm Filters, etc.).

Table 7.3 identifies individual high-risk site activities based on O.Reg. 153/04 and O.Reg. 287/07. High-risk site activities are defined as those with the potential for high levels of contamination such as hydrocarbons, metals, organic and inorganic compounds, sediments and chlorides. At this scale of study, it is impossible to predict the long-term site-specific activities of individual sites; however, **Table 7.3** can be used a screening framework for identifying portions of each site where additional focus and review is needed to where LIDs should be discouraged, due to risk associated with the specific uses.

Drainage areas containing a site with high-risk activities (**Table 7.3**) will generally be discouraged from incorporating LID techniques that utilize infiltration as its primary function within the identified catchment because of the associated risk to groundwater contamination. However, high-risk site activities do not preclude the use of those LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes. Additionally, the infiltration of rainwater from catchments that are isolated from the respective high-risk site activities such as rainwater emanating from rooftops, employee parking facilities or directly falling on permeable surfaces is generally considered relatively 'clean' and should not be excluded from infiltration.

While the application of road salt is identified in **Table 7.3** due to its inclusion in O.Reg. 287/07 as a Prescribed Drinking Water Threat, the need for winter maintenance of roads and parking surfaces, including the application of de-icers, is recognized due to safety and liability concerns. However, there is also the need to target impervious surfaces with infiltration-based LIDs in order to meet infiltration targets and sustain critical surface water – groundwater connections. To balance these needs, it is recommended that:

1) Infiltration practices are recommended for Local Roads only. Local roads typically have less intensive winter de-icer application as a result of lower usage and posted speed limits; and

2) A Salt Management Plan must be completed for the subject property for paved surfaces between 200 to 2000 m^2. Infiltration practices are discouraged for runoff originating from paved surfaces in excess of 2000 m^2 the facility is not used during winter months or an appropriate engineering solution is implemented to the satisfaction of Municipality staff.

7.1.2.2 Additional Water Quality Best Practices

In addition to providing water quality treatment, the reduction of pollutant loading through the implementation of best management practices is recommended. Recommendations include:

- Residents:
    - Reducing the use of fertilizer and pesticides on lawns and gardens;
    - Pick up and dispose of litter and pet waste in a timely manner;
    - Manage yard waste so that grass clippings and leaves stay out of the street;
    - If residents wash their car at home, make sure they do so on the grass instead of in the driveway, and use phosphorus-free detergents;
    - Promote native landscaping to reduce turfgrass. If planting grass, keep a thick cover at least 8 cm tall to reduce soil erosion; and
    - Do not leave uncovered soil exposed to the elements – stabilize it using grass or native vegetation.
- Municipalities:
    - Practice good sanitary sewer maintenance to ensure the system does not leak;
    - Reduce the use of fertilizer and pesticides, and ensure vegetative debris doesn't enter storm sewer systems;
    - Implement broader Municipality-wide initiatives to prevent pesticide use by residents;
    - Reduce turfgrass cover and use native vegetation where feasible;
    - Control waste-generating wildlife such as geese;
    - Remove debris from storm sewer system, especially inlets and catch basins;
    - Manage exposed soil to prevent wind or water erosion; and
    - Maintain vehicles to prevent pollutant releases.

Table 7.3: High-Risk Site Activities Which Preclude the Use of Infiltration-Based LID BMPs Within the Contributing Catchment Area

Potentially Contaminating Activities (O.Reg 153/04 Table 2)		
• Acid and Alkali Manufacturing, Processing and Bulk Storage • Adhesives and Resins Manufacturing, Processing and Bulk Storage • Airstrips and Hangars Operation • Antifreeze and De-icing Manufacturing and Bulk Storage • Asphalt and Bitumen Manufacturing • Battery Manufacturing, Recycling and Bulk Storage • Boat Manufacturing • Chemical Manufacturing, Processing and Bulk Storage • Coal Gasification • Commercial Autobody Shops • Commercial Trucking and Container Terminals • Concrete, Cement and Lime Manufacturing • Cosmetics Manufacturing, Processing and Bulk Storage • Crude Oil Refining, Processing and Bulk Storage • Discharge of Brine related to oil and gas production • Drum and Barrel and Tank Reconditioning and Recycling • Dye Manufacturing, Processing and Bulk Storage • Electricity Generation, Transformation and Power Stations • Electronic and Computer Equipment Manufacturing • Explosives and Ammunition Manufacturing, Production and Bulk Storage • Explosives and Firing Range • Fertilizer Manufacturing, Processing and Bulk Storage	• Fire Retardant Manufacturing, Processing and Bulk Storage • Fire Training • Flocculants Manufacturing, Processing and Bulk Storage • Foam and Expanded Foam Manufacturing and Processing • Garages and Maintenance and Repair of Railcars, Marine Vehicles and Aviation Vehicles • Gasoline and Associated Products Storage in Fixed Tanks • Glass Manufacturing • Importation of Fill Material of Unknown Quality • Ink Manufacturing, Processing and Bulk Storage • Iron and Steel Manufacturing and Processing • Metal Treatment, Coating, Plating and Finishing • Metal Fabrication • Mining, Smelting and Refining; Ore Processing; Tailings Storage • Oil Production • Operation of Dry-Cleaning Equipment (where chemicals are used) • Ordnance Use • Paints Manufacturing, Processing and Bulk Storage • Pesticides (including Herbicides, Fungicides and Anti-Fouling Agents) Manufacturing, Processing, Bulk Storage and Large-Scale Applications • Petroleum-derived Gas Refining, Manufacturing, Processing and Bulk Storage • Pharmaceutical Manufacturing and Processing	• Plastics (including Fibreglass) Manufacturing and Processing • Port Activities, including Operation and Maintenance of Wharves and Docks • Pulp, Paper and Paperboard Manufacturing and Processing • Rail Yards, Tracks and Spurs • Rubber Manufacturing and Processing • Salt Manufacturing, Processing and Bulk Storage • Salvage Yard, including automobile wrecking • Soap and Detergent Manufacturing, Processing and Bulk Storage • Solvent Manufacturing, Processing and Bulk Storage • Storage, maintenance, fueling and repair of equipment, vehicles, and material used to maintain transportation systems • Tannery • Textile Manufacturing and Processing • Transformer Manufacturing, Processing and Use • Sewage Treatment and Sewage Holding Facilities • Vehicles and Associated Parts Manufacturing • Waste Disposal and Waste Management, including thermal treatment, landfilling and transfer of waste, other than use of biosoils as soil conditioners • Wood Treating and Preservative Facility and Bulk Storage of Treated and Preserved Wood Products
Prescribed Drinking Water Threats (O.Reg. 287/07)		
• The establishment, operation or maintenance of a waste disposal site within the meaning of Part V of the Environmental Protection Act. • The establishment, operation or maintenance of a system that collects, stores, transmits, treats or disposes of sewage. • The application of agricultural source material to land. • The storage of agricultural source material. • The management of agricultural source material. • The application of non-agricultural source material to land. • The handling and storage of non-agricultural source material.	• The application of commercial fertilizer to land. • The handling and storage of commercial fertilizer. • The application of pesticide to land. • The handling and storage of pesticide. • The application of road salt. • The handling and storage of road salt. • The storage of snow. • The handling and storage of fuel. • The handling and storage of a dense non-aqueous phase liquid. • The handling and storage of an organic solvent.	• The management of runoff that contains chemicals used in the de-icing of aircraft. • An activity that takes water from an aquifer or a surface water body without returning the water taken to the same aquifer or surface water body. • An activity that reduces the recharge of an aquifer. • The use of land as livestock grazing or pasturing land, an outdoor confinement area or a farm-animal yard. • The establishment and operation of a liquid hydrocarbon pipeline. O. Reg. 385/08, s. 3; O. Reg. 206/18, s. 1.
Other Threats		
• Anthropogenically contaminated soils that have not been fully remediated		

7.1.3 Erosion Control

This section of the SWS is to accompany the Phase 2 and 3 report of the Soper Creek Subwatershed Study, building on the data collected as part of the Phase 1 investigation submitted in May of 2023. The purpose of this analysis is to summarize the method and results of the reach-based field investigations to characterize shear stress along critical reaches. A full overview of the completed analysis has been provided in **Appendix D.**

A tractive force analysis was completed on critical reaches of the Soper Creek Subwatershed within the built boundary of the Municipality of Clarington as part of the Soper Creek Subwatershed Study. The analysis was based on the field data acquired in November 2019 and confirmed with addition field investigations in October of 2024. This assessment determined that while the substrate of most reached in the subwatershed are relatively stable, the banks are highly susceptible to erosion by events smaller than the modelled 2-year flows. This watershed was found to have a high sediment transport regime which may influence not only the erosion hazard limits, but also natural heritage factors that contribute to habitat and diversity.

The Soper Creek Subwatershed Study Phase 1 Report identified several erosion and maintenance sites, along with recommendations for geotechnical investigations to further refine the erosion hazard. These recommendations are supported by this assessment, given the sensitivity of the subwatershed system to erosion.

It is unlikely that any amount of stormwater control within the areas proposed for development will prevent erosion. Given the system's natural sediment regime, a change in sediment flux at a reach scale could stave sediment from downstream and enhance the erosion elsewhere.

Erosion is a natural process within the Soper Creek Subwatershed and should be maintained at existing rates as much as possible. This would set flow targets to existing conditions if the geomorphic stability of the system is to remain consistent.

Recommendations from the Phase 1 Report to refine the geotechnical component of the identified Long-Term Stable Slope hazards should be addressed prior to development. Additionally, the erosion sites and maintenance sites that were identified as part of this report will require re-assessment and monitoring to address the risks to infrastructure. A strategy to address these concerns should include regular updates to the erosion site inventory every 5-10 years and integrated within the strategic planning of the Municipality.

This tractive force assessment has looked at peak flows and their impact on the channel's boundary material. In order to determine the impact of retained flow discharged over a prolonged timeframe, a continuous flow model is required using a validated and calibrated model to determine the differences between the existing erosion rates and proposed conditions that may increase those rates as a result of development. It is recommended that the rates of erosion be confirmed at the detailed design stage for any proposed stormwater retention facility.

7.1.4 Water Balance

The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead.

The Thornthwaite-Mather method of estimating pre-development groundwater recharge (see **Section 6.8**) provides an annual infiltration rate of approximately 88 and 124 mm/year for Soper Hills and Soper Springs, respectively. Given that there are approximately 40 rainfall events per year the average infiltration rate per event is relatively modest (approximately 2 mm per event in Soper Hills and 3 mm in Soper Springs). The actual values on a site-by-site basis will vary depending on soil type, slopes, vegetation cover and depth to water table.

The above recharge targets can be achieved by incorporating appropriate LID source and conveyance control measures as outlined in **Section 5,** together with the requirements to meet the Water Quality targets. Collectively, the LID measures should ensure that post-development infiltration rates equal or exceed pre-development levels. The impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead.

High Volume Recharge Areas (HVRAs) and Ecologically Significant Groundwater Recharge Areas (ESGRAs) will require additional attention to ensure pre-development recharge rates are maintained (see **Section 7.4**, **Figure 7.5**, and **Figure 7.6**).

7.1.5 Thermal Mitigation

Soper Creek was characterized as cold/coolwater streams by AECOM (2010). Aquatic investigations by Aquafor Beech as part of the **Soper Creek Subwatershed Study: Phase 1 Report** confirmed a cold-warmwater thermal regime (with coolwater occurring in upstream reaches with groundwater input).

Since the use of LID measures reduces stormwater temperature, it is expected that the implementation of the recommended stormwater strategy is expected to adequately cool stormwater temperatures when combined with best management practices for the SWM facilities. The latest thermal mitigation technologies should be considered in addition to more common practices which include, but are not limited to (STEP, no date):

- Bottom draw outlets;
- Cooling trenches;
- Subsurface trench outlets;
- Shading of permanent pool, outfall channel, and paved surfaces throughout the catchment;
- Improved pond design (e.g. Location, orientation, length-to-width ratio, planted berms); and
- Use of facilities without a permanent pool.

Since all proposed facilities are dry ponds without a permanent pool, there will be less opportunity for standing water to heat up.

7.2 Natural Heritage

This section provides an overview and summary of natural heritage considerations and policy requirements that were discussed previously in the Phase 1 SWS report, with additional discussion provided as appropriate related to the proposed land use plan and future requirements.

7.2.1 Application of NHS Criteria

The Municipality of Clarington's Official Plan defines the Natural Heritage System (NHS) as:

> A system made up of natural heritage features and areas, hydrologically sensitive features and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystems. These systems can include natural heritage features and areas, hydrologically sensitive features, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue.

The OP further lays out criteria to be used in identifying natural heritage features and hydrologically sensitive features which should be included in the municipal NHS. These criteria were used in Phase 1 of the Soper Creek SWS to identify eligible natural heritage features and support subsequent discussion of developmental constraints. Natural heritage features which are identified by the Municipality's OP, section 3.4.2, as being eligible for inclusion in the NHS are:

- Wetlands;
- Areas of Natural and Scientific Interest;
- Significant Woodlands;
- All significant Valleylands;
- Fish Habitat and Riparian Corridors;
- Habitat of endangered species and threatened species;
- Rare vegetation communities, including sand barrens, savannahs and tallgrass prairie; and
- Wildlife habitat.

The following Hydrologically Sensitive Features are also identified by the OP (section 3.4.2) as being eligible for inclusion in the NHS:

- Wetlands;

- Watercourses;
- Seepage areas and springs;
- Groundwater features; and
- Lake Ontario and its littoral zones.

The OP (section 3.4.3) further states that other environmentally sensitive features and areas, natural heritage features, and hydrologically sensitive features which are important to the integrity of the NHS may be identified on a site-by-site basis for protection.

Figure 7.2 illustrates the features within the study area that were determined to be eligible for inclusion in the NHS, or which required additional study in order to confirm their eligibility, per the investigations and analysis detailed in the Phase 1 SWS report. The information contained in **Figure 7.2** and the supporting technical discussion were key deliverables of Phase 1, are intended to inform the Secondary Plans and other subsequent studies, and were used during Phase 1 to identify constraints to development (see **Section 7.3**).

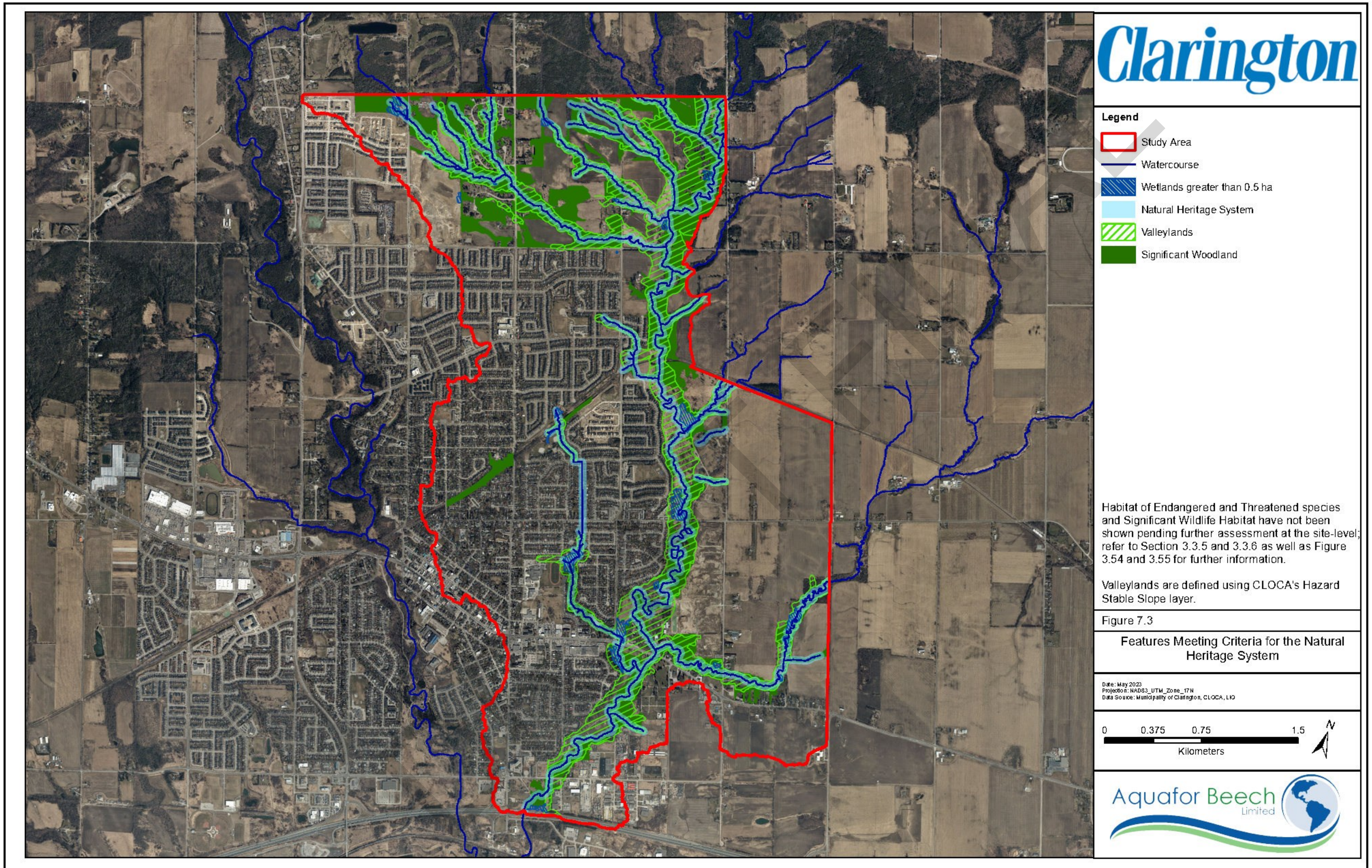

Figure 7.2: Features Meeting Criteria for Natural Heritage System

7.2.2 Vegetation Protection Zones

Vegetation protection zones (VPZs), as defined in the Municipality of Clarington's OP, are vegetated buffer areas surrounding Natural Heritage Features or Hydrologically Sensitive Features, within which development and site alteration is generally prohibited save for certain limited uses:

- Forest, fish and wildlife management;
- Conservation and flood or erosion control projects, but only if they have been demonstrated to be necessary in the public interest after all alternatives have been considered;
- Transportation, infrastructure and utilities, but only if the need for the project has been demonstrated through the completion of an Environmental Assessment, there is no reasonable alternative, and it is supported by a project-specific Environmental Impact Study (EIS);
- Low intensity recreation; and
- Low-impact development stormwater systems such as bioswales, infiltration trenches and vegetated filter strips, provided that the intent of the VPZ is maintained and it is supported by an EIS.

A VPZ "is intended to be restored with native, self-sustaining vegetation and be of sufficient width to protect the feature and its functions from effects of the proposed change and associated activities before, during, and after construction, and where possible, restore and enhance the feature and/or its function from effects of the proposed change and associated activities before, during, and after construction, and where possible, restore and enhance the feature and/or its function". The OP further indicates that "approval of any development application shall ensure that a self-sustaining vegetation protection zone be planted, maintained or restored in order to protect any on-site or adjacent natural heritage feature and/or hydrologically sensitive feature" (Municipality of Clarington 2018). Direction from CLOCA has also indicated their requirement for active restoration of VPZs with native, self-sustaining vegetation (as opposed to passive regeneration). VPZs are to be imposed where new development and/or site alteration is to occur (i.e., they do not retroactively affect pre-existing development or current land uses/practices such as agriculture).

Minimum VPZs that are to be applied to components of the NHS within the urban boundary, in keeping with the requirements of the Municipality of Clarington's OP, are as follows:

- 30 m from the outermost extent of Wetlands;
- 15 m from the outermost extent of Watercourses
- 15 m from the outermost extent of Fish Habitat and Riparian Corridors;
- 15 m from the stable top of bank associated with Valleylands;
- 15 m from the dripline of the outermost tree associated with Significant Woodlands;
- 15 m from the outermost extent of Seepage Areas and Springs; and

- An appropriate width to preserve both the form and function of Habitat of Endangered and Threatened Species, Significant Wildlife Habitat, Wildlife Habitat, and Rare Vegetation Communities, as determined through site-specific study (i.e., EIS).

Where multiple features are present and overlap, the most conservative VPZ will apply (i.e., the outermost boundary which consolidates all individual components).

With respect to the Fish Habitat and Riparian Corridors feature, please note that the VPZ is to be applied to the riparian corridor as a whole which includes any lands necessary to support fish habitat function; as such, it is not necessarily limited to the watercourse itself. The mapping prepared for this SWS has utilized a Fish Habitat and Riparian Corridor width of 30 m on either side of the watercourse, for discussion, per the definitions of the Natural Heritage System Discussion Paper (Ganaraska Conservation and CLOCA, 2013) which were also used by the Municipality during the development of its OP schedules. The minimum 15 m VPZ was then applied to that corridor per the requirements cited above. If appropriate, an EIS may establish a revised Fish Habitat and Riparian Corridor width surrounding individual watercourses based on site-specific study, with the VPZ then to be applied to that revised boundary.

In application, the Municipality allows only the outer 5 m of the VPZ to contain uses such as trails and infiltration trenches, provided these uses are supported by an EIS.

The above values denote the minimum VPZ width that is acceptable under policy around the various features. The presence of sensitive features or functions may warrant an increase to the minimum recommended VPZ; site-level studies such as an EIS shall investigate whether the minimum VPZ is appropriate for all features in its study area or whether greater than the minimum value is required to ensure ecological features and/or functions are preserved.

7.2.3 Headwater Drainage Features

Headwater Drainage Features (HDFs) are typically shallow, seasonal/ephemeral drainage features that are important in maintaining primary and secondary inputs to surface water, groundwater, and/or fish habitat as applicable. HDFs within the study area were previously defined in Phase 1 of the Soper Creek SWS using the Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (CVC & TRCA, 2014), which is the accepted protocol for the identification and classification of HDFs in Ontario. All HDFs on properties for which the study team was given permission to enter were fully evaluated using the noted guidelines and one of four Management Recommendations was applied. Briefly, the four Management Recommendations are as follows:

- **Protection**: feature and its riparian zone, groundwater discharge and hydroperiod to be protected, maintained or enhanced in-situ. Realignment generally not permitted.
- **Conservation**: feature and its riparian zone to be maintained, relocated, or enhanced such that valued functions and downstream connections are maintained.
- **Mitigation**: functions associated with the HDF may be replicated through enhanced lot level conveyance measures.

- **No Management Required**: features and/or functions are not present which require management or preservation moving forward.

The 2020 *Growth Plan for the Greater Golden Horseshoe*, prepared under the *Places to Grow Act* (2005), considers HDFs to be a component of "significant surface water contribution areas" and recommends their protection as Key Hydrologic Features. The Municipality of Clarington's OP does not specifically identify HDFs as a component of the NHS; however, those features contributing to fish habitat would appropriately be considered under the "Fish Habitat and Riparian Corridor" designation which is a protected component of the NHS.

However, it is recognized that the HDF guidelines and the Management Recommendations therein provide direction specifically related to HDF management and should therefore be taken into account when determining how these features are to be treated. Aquafor has discussed with the Municipality of Clarington how to bring the HDF Management Recommendations and the OP NHS policies into agreement, and the following practice was agreed upon:

- HDFs with a "Protection" Management Recommendation are to be treated as Fish Habitat and Riparian Corridor and part of the NHS with all applicable protections under the OP. The Fish Habitat and Riparian Corridor feature includes the drainage channel plus 30 m on either side of the channel for a total 60 m riparian corridor (unless a site-specific EIS evaluates the feature and establishes otherwise). An additional 15 m VPZ is to be applied to the feature as discussed in **Section 7.2.2**. Additional studies in the form of an EIS may be required to determine the extent and verify the functions of the protected feature and guide the VPZ delineation prior to alteration. In no circumstances is the VPZ to be less than the minimum outlined in the OP.

- HDFs with a "Conservation" Management Recommendation may be relocated or realigned in keeping with the HDF guidelines. Once in its final configuration, however, the realigned channel then is to be designated Fish Habitat and Riparian Corridor with all applicable protections as described above. In keeping with the above, site-specific studies verifying the extent and function of the feature may be required prior to alteration in order to guide VPZ delineation.

- HDFs with a "Mitigation" Management Recommendation will not be included in the NHS, but functions contributing to fish habitat and other valued components of downstream systems must be replicated. The completion of an EIS or other appropriate study will be required to demonstrate no net loss of function to downstream systems.

- There are no requirements associated with HDFs with a "No Management Required" status. The feature that was identified during desktop analysis has been field verified to confirm that no feature considered a part of the NHS is present.

7.2.4 Linkages

Sections 3.5.8, 3.5.9, and 3.5.10 of the Municipality of Clarington's OP state:

> Connections or linkages between natural heritage features and hydrologically sensitive features provide opportunities for wildlife movement, hydrological and nutrient cycling, and maintain ecological health and integrity of the overall Natural Heritage System. The Municipality recognizes the importance of sustaining linkages.
>
> The Municipality shall support the protection of connections between natural heritage features and hydrologically sensitive features and across the Natural Heritage System through the identification of linkages in subwatershed plans, subwatershed plans, Environmental Impact Studies and other studies where appropriate.
>
> Linkages shall be evaluated, identified and protected through the preparation of Secondary Plans.

The Phase 1 SWS report evaluated existing and potential linkages within the study area, including hedgerows which provided connections between disparate natural heritage areas. It was found that the majority of linkage function within the study area was provided by the main Soper Creek north-south corridor and the narrower tributary corridors branching off the main valleylands. Hedgerows were not found to provide a significant linkage function in the study area, although several areas were flagged for additional study to confirm their condition and function.

As was touched on in **Section 4.2.2**, new development, particularly that which is associated with new roads or intensification of existing roadways, can create barriers to wildlife movement on the landscape. In order to minimize the fragmentation and isolation of habitats, as well as road mortality of wildlife, new roads should first and preferentially be sited such that they do not pass through natural heritage features. Where fragmentation of habitat is determined through the completion of an appropriate study to be unavoidable, the road design should include provision for wildlife movement via the adaptation of aquatic culverts or the installation of wildlife-specific terrestrial culverts that allow animals to move beneath the road surface. Culvert design will need to incorporate all current best knowledge of wildlife movement principles, such as sizing (e.g., shorter culverts with larger openings are typically better), light penetration (e.g., via surface grates), and materials (e.g., concrete versus steel; natural substrate placed within the culvert), and will need to be tailored both to the site conditions and to any specific target species that are to be addressed. Fish passage must also be considered where new aquatic crossings are constructed or where existing crossings are retrofitted. Exclusion fencing must be installed in association with crossing culverts such that animals are directed to the crossing locations and restricted from entering the road corridor.

7.3 Identification of Constraints to Development

The natural heritage features and hydrologically sensitive features discussed in the preceding subsections were considered in concert with natural hazards in order to identify constraints to future development. Constraints were classified as High, Moderate, or Low, where:

- **High** was applied to areas where development intrusion is generally not allowed (although specific exceptions may be applicable to flood hazard constraints) - these areas have been or will be carried forward as 'Environmental Protection Area' or similar designation on the proposed land use plans;
- **Moderate** was applied to areas requiring further study to fully define natural heritage features or determine the appropriate level of protection, or where some development intrusion or modification of features may be allowed if supported by a scoped Environmental Impact Study, Geotechnical Slope Stability Study, or other appropriate study; and
- **Low** was applied to features or areas for which municipal policy does not preclude development intrusion, but which represent natural cover on the landscape and therefore may be associated with ecological offsetting requirements (as previously touched on in **Section 4.2.2**) or to which other requirements may apply. Such features are generally recommended for incorporation into site-level plans where possible (e.g., parks or SWM blocks, preservation of individual specimen trees, alignment with rear lot lines or trail routes, etc.), so as to avoid the loss of natural cover on the landscape.

Features which were included in the above-listed categories are illustrated in **Figure 7.4** include:

High
- Natural Heritage System features (discussed in **Section 7.2.1**).
- Natural hazards – meander belt, regulatory flood line, slope hazard, and long-term stable slope setback.
- HDFs with a 'Protection' management recommendation.

Moderate
- Vegetation Protection Zones – some development or site alteration may be permitted as discussed in **Section 7.2.2**.
- Existing linkages - since it is typically the linkage *function* that is valued, some modification or relocation of the feature itself may be considered so long as the function is maintained.
- HDFs with a 'Conservation' or 'Mitigation' management recommendation.
- Agricultural/pasture lands evidencing hydrologic function (e.g., ponding, saturated soils, wetland plants).
- Natural heritage features not previously identified as High constraint, for which additional study is required to confirm sensitivity or presence/absence, such as candidate Significant Wildlife Habitat, complex vegetation communities containing both high/medium- and low-constraint areas, Species at Risk habitat/setbacks.
- Additional areas or features specifically identified in the Phase 1 SWS report, where those areas may meet NHS criteria but are isolated or of lower quality/function and therefore could be reviewed related to proposed development if supported by an EIS and if suitable protection/mitigation/compensation is also proposed.

Low

- Natural heritage features not meeting the criteria for inclusion in the municipal NHS and not identified by this SWS as significant.
- HDFs with a 'No Management Required' management recommendation.

The above information and the mapping shown in **Figure 7.4** were key deliverables of Phase 1 of this SWS, and provided a basis for the land uses developed in the Secondary Plans. As the SWS is a landscape-scale study, natural heritage features were not field-delineated and surveyed. It is the intention that site-level studies such as an EIS (see **Section 8.4.2**) may confirm and/or refine the boundaries of features at a later date (e.g., by staking and surveying the dripline of a woodland or a wetland boundary).

7.3.1 Enhancement, Restoration, and Compensation Opportunities

7.3.1.1 General Principles

The Phase 1 SWS report identified potential locations where ecological restoration or enhancement could be carried out to improve upon the existing NHS (see **Figure 7.3**). Similar to the new linkage opportunities mentioned in **Section 7.2.4**, the identified restoration and enhancement areas do not represent binding constraints nor are they intended to be interpreted as the only locations where restoration could be undertaken in the study area. The SWS, by necessity, looked at the subwatershed as a whole and identified large-scale opportunities based on the natural heritage features and functions that were identified. Site-level studies may refine the shown locations and/or identify more localized opportunities in keeping with the following general principles:

- **Size**: Larger patches of habitat are generally more valuable than smaller. Opportunities to increase the size of existing patches of natural cover (e.g., by designating open space or establishing parks adjacent to existing natural areas) should therefore be considered.

- **Shape**: Habitat patches which are compact (i.e., those which have less 'edge' per area) are generally more valuable than those which are linear or elongated. Opportunities to fill in gaps and reduce the edge to interior ratio of natural heritage patches should therefore be considered.

- **Complexity**: Natural areas with a high diversity of vegetation communities, microhabitats, and topographical features often support a wider variety of species (and a greater proportion of rare species) than those which are more uniform. Opportunities to increase the diversity of habitat across the landscape (e.g., by planting restoration areas with a variety of native species, by creating sloughs or pit/mound topography in restoration areas, or by conserving successional meadows and thickets in addition to forests) should therefore be considered.

- **Connectivity**: Fragmentation of natural areas by development can lead to the isolation of habitat patches and the wildlife they support, limiting dispersal of individuals and reducing genetic variability within the population. Opportunities to improve existing connections between natural areas and to create new connections where they are currently lacking should therefore be considered.

Proposed restoration/enhancement in keeping with the above are recommended for the study area overall, and must be considered wherever ecological offsetting or compensation is required related to anticipated impacts of development (see **Section 7.3.1.2**).

Restoration and/or enhancement of a site may be done either actively (i.e., by planting or seeding native vegetation, potentially accompanied by grading to create specific topography or features such as constructed wetlands) or passively (i.e., by ceasing management and allowing vegetation to colonize according to the in-situ seed bank). Active restoration is a more costly and labour-intensive approach, but it offers opportunities for community involvement (e.g., tree planting days) and can accelerate a site to a more advanced stage of succession (i.e., promote forest development through tree and shrub planting). It is also more likely to achieve a target vegetation community or species diversity target; passively allowing succession to occur is more likely to allow colonization of a site by non-native and/or invasive species. Active restoration is likely to be a component of mitigation or compensation plans related to impacts of proposed development; the need for and scope of such a plan would be identified through the development application process (i.e., addressed as a component of a site-specific EIS or equivalent study) and would need to be developed in consultation with the Municipality and CLOCA.

Aquatic corridors often provide a valuable opportunity for restoration and enhancement. Not only do these features provide both aquatic and riparian habitat in themselves, they also often provide corridors across the landscape which allow for wildlife movement. Many HDFs occur on cropped agricultural properties with little to no natural vegetation currently present. These HDFs may be enhanced through riparian plantings, as may watercourses within the study area that currently do not have consistent riparian vegetation.

Management of restored areas over the short term is expected to be required in order to ensure establishment of the intended species and habitat, and discourage the establishment of non-native and/or invasive species. Where invasive species are identified on a property or there is a risk of spread from an adjacent property, a management plan for these problem species should be developed as part of the EIS.

7.3.1.2 Responses to Development Impacts

The policies of the Municipality of Clarington’s OP support sustainable development and enhancement of the natural heritage system. With regard to impacts from site alteration or development, it is required first to avoid or mitigate the identified impacts to the greatest extent possible (e.g., through the relocation of structures or infrastructure such that there is no overlap with the Natural Heritage System, or the provision of enhanced VPZs to minimize noise or disturbance impacts from adjacent developments).

Where impacts cannot be avoided or mitigated, then the Municipality may consider compensation as a last resort to offset the identified impacts; however, the proponent would need to demonstrate that avoidance and mitigation measures were considered and determined not to be viable, and that there is a confirmed need to proceed with the proposed site alteration or development regardless of the impacts to the Natural Heritage System. The minimum goal for offsetting/compensation should be no net loss of natural cover or ecological function within the subwatershed, with a preference towards a net improvement or benefit to the NHS.

It was noted in **Section 7.2.2** that certain limited land uses and activities could be permitted within a VPZ subject to the completion of appropriate studies which support the action and, specifically such as in the case of transportation infrastructure identified through an approved Environmental Assessment, where there is demonstrable need and no viable alternative. In such cases, the supporting studies (e.g., EIS) will be expected to not only demonstrate that alternatives were considered (and provide the reasons for why those alternatives were not viable) but also to provide avoidance, mitigation, and/or compensation measures to address any impacts to the VPZ's form and function.

Where compensation is approved as a measure to address proposed impacts, measures should preferentially be applied to the affected feature and not 'offsite' (e.g., additional planting area connected to a woodland with reduced VPZ, as opposed to planting in an isolated park some distance away). This will provide a more meaningful benefit directly to the impacted feature and reduce the necessary adjustment period for local wildlife species using the habitat.

Planting of vegetation within the minimum VPZ is not eligible to propose as compensation since, as stated above, the VPZ is already intended to actively "be restored with native, self-sustaining vegetation". Restoration of the VPZ is therefore considered the baseline requirement, to which additional compensation measures must be added where required.

The Municipality is recommended to implement an NHS Accounting System through which the Municipality reports to the public on an annual or semi-annual basis.

7.3.2 Erosion Hazards for Development Constraints

Interim erosion hazard limits have been evaluated in Section 3.2.2 of the Phase 1 report based on meander belt delineation approaches (TRCA, 2004 subwatershed study procedures) and identification of potential slope hazard areas requiring additional geotechnical investigations. Recommended meander belt widths are provided for reaches within the development lands, ranging between 30 - 275 m in width, to be centered around the belt axis. These meander belt widths may be refined based on further detailed studies.

In addition to meander belt delineations intended for unconfined fluvial systems (MNR, 2002), erosion hazards for confined and partially confined reaches require that long-term stable slope (LTSS) setbacks be defined to determine development setbacks and constraints. Conservative estimates of the LTSS have been delineated as part of this Subwatershed Study using generic provincial guidelines (MNR, 2002) and CLOCA's GIS-based procedure for hazard mapping. Referred to as "priority LTSS areas", these are generally locations where the watercourse is within 15 m of the toe of slope for embankments with slopes steeper than 15% and heights greater than 3 m. The priority LTSS areas are to represent preliminary mapping of the stable slope component for delineation of the erosion hazard limit and development constraints. It must be emphasized here that these mapped areas from this sub-watershed study do not provide conclusive LTSS setbacks consistent with the provincial MNR (2002) guidelines, and may not provide a conservative enough estimate for the LTSS setback in all cases. Ultimately, the LTSS will need to be confirmed and/or refined with detailed geotechnical analysis as part of Functional Service Reports, and is to include a stable slope allowance that accounts for future channel erosion, long-term stable slope formation, and an erosion access allowance of 6 m. It is recommended that the Slope Inspection Record (Table 4.1) and Slope Stability Rating Chart (Table 4.2) of the MNR (2002) Technical Guide – River and Stream Systems be completed for all priority LTSS areas to determine detailed geotechnical stable slope investigation requirements and document existing slope conditions.

For the Subwatershed Study constraint mapping, the erosion hazard limit is the greater of the meander belt and the priority LTSS hazard lines. The final erosion hazard limits for the corridors including both meander belts for unconfined reaches and stable slope setbacks in identified confined reaches—are to be integrated with other development constraints to delineate final development limits (e.g., Regulatory floodplains and NHS protected areas).

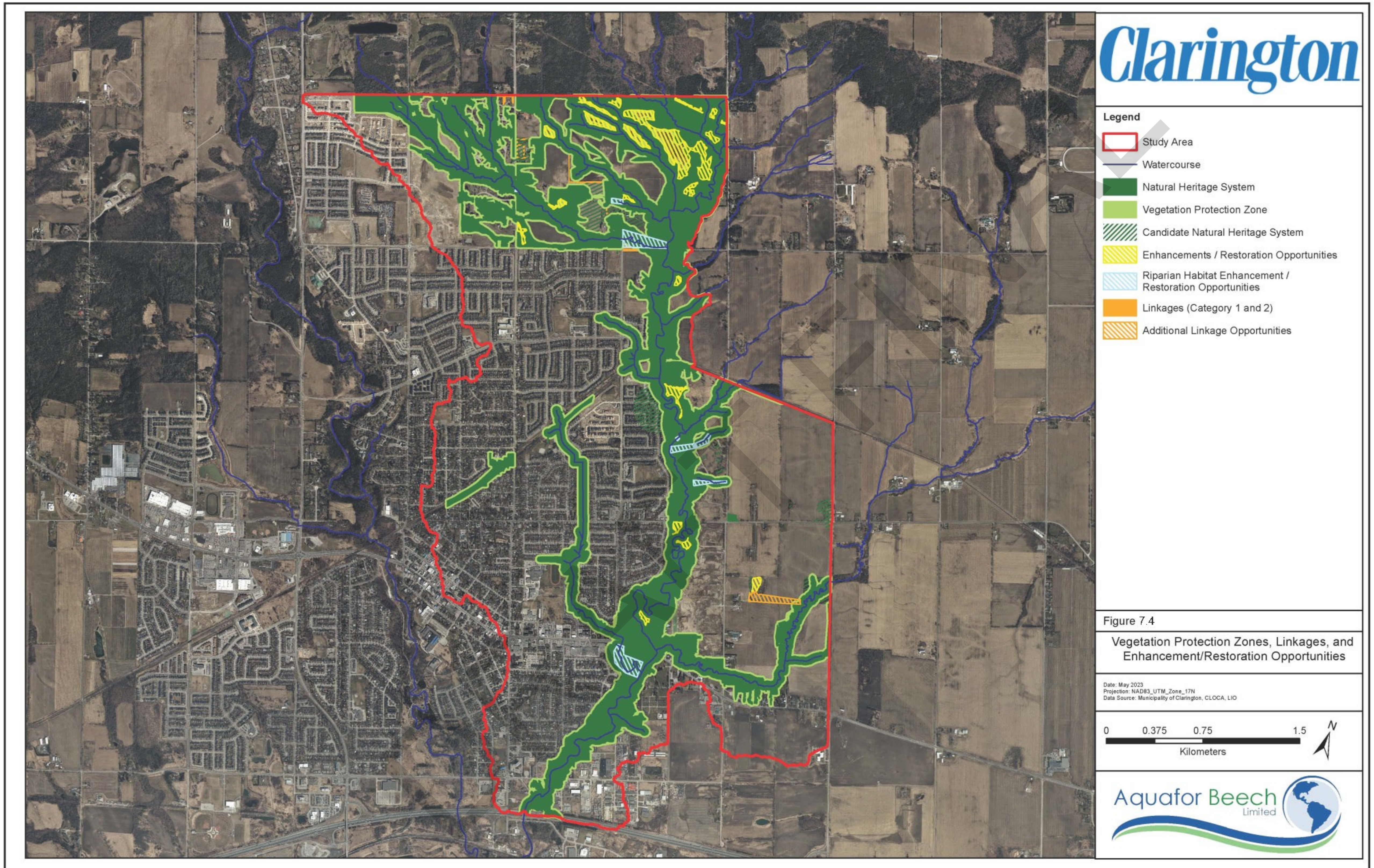

Figure 7.3: Vegetation Protection Zones, Linkages, and Restoration/Enhancement Opportunities (from SWS Phase 1)

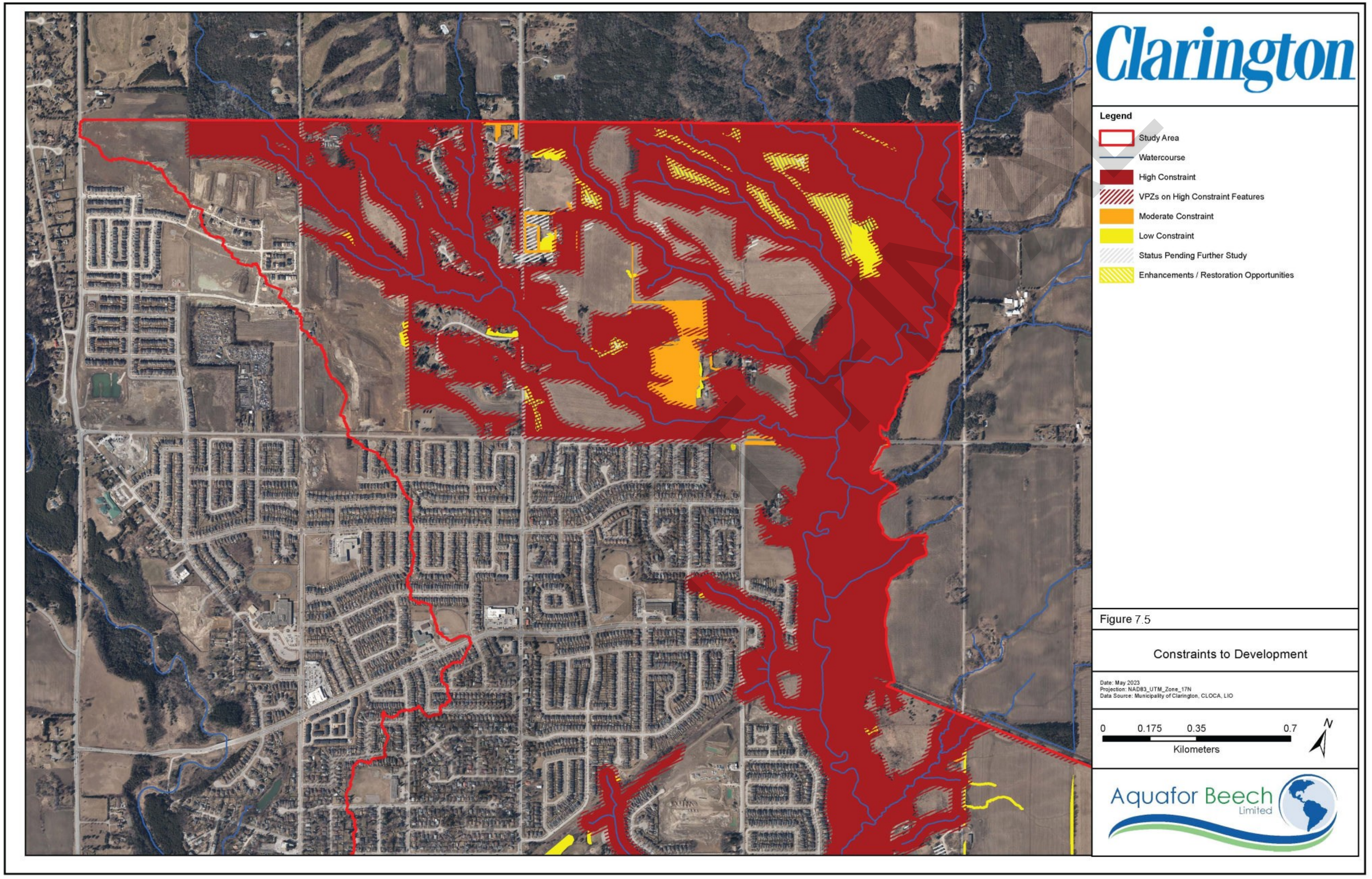

Figure 7.4: Constraints to Development

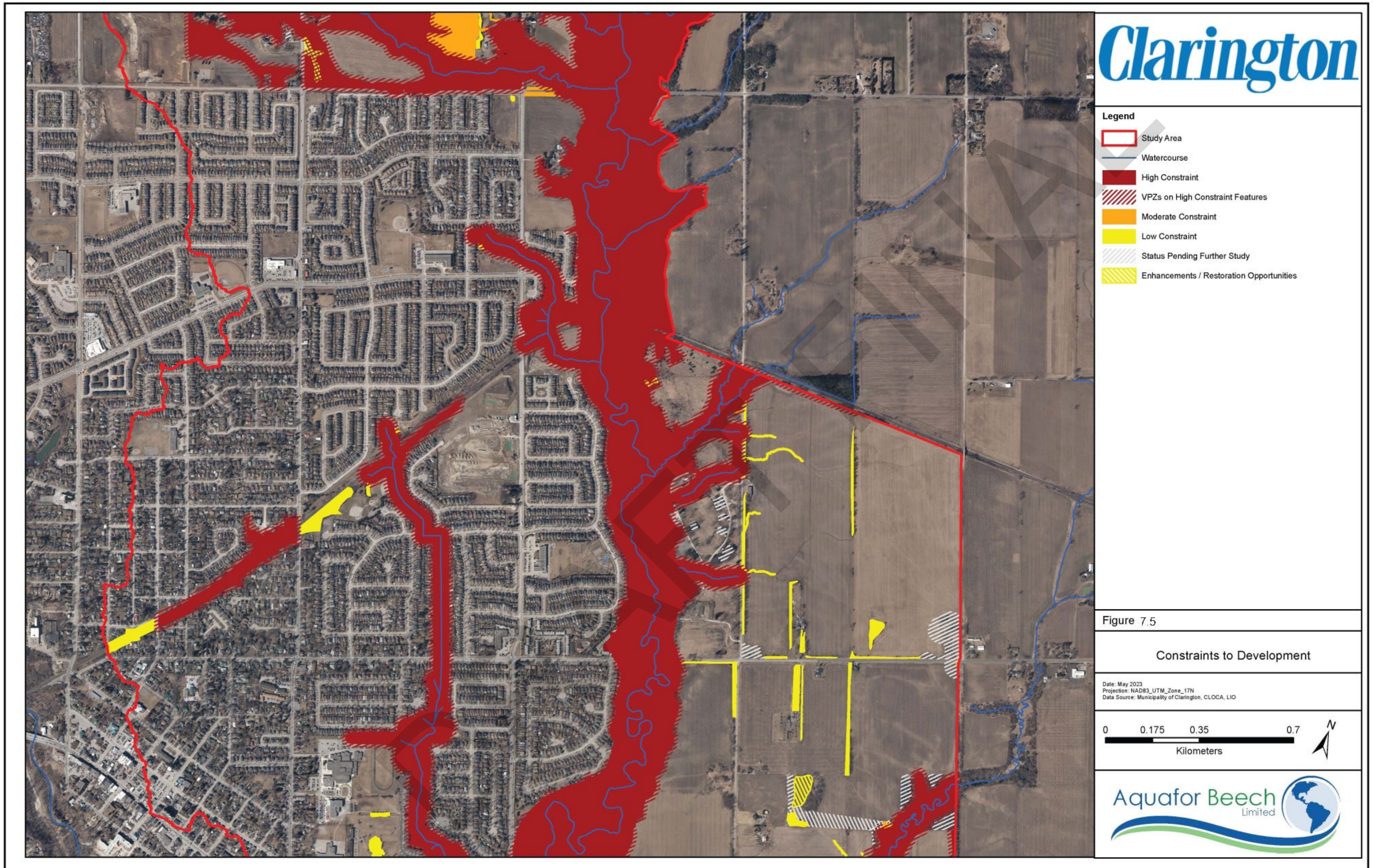

Figure 7.4 Constraints to Development 2 of 3

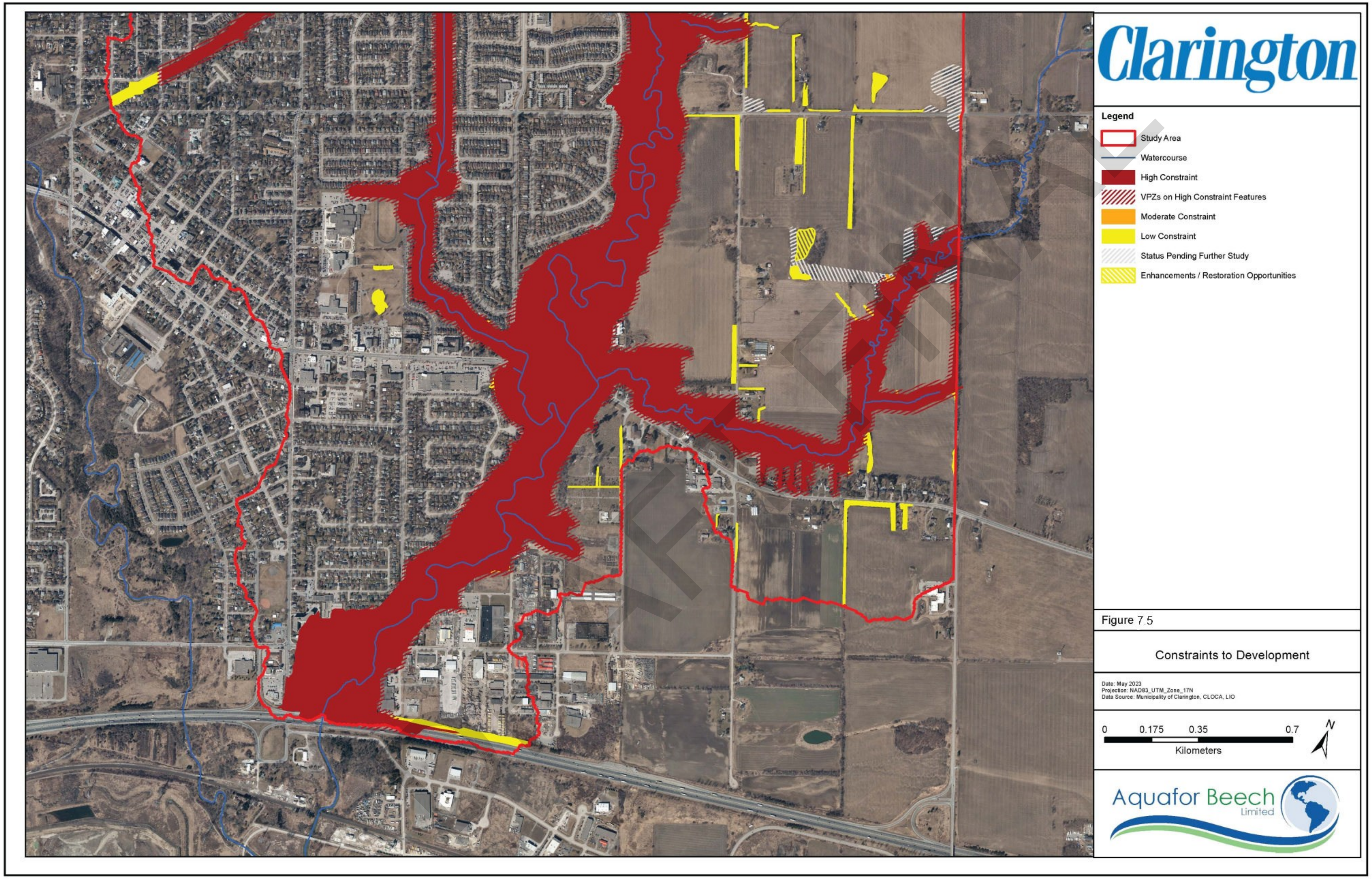

Figure 7.4 Constraints to Development 3 of 3

7.4 Groundwater Strategy

7.4.1 High Volume Recharge Area

High Volume Recharge Areas (HVRA) were identified during the modelling completed as part of the **Soper Creek Subwatershed Study: Phase 1 Report** and are presented in **Figure 7.5**. The Ministry of Environment (2007, Page 142) defines five methods to delineate high volume recharge areas. Methods 1 through 4 are simpler methods whereas Method 5 is described as follows: "Recharge rates are developed from a calibrated complex model and are therefore likely to be more accurate". The combination of PRMS and MODFLOW models used by EarthFX in this study conform to the Methods 5 approach and level of accuracy (see EarthFX, 2008 for additional model development details).

The HVRA map areas generally correspond to the location of surficial sand and gravel deposits, however as these are based on the average recharge in the local subwatershed, some silt deposits in Soper Creek are also considered locally important.

7.4.2 Ecologically Significant Groundwater Recharge Area

Ecologically Significant Groundwater Recharge Areas (ESGRAs) are present in the Soper Creek Subwatershed (**Figure 7.6**). Maintaining infiltration in ESGRAs will ensure baseflow contributions to the annual flow regime are maintained which is essential for the ecological health of the stream systems, wetlands and lowland habitat. Water quality degradation is possible if proactive measures are not taken during development. The main groundwater quality concern will be chloride loading to the groundwater as a result of salt application for winter maintenance. Salt management planning and contractor certification for development areas in and draining to the ESGRAs will be essential to maintain water quality.

7.4.3 High Aquifer Vulnerability Area

The Regional Municipality of Durham has identified High Aquifer Vulnerability Areas (HAVA) throughout the Soper Creek subwatershed (**Figure 7.7**). HAVAs are lands whose uppermost aquifer is most vulnerable to contamination as a result of surface activities or sources. These areas are to be protected per the Region's guidelines, as outlined in the Official Plan, as amended from time to time. Per the 2020 Consolidation of the Region's Official Plan, the following requirements are applicable:

> 2.3.30 Areas of high aquifer vulnerability are shown on Schedule 'B' – Map 'B2', High Aquifer Vulnerability and Wellhead Protection Areas. Additional areas may be identified through future studies such as source water protection plans or watershed studies. The Region and area municipalities shall protect areas of high aquifer vulnerability, when considering new development or site alteration. Outside of designated Urban Areas, uses considered to be a high risk to groundwater, as identified in Schedule 'E' – Table 'E5', shall be prohibited. The Region may also require a hydrogeological investigation to assess whether other uses not included in

Table 'E5' will be a potential risk to groundwater within the areas of high aquifer vulnerability thereby requiring potential prohibitions, restrictions and/or mitigation.

2.3.31 Within Urban Areas, an application to permit any of these high-risk land uses within a high aquifer vulnerable area shall be accompanied by a contamination management plan that defines the approach to protect water resources.

2.3.32 Existing land uses considered to be a high risk to groundwater that are located within high aquifer vulnerability areas, are encouraged to implement best management practices.

When completing a Contamination Management Plan for high-risk land uses within an HAVA, proponents are directed to **Table 7.3**, which outline high-risk site activities which preclude the use of infiltration LID BMPs within the contributing catchment area. The infiltration of rainwater from catchments that are isolated from the respective high-risk site activities such as rainwater emanating from rooftops, employee parking facilities or directly falling on permeable surfaces is generally considered relatively 'clean' and may therefore be considered for infiltration.

7.4.4 Submission Requirements

A water budget is to be submitted to CLOCA and the Municipality of Clarington as part of the stormwater management submission when a proposed development contains an HVRA or ESGRA. Infiltration rates should be measured in situ using test pits and/or boreholes, and post-development infiltration rates should match pre-development rates on an annual basis.

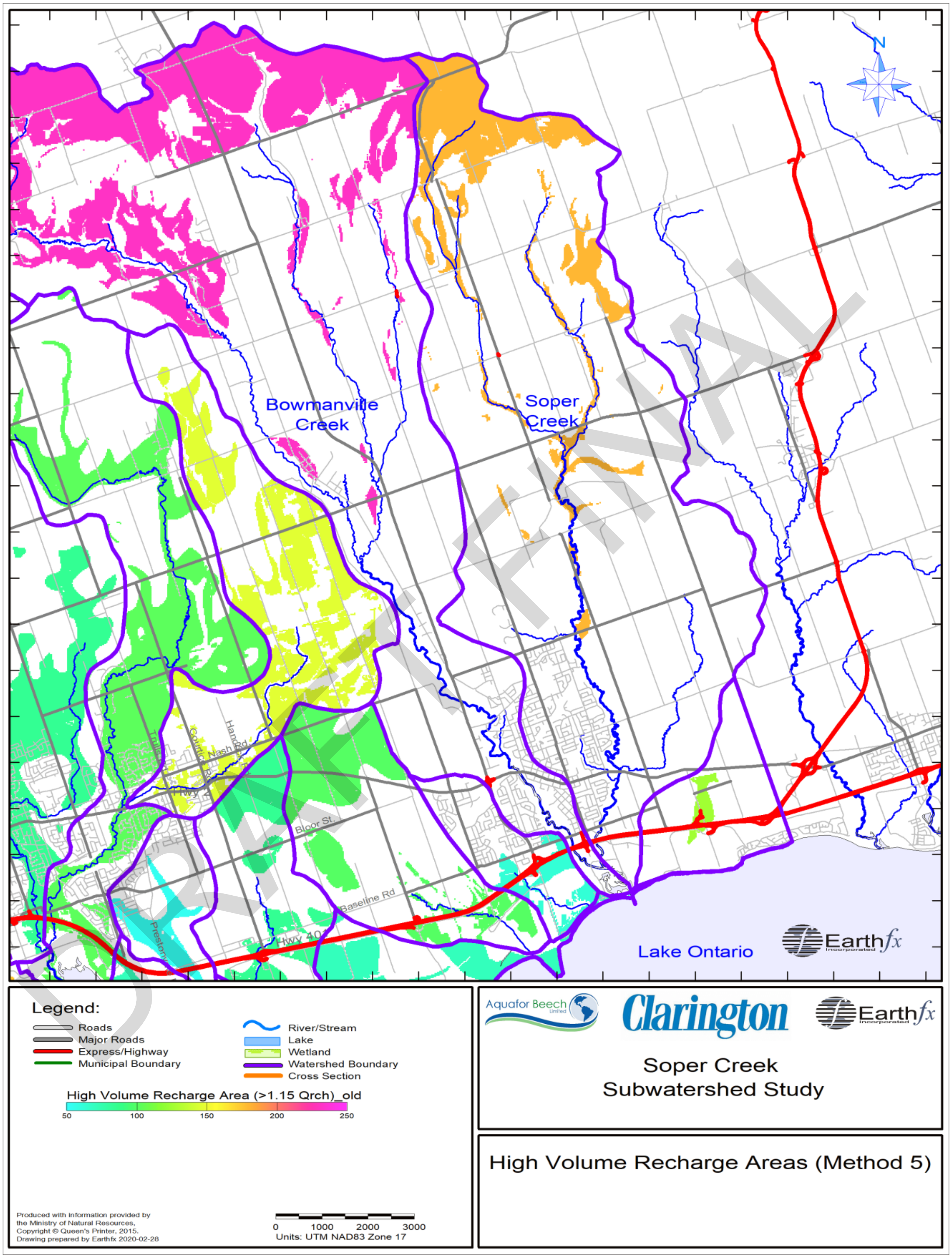

Figure 7.5: High Volume Recharge Areas

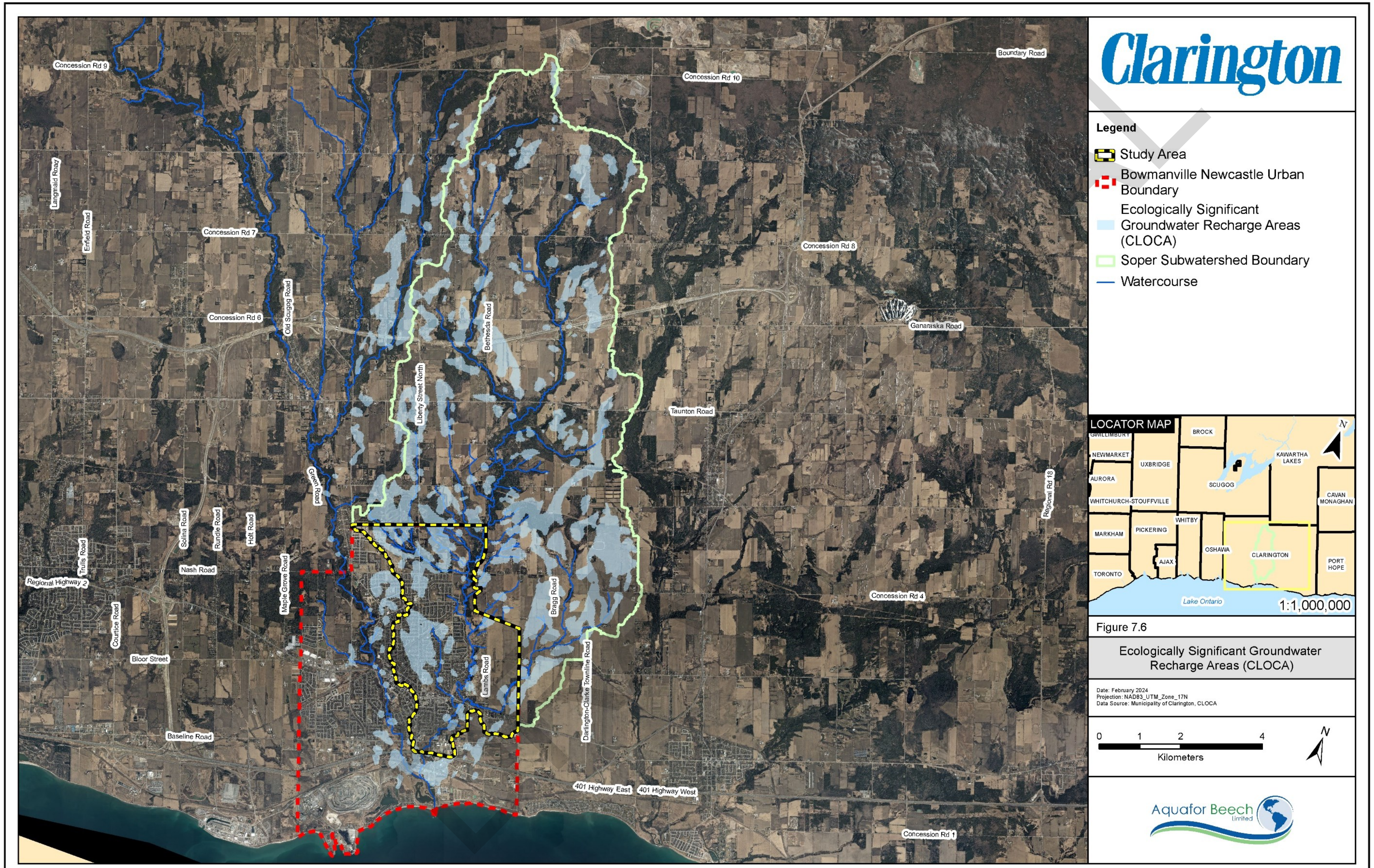

Figure 7.6: Ecologically Significant Groundwater Recharge Areas

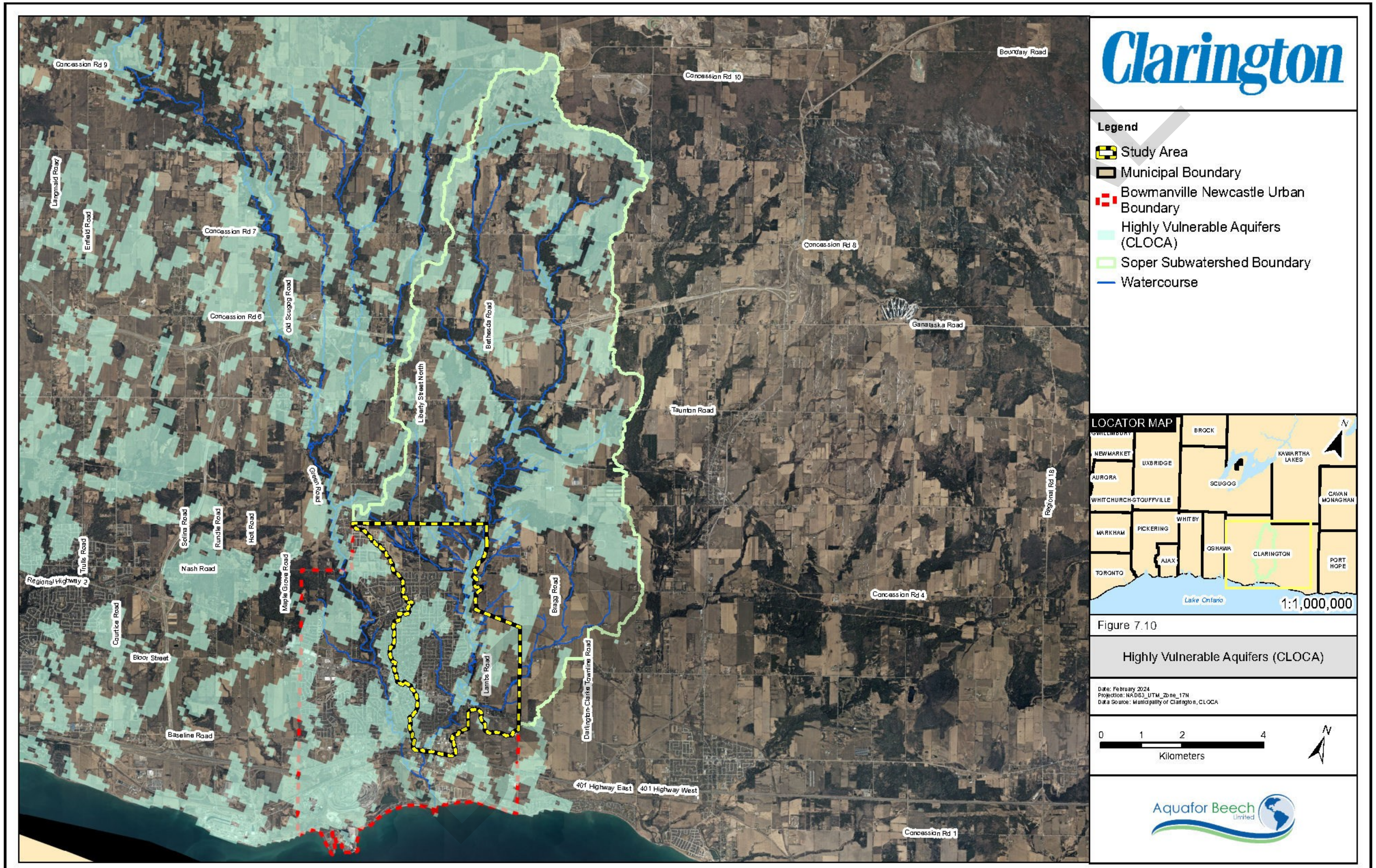

Figure 7.7: High Aquifer Vulnerability Areas

8 Implementation

8.1 Introduction to Implementation Strategy

The preceding chapters have summarized the investigations, inventories and analyses used to define existing environmental conditions, future impacts, and recommended management measures for the Soper Springs, and Soper Hills Lands Secondary Plans. The recommended measures include actions to address stormwater management requirements, protection of the natural heritage system and associated ecological features together with groundwater resources.

In terms of the land development and environmental planning process, the role of the Soper Creek Subwatershed Study is to provide a framework and broad-scale guidance to the next level of planning and design study as urban development proceeds. As such, the focus of this chapter is to provide guidance for the future work required to implement the recommendations. This includes direction with respect to future studies, timing/phasing of the works, policy/design guidance, and approvals.

8.2 Stormwater Management Controls

Stormwater management controls consist of the recommended works required to mitigate the impacts from proposed future development. This includes:

- End-of-pipe stormwater ponds for SWM Quantity Control; and
- Low Impact Development (LID) source control techniques to meet water quality, water balance and erosion requirements.

The Visual Otthymo model was used to define flows for existing and proposed development conditions. **Table 7.1** of this document summarizes the names, type, drainage area and flood storage requirements for each of the proposed facilities.

Sections 7.1.1 through **7.1.5** of the report outline the requirements for water quality, water balance, erosion control and thermal mitigation. As noted, the primary driver is to control the runoff generated from a 27 mm rainfall event, using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are to be implemented. Where the LID approach is utilized and the runoff volume from the full 27 mm event is controlled, end-of-pipe SWM facilities may be designed without the water quality component. The approach to meeting stormwater management targets is outlined in **Table 8.1**.

Table 8.1: Approach to Meeting SWM Targets

Target Category	Target	Approach	Notes
SWM Quantity Control	Peak flow rates from the 1:2-year to 1:100-year events must be controlled to pre-development levels in Soper Creek.	End-of-Pipe SWM facilities in the form of Dry detention ponds in Soper Springs Secondary Plan Area. Overcontrol of these facilities will be required.	
Regulatory Quantity Control	Post-development peak flow rates from the Regulatory storm must be below Existing Regulatory peak flow rates.	The Regulatory storm is the Regional storm in Soper Creek Subwatershed. Post-development peak flow rates are below Existing Regulatory peak flow rates, so no action required.	
Water Quality	Preferred Target: Capture and retain runoff resulting from the 27 mm rainfall event using infiltration-based LIDs.	Infiltration-based Low Impact Development Practices following the runoff control hierarchy (**Figure 7.1)**, and with type based on land use (**Table 8.2**).	
Stream Erosion Control	Runoff from a 27 mm rainfall event must be retained on site through infiltration, evapotranspiration, reuse, bioretention, etc. to the maximum extent practical with a minimum of 5 mm. Peak flow rates from the 1:2-year to 1:100-year events must be controlled to pre-development levels in Soper Creek.	Site-level Low Impact Development practices (See **Section 5.3**)	Where site-level LIDs cannot meet the 27 mm retention target, any remaining runoff volume from the 27 mm event must be detained on site for 24 to 48 hours. Design of all outfalls must include evaluation of erosion risk to receiving watercourses.

Target Category	Target	Approach	Notes
Water Balance	Match pre-development annual infiltration volume in all stormwater catchments.	Infiltration-based Low Impact Development Practices located on private property and municipal property. A site-specific water budget will need to be completed as part of the stormwater management submission for sites within an HVRA or ESGRA.	This target is to be refined via in-situ infiltration testing (see **Section 8.4.1**). It was calculated in **Section 7.1.4** that an average infiltration target across the study area of approximately 2 mm per event in Soper Hills and 3 mm in Soper Springs per rainfall event would be sufficient to maintain pre-development water balance. Within HVRAs or ESGRAs the target will be higher.
Thermal Mitigation	Cool runoff as appropriate for a cold/coolwater receiver.	Use of Low Impact Development and dry stormwater ponds.	

Land use mapping completed as part of the Soper Hills and Soper Springs Secondary Plans indicated the location of the stormwater management facilities. Further direction regarding stormwater management facilities is provided below in **Section 8.4**.

All stormwater management facilities must be designed to meet the design requirements set out in the Technical Guidelines developed by CLOCA (2020), in addition to the MECP Stormwater Management Planning and Design Manual (SWMPDM) which provides technical and procedural guidance for the planning, design, and review of stormwater management practices. As discussed in **Section 7.1.1**, overcontrol of the Soper Springs facilities will be required in order to mitigate the impact of development on flow rates in Soper Creek.

8.2.1 Low Impact Development

The starting point for this Subwatershed Study was to complete the study using an environment-first approach. A meeting was therefore held with the Municipality of Clarington to discuss the type of LID measures that are suitable for different land uses. These also align with the LID measures accepted by CLOCA for meeting water quality, erosion control, and water balance criteria. These acceptable LID measures are described in **Section 5.3** for different land uses, with a summary table provided in **Table 8.2**.

LID design requirements are provided in Table 5-1 of CLOCA's 2020 Technical Guidelines which provides direction with respect to the requirements that must be considered for approval. These requirements, together with other technical manuals, should be used as a basis for conceptual and design drawing submissions.

In Ontario, the Toronto Region Conservation Authority (TRCA), Credit Valley Conservation (CVC) and Lake Simcoe Conservation Authority (LSRCA) are supporting a Wiki-based "living design manual" on the Sustainable Technologies website. This is a key resource for consultants as well as the public with respect to general information and design considerations surrounding LID systems.

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a LID Stormwater Management Guidance Manual. The draft manual outlines a Runoff Volume Control Target (RVC_T) to be used for new development, and should be referred to for additional design guidance.

The use of LIDs may be constrained by site-specific conditions, as outlined in **Section 7.1.2.1**. If any of these factors apply to a specific site, then LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes should be considered. If control of the full 27 mm is still not feasible through the use of LID measures, then the use of stormwater management facilities (e.g. wet ponds, wetlands, or hybrid ponds) or manufactured treatment devices (e.g. oil and grit separators) are permitted. Regardless of the method used to achieve the water quality criteria, SWM quantity controls to control peak flows will still be required at the end-of-pipe in Soper Springs. It is recommended that in-situ infiltration testing be completed early in the development process to ensure ideal locations for LIDs are considered during the formation of draft plans.

Additionally, the use of scarified subsoil, amended topsoil, and extra topsoil depth on yards is recommended on all sites to reduce post-development runoff volume, but these amendments will not be accepted to meet the above stormwater targets. All soil amendments are considered to complement LIDs as a part of a widespread treatment train approach and are not acknowledged for credit individually.

Recommended types of LID practices that are generally appropriate for different land uses are listed in **Table 8.2**.

Table 8.2: Municipal LID Applicability by Land Use

Land Use		Single Family Residential	Multi-Family (Medium Density)	Multi-Family (High Density)	Industrial, Commercial & Institutional
Soil Amendments		✓	✓	✓	✓
Perforated Pipe (PP)	PP as Storm Sewer	✓	✓	✓	✓
	Parallel PP (“3rd Pipe”)	✓	✓	✓	✓
	Grassed Swale PP System	✓	✓	✓	✓
Permeable Pavements			✓	✓	✓
Bioretention, Bioswales and Enhanced Swales			✓	✓	✓
Rainwater Harvesting				✓	✓

8.2.2 SWM Facility Maintenance

Regardless of the type of stormwater management infrastructure that is in place, maintenance, rehabilitation, and replacement is necessary to maintain the intended level of service to the public. SWM ponds may require sediment dredging and disposal at a recurring interval dependent on loading rate and facility design. LID operation and maintenance varies with practice. For perforated pipes, very little maintenance is required. For bioswales and bioretention facilities, the O&M is similar to that of municipal gardens which require weeding and mulching occasionally (or mowing if the low maintenance turf option is preferred).

8.2.3 Ecologically Significant Groundwater Recharge Areas and High-Volume Recharge Areas

A site-specific water budget is required to be submitted as part of the stormwater management submission when a proposed development contains an HVRA or ESGRA (see **Figure 7.5** and **Figure 7.6** for locations). The site-specific water budget should be completed per the 2003 SWMPDM requirements and the 2013 Conservation Authority Guidelines for Hydrogeological Assessment Submissions (Cuddy et al., 2013).

8.3 Monitoring Program

It is recommended that a water quality monitoring program be developed, taking an Adaptive Management Approach (AMA) and span pre-construction, construction and post-construction phases. This approach will allow for adjustments to monitoring sites, parameters and protocols to be made over time, as gaps are identified in order to optimize the program. The monitoring program will likely require extensive coordination and collaboration through annual monitoring meetings among representatives of CLOCA, the Municipality, the development community and their consulting teams. Specific monitoring details would be defined in an EIS or similar study.

The Phase 1 Soper Creek Subwatershed Study identified multiple erosion and maintenance sites. These sites should be monitored on an ongoing basis, including before development, during development, and post-development. In 2029, it is recommended that creek walks occur throughout the study area to identify whether there are additional erosion and/or maintenance sites that have developed since the original investigations were completed in 2019.

8.4 Future Studies

This Subwatershed Study also lays the groundwork for future studies. Additional studies will be required as follows:

8.4.1 Stormwater and Groundwater

While the Soper Creek Subwatershed Study has provided significant information on the proposed development lands, additional studies will be required. CLOCA outlines all study requirements as part of the Technical Guidelines for Stormwater Management Submissions (2020) in Table 6-1. Some of these requirements have been met through the completion of the Soper Creek Subwatershed Study, but the list below outlines the study contents which must still be completed.

Notes and assumptions to be carried forward through all future studies:

- Note: SWMF locations have already been identified as part of the Soper Hills and Soper Springs Secondary Plans, and were maintained through this Subwatershed Study.
    - Based on the detailed design modeling, the design team may consider alternate discharge locations for the SWMF in Soper Hills to mitigate the increase in peak flow observed in tributaries.
- Note: The LID strategy was outlined in **Section 7.1.2**, and includes control of the runoff from the 27 mm storm using infiltration practices preferentially, followed by filtration measures and/or reuse. A minimum of the runoff volume of 5 mm shall be retained on site if it is not possible achieve the full volume due to the factors outlined in **Section 7.1.2.1.**
- Note: A Conceptual Grading and Servicing Study is still required to identify required services or improvements to municipal infrastructure required to support development.

Additional study requirements include:

- Hydrological Modelling Calibration and Validation - The deterministic hydrologic modelling completed for the Soper Creek SWS utilises design based hydrologic parameters and methodology approved for use by both the Municipality of Clarington and CLOCA. Using the approved designed based hydrologic parameters and methodology, the VO hydrologic modelling has been constructed to represent field conditions to the best extent possible in the absence of a formal calibration and validation process. Both timing and magnitude of peak flows associated with external drainage areas directly influence the assessment of peak flows, attenuation requirements, erosion and roadway crossing analysis to name a few. While the Soper Creek SWS VO Hydrologic Model has been constructed to the best extent possible at the time of writing of this report, we note that the model has not been calibrated or validated to replicate field conditions. Given the presence of sandy based soils with high infiltration rates, we suspect that the peak flows associated with external drainage areas and further throughout the Soper Creek SWS, may be over estimated. As the direct comparison of attenuation alternatives has been provided at key flow nodes throughout the watershed, both the magnitude and timing of external drainage areas is critical to the assessment of attenuation requirements within the Soper Springs, Soper Hills, Camp 30 and Timber Trail Developments. Accordingly, it is the recommendation of this report to complete a formal calibration and validation of the VO model to confirm field flow conditions. Following a formal model calibration/validation, we would further recommend that all Storm Water Quantity Control alternatives be revisited to properly assess the impacts of attenuation within the Development Areas.

- New road crossing evaluations/checklists (hydraulics, fish passage, wildlife passage, etc.). As the developments proceed, proposed watercourse crossings will need to be sized based on the Regulatory floodlines and the standards provided by CLOCA (2020). The impact of the proposed watercourse crossings will also have to be incorporated into the Hec Ras model to define the impact on adjacent upstream lands. In some cases, it may be necessary to oversize structures in order to preserve lands that are proposed for development and to protect existing lands. Where this requires raising the roadway profile, impacts to Regulatory floodlines must be evaluated. In addition, these crossings must ensure that at any time of year, the free movement of water and the passage of fish may not be blocked or otherwise impeded up and down stream of the crossing, with the exception of a temporary blockage due to water crossing construction/removal activities. In most cases, clear-span bridges or open bottom culverts are preferred with appropriate span to accommodate natural channel migration. All in-water construction and removal activities must abide by the appropriate fisheries in-water timing windows documented in approved FMPs and/or forest management guides in order to avoid disrupting sensitive fish life stages. In cases where the fish community inventories at the location of the proposed project are not well documented, the most restrictive in-water timing window must be used. All in-water construction and removal activities must be undertaken in an uninterrupted fashion and be completed in an appropriate timeframe to minimize the potential for site disturbance. The construction and removal activities must not employ the use of any explosives.

- Master Environmental Servicing Plan / Master Drainage Plan
    - Requirements for an MESP/MDP have not been completed for the Soper Hills or Springs Secondary Plan and will be required as the secondary plans move forward.

        - Note: Location planning and design of future stormwater management ponds should take into account adjacent developments within a catchment, rather than on a site-by-site basis, in order to identify opportunities to minimize the overall number of facilities by providing larger, more efficient centralized ponds. The centralized ponds would provide benefits to both the development proponent and the Municipality through savings in land and lower future maintenance requirements, as long as the impact from these ponds on erosion in the receiving watercourse can be mitigated, as described above. From a land use perspective, ponds are 'green infrastructure' that contribute to the urban fabric and can contribute as a connective element in the overall pathways system.

    - The MESP/MDP must follow all requirements outlined by CLOCA and the Municipality. Additional requirements may be subsequently identified by the Municipality.

- Functional Servicing Report (In support of draft plans)
    - This report will require the following:
        - Top of bank staking/slope stability analysis
        - Minor and major flow routes identified, and capacities verified
        - Preliminary sizing for SWM Facility
        - SWM outfall locations (may require site walk with approval agencies)
        - Model updates with finalized impervious values, SWMF locations, outfall locations, etc. to confirm peak flow and timing considerations
        - SWM outfall preliminary design in consideration of erosion mitigation
            - Consider the use of the Distributed Runoff Control (DRC) Approach, per Appendix D of the 2003 SWMPDM.
        - LID siting, footprints, soils and infiltration values, and preliminary sizing. Define the types of LID techniques that are to be incorporated into the future urban landscape to meet the targets identified in **Table 8.1** over the respective study areas. Infiltration rates should be measured in situ using test pits and/or boreholes, and post-development infiltration rates should match pre-development rates on an annual basis. In–situ infiltration testing characterizes the field saturated hydraulic properties of the existing native material on-site. On-site infiltration testing using industry standard methodologies (e.g. Guelph Permeameter, Double ring infiltrometer, etc.) to determine the in-situ field saturated hydraulic conductivity infiltration rates and the design infiltration rate per the LID Stormwater Planning and Design Guide is recommended (https://wiki.sustainabletechnologies.ca/wiki). Field testing should be performed within the approximate location and invert of proposed LID practices.
        - Other requirements as may be outlined by the Municipality

- Stormwater Management Report
    - None of the requirements for a Stormwater Management Report have been completed yet. This stage of planning builds upon the preliminary work at the functional design level in order to finalize the drainage and stormwater pond designs. This report will require:
        - Detailed SWMF design
        - Detailed LID design
        - Other requirements as may be outlined by the Municipality
- Stormwater Management Brief
    - None of the requirements for a Stormwater Management Brief have been completed yet. This report will require:
        - Detailed BMP design (SWMFs, LIDs, OGS, etc.)

- Other
  - Hydrogeologic Assessment - It is recommended that field testing, through the installation of boreholes and monitoring wells, be used to verify soil and groundwater conditions, including any constraints associated with high or perched groundwater. High groundwater may constrain the construction of some infrastructure, such as underground parking structures; groundwater conditions should be evaluated in these cases.
  - Geotechnical Assessment - As part of a complete field program soil samples should be collected as part of geotechnical and/or hydrogeological investigations in order to characterize the soil properties.
  - Erosion and Sediment Control Plan

8.4.2 Environmental Impact Studies

Phase 1 of this SWS characterized natural heritage features and hydrologically sensitive features within the study area, and identified constraints to development which were to be carried forward by the Secondary Plans (see **Section 7.2** for an overview of these tasks). As this SWS is a landscape-level study, it is appropriate to complete site-level studies moving forward to: refine or expand upon the current findings (e.g., by field-staking and surveying feature boundaries); address features which require additional assessment (such as some of those included in the Moderate constraint category, or those present on properties for which site access permission was not granted for this SWS); and ensure that up-to-date information is available to assist approving agencies in their decision-making. Environmental Impact Studies (EIS) are the primary tool identified by the Municipality of Clarington's OP for this purpose.

The OP indicates that the purpose of an EIS is "to determine the potential for development to adversely impact environmentally significant and sensitive areas, and natural heritage features". The OP further states that an EIS shall be undertaken for all development proposals within 120 m of a natural heritage feature and shall:

a) Examine the functions of the natural heritage features;
b) Identify the location and extent of natural heritage features;
c) Identify the potential impacts of the proposed development on the natural heritage features and their ecological functions;
d) Identify any lands to be preserved in their natural state;
e) Identify mitigating measures to address the adverse effects of development on the natural heritage features and their ecological functions, including setbacks for development;
f) Identify the potential for restoration and/or creation of wildlife habitat; and
g) Examine the cumulative impact of the existing, proposed and potential development, including the impact on groundwater function and quality.

Any proposed development within 120 m of identified components of the NHS (see **Section 7.2.1**) must therefore complete an EIS in keeping with the above requirements and demonstrate, at minimum, that the proposed development or land use change will have no negative impact on the NHS. Where possible, the selected protection and mitigation (preferred) or compensation (where approved) measures should also see to create a net benefit to the NHS.

The scope of an EIS is to be determined at the onset of a project through pre-consultation with the Municipality and any applicable stakeholders, typically through the preparation and submission of a study Terms of Reference. The necessary scope of each EIS will vary depending on: the nature and proximity of natural heritage features; the amount of existing data available for the study area; and how recently the existing information was obtained. Ecological conditions change over time, and therefore past ecological survey data may be considered to ‘expire’ and need updating as part of a current EIS scope.

For example, the land use plans described in **Section 4.1.2** have proposed multiple road crossings that encroach on or transect the identified NHS within the Soper Springs Secondary Plan area. The transportation study and EIS completed for this proposed development area must evaluate the specific features and functions that will be affected and propose sufficient protection and mitigation measures to avoid negative impacts, or sufficient restoration and compensation measures to offset the predicted impacts of that development pending the approval of the Municipality and other approving agencies. Measures that might be considered include: oversized culverts or bridges to minimize watercourse impacts and restrictions to wildlife movement along riparian corridors; larger VPZs on adjacent sections of the NHS to offset areas that will be removed and create additional habitat; drainage design to direct road runoff away from watercourse crossings and mitigate impacts of road salt and other introduced contaminants; or enhanced planting plans in parks, stormwater blocks, and other open spaces. Whatever strategy is adopted, the final design must demonstrate that it will not adversely impact natural heritage features and their ecological functions, in order to be in compliance with municipal policy.

Specific components that may be included in the scope of an EIS include (but are not necessarily limited to) the list provided below. Pre-consultation and study scoping, as described above, will confirm the specific tasks that will be required for the subject property addressed by the EIS, and also whether additional work may be appropriate based on updated conditions. The presence of habitat as well as the potential impact to that habitat should be used to determine the need for related surveys.

- Confirmation/refinement of natural heritage feature boundaries assessed and identified as part of this SWS (e.g., staking and surveying the dripline of a woodlot, or wetland delineation per the provincial Ontario Wetland Evaluation System protocol) and confirmation on the presence/absence of ‘other’ features as identified in Section 3.4.3 of the Municipality’s OP which may warrant protection despite not meeting the OP criteria for inclusion in the NHS;

- Targeted aquatic surveys (e.g., Ontario Stream Assessment Protocol, fish community assessment) to confirm the presence of fish, direct construction timing considerations, update existing records, and/or fill in data gaps;

- Targeted wildlife surveys (e.g., breeding bird survey, amphibian calling survey) to confirm the presence/absence of Significant Wildlife Habitat, update existing records, and/or fill in data gaps;
- Targeted botanical inventories to confirm vegetation community assessment and address data gaps (e.g., additional seasonal surveys to target spring ephemerals – most botanical surveys for this SWS occurred in the summer and fall);
- Species at Risk assessment and associated consultation with the Ministry of the Environment, Conservation, and Parks (see also **Section 8.6.1**);
- Review of areas identified by this SWS as Low Constraint and areas identified for future studies to confirm the presence/ absence of features such as heritage trees/wildlife trees, regionally rare or uncommon plants, and similar features which may be appropriate to preserve or may be subject to offsetting or mitigation requirements;
- Assess linkages on the site level and discuss how the proposed development will maintain or enhance landscape connectivity, including discussion of applicable wildlife road crossing design principles if appropriate;
- Identification of appropriate VPZ widths to provide adequate protection for natural heritage features on the site (minimum VPZ as per the municipal OP must be observed, but the EIS should assess if this minimum is sufficient for the protection of identified features and functions or whether additional area is required; e.g., adjacent to sensitive features or areas, or where high-impact adjacent land uses are proposed); and
- Identification of site-specific restoration and enhancement opportunities, including species suggestions for planting plans as appropriate (e.g., for VPZ naturalization). Other restoration and enhancement opportunities could include the daylighting of tiled agricultural fields and/or buried watercourses which should be evaluated as a part of an EIS to determine the form and function of the feature(s).

8.4.3 Headwater Drainage Feature Assessment

HDF assessments were completed as part of this SWS for all properties for which staff were granted permission to enter. In some areas a lack of land access restricted surveys from occurring as part of this subwatershed study, however. As such, HDF assessments have yet to be completed in areas where valuable features may be found and must be completed as part of site-specific environmental assessments prior to any approval of a proposed development plan.

Furthermore, the HDF assessment protocol is limited to field observations and is inherently biased, limiting the scope of observations to a number of external factors such as weather, timing, resources and land access among other factors. Many HDFs may have been overlooked during this exercise and should be considered in future site-specific exercises.

It should also be noted that the Guidelines and Classification process recommends that features defined by, "…evidence of cultivation, furrowing, presence of a seasonal crop, lack of vegetation, and fine textured soils," should be considered to provide Limited or Recharge Hydrologic Functions. These defining characteristics are typical of agricultural fields, which contain some of the larger and potentially hydrologically significant drainage features. This is the case for features given the lowest management recommendations within the two subwatersheds, that are not ponds. Furthermore, these assessments do not account for agricultural features that are tiled. In these cases, management recommendations would be up-ranked if the agricultural fields would be left to re-naturalize making these areas suitable for restoration works. It is the opinion of Aquafor Beech Limited, in support of the Municipality, that additional HDF Assessments be undertaken on features identified on agricultural properties prior to any development approval in order to accurately assess hydrologic functions of these features. This is especially the case if cultivated lands are allowed to go fallow in the intervening time. If, based on detailed assessments and review, it is determined that the feature provides form and function that would increase the management characterization, it is recommended that the more conservative management approach be adopted. Alternatively, if the feature represents that with the same or less function, management in the form of mitigation through appropriate lot conveyance may be appropriate.

8.4.4 Geomorphology

Confined fluvial systems tend to migrate within the valley; this process is evident from the incision of the valley itself. Where a channel is capable of migrating within its floodplain on the valley floor, is dependent upon the meander amplitude within a given reach and the rate of erosion of a given bank material. In this regard, valley margins confine the meander belt where a channel is in contact with the valley slope. The erosion hazard limit of a valley will be defined based upon the compilation of stable slope offset, 100-year erosion hazard, and erosion access allowance, as illustrated in **Figure 8.1**. Erosion hazard limits for confined stream systems are to include a stable slope allowance that accounts for future channel erosion, long-term stable slope formation, and an erosion access allowance.

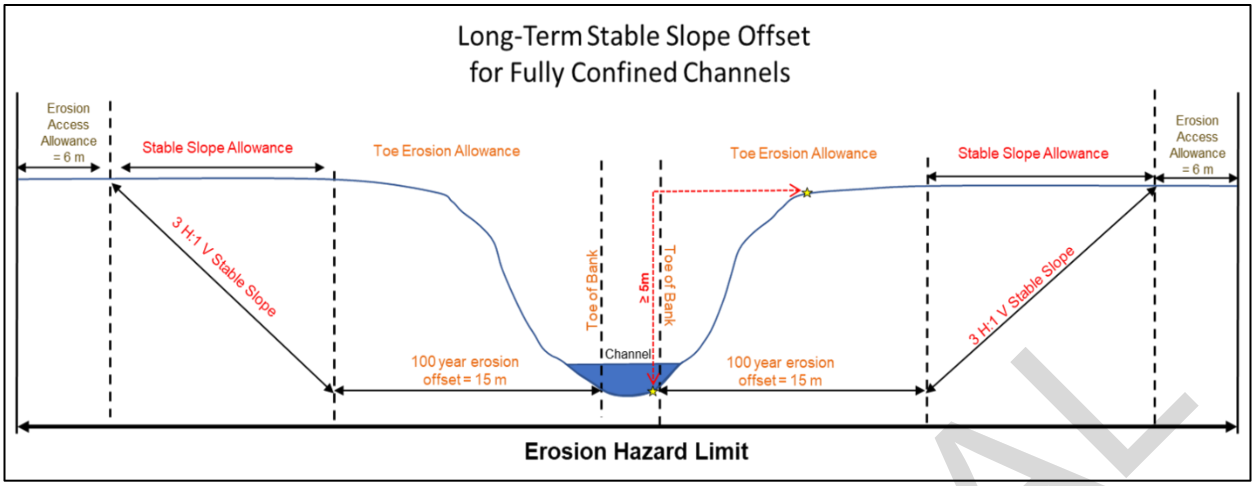

Figure 8.1: Erosion Hazard Limit for a fully confined channel

Estimates of the Long-Term Stable Slope (LTSS) hazard were provided in the Phase 1 report, and presented below in **Figure 8.2.** This figure shows where the LTSS should be confirmed and/or refined with detailed geotechnical studies. Typically, these studies include detailed topographic surveys and borehole investigations in the field. Site specific geotechnical analysis will be needed with each development application.

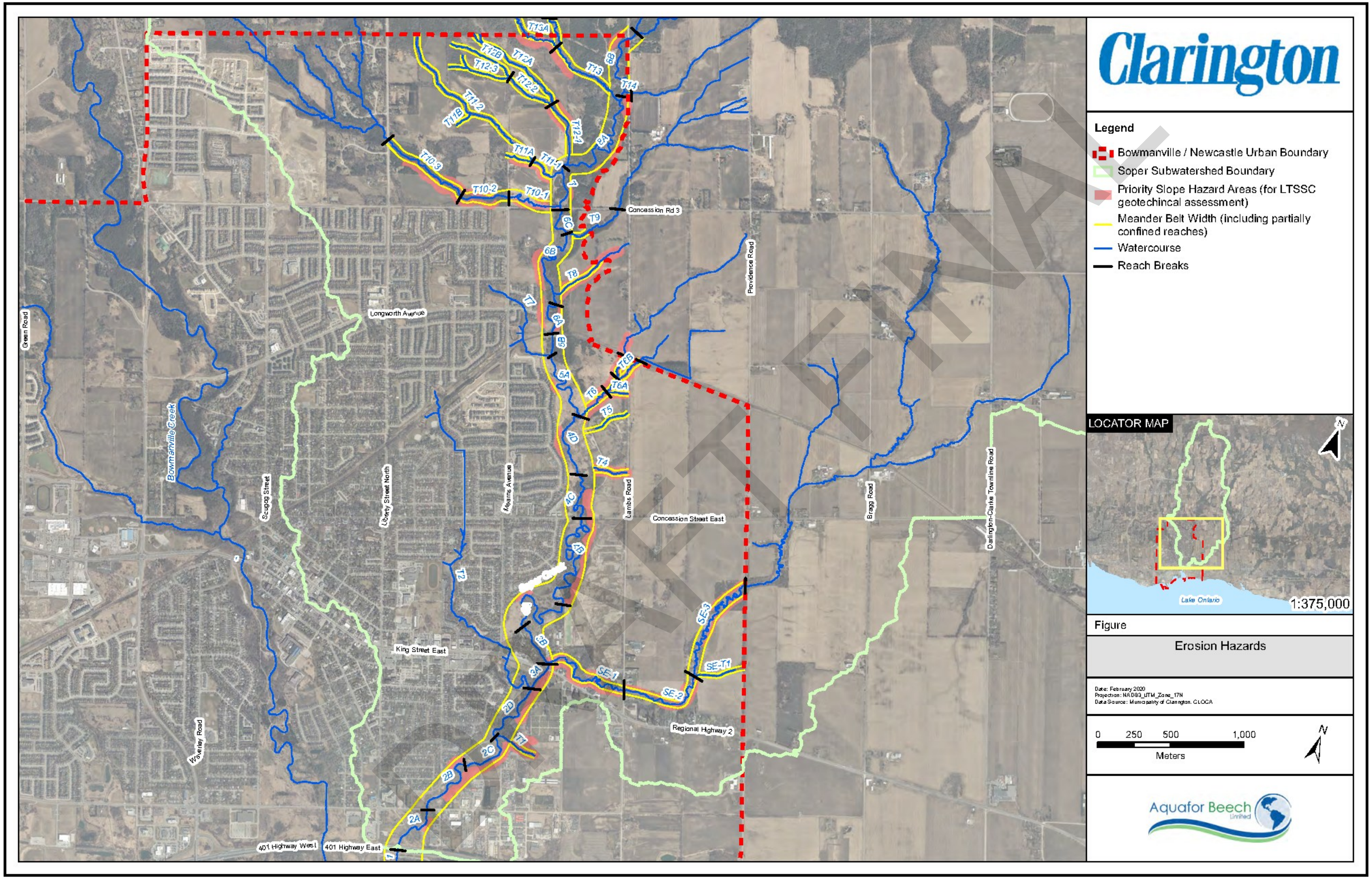

Figure 8.2: Erosion Hazards within the Soper Creek Subwatershed

For slope hazard areas, the erosion hazard limit will be required to include a "toe erosion allowance" associated with the creek channel and a "erosion access allowance" beyond the top of slope. Priority stable slope hazard areas have been identified in the following reaches as a part of the existing conditions assessment in Phase 1 (**Figure 8.2**):

- Reach 2A-D
- Reach 3A-B
- Reach 4A
- Reach 4B-D
- Reach 5A
- Reach 6A-B
- Reach 7
- Reach 8A
- Reach SE-1
- Reach SE-2
- Reach SE-3
- Reach T1
- Reach T4
- Reach 6-1
- Reach 6-2
- Reach 6A
- Reach 6B
- Reach T8
- Reach 10-1
- Reach 10-2
- Reach 10-3
- Reach 11-1
- Reach 11-A
- Reach 12-1
- Reach 13-1
- Reach 13A

The generalized delineation of the stable slope hazard limit is based on the sum of the following setbacks as illustrated in **Figure 8.1**:

- Toe erosion allowance – evaluated through an erosion assessment or 15 meters from the channel bank;
- Stable slope allowance – stable slope plus a 1.5 factor of safety obtained from a geotechnical assessment or 3-horizontal to 1-vertical for slope heights above 3 meters;
- Erosion access allowance – provincial minimum suggests a 6-meter offset from the stable slope allowance be provided to allow emergency and construction access to the long-term slope.

Erosion and Maintenance Sites

The Phase 1 Report identified erosion sites and maintenance sites; these will require re-assessment and monitoring to address the risks to infrastructure. A strategy to address these concerns should include regular updates to the erosion site inventory every 5-10 years and integrated within the strategic planning of the Municipality.

8.5 Secondary Plan Policy

As stated in **Section 3** of this report, the Soper Creek Subwatershed Study was undertaken through an integrated approach with the Soper Springs Secondary Plan and the Soper Hills Secondary Plan. The Phase 1 subwatershed characterization report provided a detailed summary of existing conditions associated with subwatershed health and defined constraints to development associated with natural heritage features and natural hazards. The subwatershed characterization report also provided direction for policy development related to natural heritage features, natural hazards, and headwater drainage features, and provided recommendations for a volume-based stormwater approach where runoff is treated as a resource and pre-development water balance rates are maintained to the greatest extent possible.

Using the subwatershed characterization report as a foundation for development constraints for Secondary Plan development, the Secondary Plan teams responsible for the Soper Hills Secondary Plan and the Soper Springs Secondary Plan developed preliminary land use plans and associated Secondary Plan policies. An encompassing policy has been included in the Secondary Plans that directs the reader to the Subwatershed Study when they are preparing studies.

8.6 Permits and Approvals

8.6.1 Ontario Endangered Species Act

The Ontario Ministry of the Environment, Conservation, and Parks (MECP) is responsible for the administration of the *Endangered Species Act* (ESA), under which Species at Risk (SAR) and their habitat receive protection in Ontario. As the list and rankings of SAR in the province is always being updated with new information, future studies (e.g., EIS) will be required to include an updated screening and assessment for SAR and SAR habitat within their study area. This process may be required to include consultation with the MECP to identify any targeted surveys that will be necessary for the project.

New developments and site alterations which will potentially impact Endangered or Threatened species are required to submit an Information Gathering Form (IGF) to the MECP so that they may review the project and determine the requisite actions under the ESA (i.e., whether a permit will be required for the proposed action or whether it may be covered under a regulatory exemption or letter of advice).

Eight Endangered or Threatened species were identified as occurring or potentially occurring in the subwatershed, and are expected to require additional work or consultation to determine their requirements under the ESA, either because they are commonly found in anthropogenic habitats (e.g., buildings, agricultural fields) and therefore their habitat is not protected in the NHS, or because their general habitat extends out of the NHS into adjacent lands (e.g., habitat radius around a tree trunk). These species are as follows:

- **Bank Swallow (*Riparia riparia*)** - A Threatened bird species that nests colonially by excavating nest burrows in eroding vertical banks (e.g., riverbanks, lake bluffs, road cuts, aggregate pits) situated near suitable grasslands, pastures, and other open terrestrial sites that provide adequate foraging habitat. This species was documented foraging within the study area, although breeding habitat was not confirmed during Aquafor's field investigations. Nesting habitat may be present in the area but, if extant, is expected to occur along Soper Creek, its tributaries, and/or the Lake Ontario shoreline where vertical eroding banks are present.
- **Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*)** – These two Threatened bird species utilize meadows, pastures, old fields, and similar open habitats. The presence/absence of these species should be confirmed prior to land development or site alternation which would destroy potential habitat. At the time of this document's publication, there is a regulatory exemption available for land

development in Bobolink and Eastern Meadowlark habitat within certain defined parameters; outside of those parameters, a permit under the ESA may still be required.

- **Butternut (*Juglans cinerea*)** – An Endangered tree species confirmed to occur at multiple locations within the SWS study area. Additional locations not specifically identified in the SWS are possible, and site-specific surveys should be completed to identify all Butternuts present in areas associated with proposed future development, including hedgerows and other treed areas not identified as part of the NHS. General habitat for Butternut includes the area up to 25-50 m from the stem. Where development is proposed that would impact a Butternut or its habitat, a Butternut Health Assessment must be completed according to the provincial protocol. This Assessment will result in the ranking of trees as Category 1, 2, or 3 which have different requirements under the ESA. DNA testing may be carried out if hybridity is suspected; only pure Butternut trees are protected under the ESA.
- **Little Brown Myotis (*Myotis lucifugus*), Northern Myotis (*M. septentrionalis*), Eastern Small-footed Myotis (*M. leibii*), and Tricolored Bat (*Perimyotis subflavus*)** – The four bat species currently listed as Endangered in Ontario are typically associated with wooded habitats containing cavity trees or other features suitable for maternity roosting. However, isolated trees, or trees in hedgerows or other areas outside of woodlands, may also provide suitable habitat conditions, particularly in areas where woodlands are scarce or lacking. Any tree in use by an Endangered bat species is considered habitat under the ESA and is protected under the associated legislation; potentially suitable trees cannot be discounted or dismissed as habitat without at least a due-diligence review, simply because they do not occur in a woodland. Derelict buildings or other structures proposed for removal which could provide roosting habitat for bats would also have requirements under the ESA and would need to be subject to further assessment. Proposed tree removals adjacent or near to woodlands, or the removal of small woodlands or hedgerows that are not part of the NHS, may required additional work to identify the potential to support bats. Requirements under the ESA for these species would be determined on a case-by-case basis in consultation with the MECP.

8.6.2 Fisheries Act: Department of Fisheries and Oceans Canada Regulatory Review

The federal *Fisheries Act* requires that projects avoid causing the death of fish and the harmful alteration, disruption or destruction of fish habitat unless authorized by the Minister of Fisheries and Oceans Canada (DFO). This applies to work being conducted in or near waterbodies that support fish at any time during any given year or are connected to waterbodies that support fish at any time during any given year. The majority of watercourses and aquatic features within the study area fit this definition and therefore, the *Fisheries Act* applies to works conducted in or near water in many cases. However, review of the *Fisheries Act* and the site-specific aquatic resources should be reviewed on a site-by-site basis to determine if the Act applies to the aquatic resource.

Upon completion of the detailed design for the channel works at the study site, the works should be cross-referenced with the DFO “Projects Near Water” online service to determine if a request for regulatory review under the federal Fisheries Act is required (Fisheries and Oceans Canada, 2023). Using field investigations, background information and correspondence with regulatory bodies, the site-specific study area shall be examined to determine if the potential to contain fish at any time during any given year, or that a certain connection to waterbodies that do support fish at any time during any given year, is demonstrated. Following the guidance of the DFO, the need for a request for regulatory review by Fisheries and Oceans Canada will be determined. It is recommended that a proponent exercise the measures listed by Fisheries and Oceans Canada to avoid contravention with the Federal *Fisheries Act* and exercise due diligence by further mitigating accidental death of fish and the harmful alteration, disruption or destruction of fish habitat.

8.6.3 Central Lake Ontario Conservation Policy and Procedural Document for Regulation and Plan Review

In accordance with the Technical Guide for River and Stream Systems: Erosion Hazard Limit (MNR, 2002) an erosion access allowance is applied to all erosion hazard limits. Within the jurisdiction of the Central Lake Ontario Conservation Authority (CLOCA), the erosion access allowance is consistent with the provincially recommended minimum of 6m to the most conservative erosion hazard, (meander belt, stable slope allowance, toe erosion limit. This erosion access allowance. CLOCA may approve the increase or reduction of this Access Allowance based on studies to the satisfaction of CLOCA. Instances of where CLOCA will consider a reduction include where development already encroaches within this setback.

9 References

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Appendix A – LID Presentation (March 2020)

Appendix B – Hydrologic and Hydraulic Model Inputs and Outputs

Appendix C - Detailed Floodplain Mapping and New Hydraulic Structures

Appendix D – Erosion Assessment – Tractive Force Analysis