Bay of Quinte Regional Master Drainage Planning Project

DRAFT

April 2009

MAYHEW CREEK

MASTER DRAINAGE PLAN

WaterPlan Associates

XCG

The Big Cleanup THE BAY OF QUINTE

QUINTE CONSERVATION

LOWER TRENT CONSERVATION

Mayhew Creek Master Drainage Plan

Final Draft
April 23, 2009

This report was prepared for the Ontario Ministry of Environment in partnership with the Water Environment Association of Ontario and Environment Canada's Great Lakes 2000 Cleanup Fund. The views and ideas expressed in this report are those of the authors and do not necessarily reflect the views and policies of the aforementioned governments and agencies, nor does the mention of vendors, trade names and commercial products constitute an endorsement or recommendation for use.

Executive Summary

The Mayhew Creek Master Drainage Plan was prepared for the identified growth area in the lower reaches of the Mayhew Creek watershed in the City of Quinte West. As a tributary of the lower Trent River and Bay of Quinte, Mayhew Creek is of specific interest for stormwater management (SWM) in the Bay of Quinte Remedial Action Plan.

The study was completed as a cooperative effort through the financial inputs and work efforts of the federal and provincial governments, Quinte and Lower Trent Conservation Authorities, the City of Quinte West and consultant support.

The approach taken was to compile historical resource information supplemented with new field work and current analyses in a variety of relevant component areas including hydrology, water quality, land use planning, topographic mapping, soils and groundwater, aquatic and land-based ecology. This information was analyzed on a sub-catchment basis, with 25 SWM prospective pond locations identified. The purpose of developing these ponds would be to maintain the existing Mayhew Creek flow regime as future development occurs, thus protecting downstream areas and the Bay of Quinte from higher flows and water quality degradation.

In addition to providing a detailed methodology for practitioners to follow for design of stormwater management systems that would meet the above objective, there are detailed examples of how to plan and size an industrial SWM pond and a low density residential/ commercial SWM pond.

This report is intended to serve as a companion document to the City of Quinte West Official Plan, providing stormwater management guidance and a basis for development approvals. The final section identifies areas of SWM responsibility and makes specific implementation recommendations for the City, the Conservation Authority and for developers.

Acknowledgements

The Mayhew Creek Master Drainage Plan was undertaken as part of the 3-year *Stormwater Management/ Pollution prevention and Control Plan for Bay of Quinte Municipalities*.

This project was a large team effort. Key agencies and individuals are acknowledged below.

Funding support was provided by three levels of government:

- Federal – the Great Lakes Sustainability Fund administered by Environment Canada
- Provincial – Ontario Ministry of the Environment
- Municipal – the City of Quinte West

Substantial in-Kind work effort was provided by the staff of:

- Quinte Conservation:
  - Bryon Keene, P.Eng., Project Director;
  - Amy Dickens, GIS Specialist;
  - Tim Trustham, Plan Review Ecologist;
  - Brad McNevin, Fisheries Biologist;
  - Mark Boone, P.Geo., Hydrogeologist.
- Lower Trent Conservation:
  - Mike Lovejoy, Hazard Lands Program Coordinator;
  - Jeff Borisko, BQRAP Implementation Coordinator.
- The City of Quinte West:
  - Brian Jardine, Supervisor of Planning Services;
  - Charlie Murphy, Director of Planning and Development Services;
  - Chris Angelo, Director of Public Works Services.

Consultant support was provided by:

- WaterPlan Associates – Project Management and report coordination
- XCG Consultants – Hydrologic modelling and water quality analysis
- DigitalWorld – LiDAR Mapping

Table of Contents

List of Figures

List of Tables

List of Maps

Appendices

1. Introduction

The 38.31 km^2 Mayhew Creek watershed is located primarily in the City of Quinte West, with a small area at the extreme west in the Municipality of Brighton (see Map 1.1). Being a tributary of the Bay of Quinte, Mayhew Creek is of specific interest in the Bay of Quinte Remedial Action Plan (BQRAP) as it falls within the implementation area for stormwater management guidelines developed for the BQRAP. Lower Trent Conservation partners with Quinte Conservation to implement the stormwater management guidelines for the Bay of Quinte Remedial Action Plan.

Mayhew Creek flow originates north of the Hamlet of Smithfield. Several groundwater springs located in the Murray Hills feed steep south-flowing tributaries that join the east-flowing main channel that empties into the Trent River about 2 km upstream of the Bay of Quinte. Total elevation drop is about 175m, from ~255m (geodetic) at the apex of the Murray Hills north of Highway 401 to ~80m at the mouth of Mayhew Creek.

The lower part of Mayhew Creek is urbanized, where it flows through the Trenton Ward, City of Quinte West. The City is growing rapidly in this area and the presently undeveloped lands located between existing Trenton Ward and County Road 40 (Wooler Road) to the west are experiencing development pressure (proposed development detail is discussed in the City of Quinte West description of land use designations in Appendix B.

The Mayhew Creek watershed is bisected north to south by nine kilometres of Highway 401, from km markers 516 in the west (7 km east of the County Road 30 Brighton interchange) to km 525 in the east (at the Trenton County Road 33 interchange at the Trent River). The Wooler Road (County Road 40) interchange is at Highway 401 km marker 522.

The November, 2000 *Mayhew Creek - State of the Watershed Report* prepared by Lower Trent Conservation for the City of Quinte West was undertaken as a first phase towards developing a watershed plan for Mayhew Creek. That report contains a lot of useful background information, much of which is summarized throughout this Master Drainage Plan.

1.1 Cultural History

Like many of the watersheds in Southern Ontario, the Mayhew Creek watershed has undergone a significant transformation from being primarily wooded, to currently being a mix of agricultural and urban land use. The raw timber resource of the watershed was converted to a merchantable product as early as 1806, with the construction of a lumber mill at Trenton. Numerous smaller impoundments were created along Mayhew Creek in subsequent years for the operation of woolen and grist mills. In 1984/85, flood control works were implemented in the lower reaches of Mayhew Creek to divert a portion of the Timmins flood event from the main channel.

1.2 Bedrock Geology

The bedrock underlying the Mayhew Creek watershed originated from the deposition and compaction of calcareous sediments during the Middle Ordivician Period (approximately 500 million years ago). The limestone, part of the Ordovician Black River Series, is highly fractured with many seams containing dark grey clay.

1.3 Surficial Geology

The northern boundary of the Mayhew Creek watershed is defined by steep shorecliffs formed by the glacial meltwater Lake Iroquois. The southern boundary is defined by a sand and gravel kame deposit (named the Trenton Kame Moraine). The eastern portion of the watershed is largely characterized by a sand plain that was created by glacio-lacustrine activity. A beach and shore cliff in the central part of the watershed is carved into the drumlinized till plain that forms the western portion of the watershed. A small portion of the northwest corner of the watershed contains a low-lying clay plain.

1.4 Existing Land Uses

Much of the watershed has severe limitations for agricultural productivity according to the Canada Land Inventory mapping. A comparison of historic and present air photographs indicates that the amount of cultivated lands has decreased since the end of World War II. During the same time period, urban sprawl has converted former agricultural lands to urban uses adjacent to Trenton Ward. Within the existing urban core, there are residential, commercial and light industrial land uses. Outside of the urban centre, rural strip development, agricultural facilities and aggregate extraction are the predominant land uses.

1.5 Surface Water

The main branch of Mayhew Creek is approximately 10.8 km long, flowing easterly from Middle Ridge Road near the east boundary of the Municipality of Brighton to the Trent River outfall. Mayhew Creek is 1 to 2 km south of and roughly parallel to Highway 401. The average stream gradient within the identified urban growth study area is 0.008, ranging from virtually flat in the established urban reaches downstream along Mayhew Creek to as high as 0.150 for short tributary reaches located in the north-west part of the study area and south of Highway 401.

There are several historic dams and impoundments on the eastern end of the main channel that act to increase water temperatures. A small distance upstream from the mouth, there is a flood reduction bypass channel which is maintained by Lower Trent Conservation. Although dry for large portions of the summer, the bypass channel conveys peak flows during spring runoff and storm events. Within the urban limits of the watershed, several stormwater outfalls are located directly on the banks of the creek. These discharges lack water quality management controls. Mayhew Creek enters the Trent River approximately 2 km upstream of the Bay of Quinte via a man-made channel which flows parallel to the actual Trent River channel. This channel was originally intended for use in the Trent-Severn canal system.

The stream flows all year and temperatures suggest it is a cold water system. Field observations taken between May & August 2008 (Appendix C) indicate that stream water temperature increases towards the mouth; this is most likely due to a combination of less vegetative cover and on-stream impoundments. Further discussion on field observations can be found in Section 10.

As described in Section 2, a separate Pollution Prevention and Control Planning (PPCP) process was undertaken in parallel with this Master Drainage Plan.

2. Scope and Objectives

The development of Master Drainage Plans (MDPs) for urban growth centers around the Bay of Quinte is part of a 3-year cooperative, multi-partner, *Bay of Quinte Regional Master Drainage Planning Project* initiative that includes: the federal government (Environment Canada through the Great Lakes Sustainability Fund), the Ontario provincial government (Ministry of Environment), Quinte Conservation (Project Coordinator), Lower Trent Conservation and local municipalities.

The Mayhew Creek MDP is the first of four similar Master Drainage Plan projects around the Bay of Quinte, and thus the approach and methodology for Mayhew Creek in the City of Quinte West is a template for undertaking similar studies at the City of Belleville, the Town of Greater Napanee and Picton in Prince Edward County.

The Master Drainage Planning (MDP) process for Mayhew Creek and the other urban growth areas around the Bay of Quinte is being conducted separately but in parallel with the Pollution Prevention and Control Planning (PPCP) analysis. Separate MDP and PPCP reports will be produced within the three-year program timeframe.

The ultimate goal of undertaking select MDPs is to identify and implement stormwater management strategies and treatments that will improve stormwater quality outflows entering the Bay. Collectively, the stormwater management improvements achieved through master drainage planning will provide overall ecological, health, recreation, tourism and aesthetic enhancement benefits to the Bay of Quinte.

Specifically for the Mayhew Creek MDP process, the City of Quinte West and Lower Trent Conservation are directly involved. Project input contribution from all partners includes both funding and commitment of in-house staff time. In addition, consultant support is included to undertake project management and specialized technical water quality and hydrology support functions.

As highlighted in the 2000 *Mayhew Creek State of the Watershed Report*, stormwater management associated with urban growth is the primary force driving water management planning for the Mayhew Creek watershed.

SWM options are identified and evaluated from a technical, location, growth sequencing, cost and environmental standpoint. Detailed design is not part of this study. The City will integrate the recommended agreed SWM treatments and associated policies into the Official Plan.

Beyond the strict analysis of where various SWM ponds may best be located in the system to control storm runoff from future growth, other related water management and planning issues have been integrated into the report. These include discussion of flooding and flood control, hydraulic capacity of channels and structures, channel erosion, on-stream ponds, lakes and controls, fish, aquatic and terrestrial wildlife, vegetation, water quality sampling, soils and hydrogeology and planning analysis. Recommendations are made regarding areas identified requiring additional technical and policy analysis. Thus, the resultant plan expands beyond the traditional limited engineering concept of master drainage planning and establishes the framework for the development of a broader multi-disciplinary subwatershed plan for the study area located in the lower part of Mayhew Creek.

In consideration of the above-mentioned stormwater planning issues, the Master Drainage Plan is restrictive in terms of meeting SWM quality and quantity control objectives without being prescriptive as to specific treatments and locations – the development community is responsible for this level of detail to support their approval applications.

3. Methodology and Approach

An issue common to Mayhew Creek and other candidate MDP project watersheds around the Bay of Quinte is that existing topographic mapping is generally limited to Ontario Base Maps with contour intervals of 5 metres and a vertical accuracy of only $^{+}/_{-}$ 2.5m. This is not sufficiently precise to assess the stormwater management implications of proposed land use changes, especially in flatter downstream areas. Therefore an integral part of the MDP planning process was to obtain laser-based high resolution LiDAR (Light Detection And Ranging) contour mapping and photography. This process enables the integration of lasers, global positioning and inertial navigation systems with fixed-wing (or helicopter) flights to achieve a high degree of vertical (~15cm) and horizontal (~30cm) map resolution.

The identified urban growth areas in Trenton Ward are in the lower reaches of Mayhew Creek. The existing Ontario Base Mapping provides sufficient data to develop basic hydrology models for the headwater Mayhew Creek watershed, upstream of the growth area. However, a selected area of 12.9 km^2 of LiDAR mapping per Map 3.1 was flown and generated to enable detailed analysis of the defined downstream urban growth area that is centered on the area of the Telephone Road and Wooler Road (County Road 40) intersection.

A heavy emphasis was placed on digital GIS (Geographic Information Systems) mapping to illustrate and integrate various plan elements – the maps included in the map folio/attached fold-outs are numbered according to the report section in which they are referenced.

The Mayhew Creek watershed is broken into numbered sub-catchments, as are shown on all maps, to enable the hydrology modeling process to determine cumulative pre-development (ie existing) flows at specified system locations as the basis for assessing impacts of and necessary SWM treatments for controlling future development.

The tasks undertaken to complete the Mayhew Creek Master Drainage Plan include:

a. Characterize the hydrology, hydraulics, land use, hydrogeology, aquatic and land-based biology of the watershed from existing information and mapping;

b. Define the short- and intermediate-term urban growth areas;
c. Disaggregate the watershed into relevant sub-catchments;
d. Using detailed LiDAR contour mapping of the growth area, undertake detailed hydrologic and hydraulic analysis of various flood frequency flows in the streams, ponds, control structures and related water resources features in the growth areas;
e. Undertake hydrogeological soils and water table analysis in the growth area to determine which areas exhibit good infiltration and SWM treatment potential versus areas normally above the water table where SWM would not be appropriate;
f. Preliminary investigation of the important terrestrial, aquatic and fisheries biology resources along Mayhew Creek and its downstream tributaries, discuss existing impediments and enhancement opportunities and define areas both suitable and unsuitable for use as SWM facilities;
g. Define the characteristics of soils in the growth area and the potential for use of infiltration techniques to recharge the water table and sustain base flows of Mayhew Creek;
h. Define possible SWM options at both a conceptual and a preliminary engineering level and evaluate the required size, locations, technical effectiveness, cost, sequencing, land ownership/ assembly and funding implications of each;
i. Assist the municipality in discussing options with the stakeholders and the public;
j. Prepare an implementation plan as a companion document to the City Official Plan.

The intent is to keep the report text as concise as possible while maximizing use of the powerful LiDAR-based GIS mapping generated for the project. Sections 11 & 12 deal at the sub-catchment level to describe the various SWM options and factors related to the identified growth areas in each individual sub-catchment and to develop SWM management policies and strategies required to be undertaken by developers at the future site plan application phase.

4. Consultation

The large majority of the Mayhew Creek watershed is within the City of Quinte West and the municipality is an integral team member and funding partner. City staff are directly involved along with staff from Lower Trent Conservation and Quinte Conservation, including those involved and experienced in the Bay of Quinte Remedial Action Plan plus consultant support in the development of the initial planning and technical elements of the Master Drainage Plan for Mayhew Creek.

Landowners, stakeholders and the general public will have an opportunity to review and comment on the draft plan prior to City adoption of an SWM implementation strategy.

A minor part of the extreme western headwater is within the Municipality of Brighton. Discussions with Brighton will be undertaken to review the MDP process once the initial general watershed data gathering and analysis is documented.

5. Background Information

Each project team member accessed and utilized data and information sources from their own component perspective. Where additional data was needed field work was undertaken to fill those gaps. The project relied extensively on mapping data from the provincial mapping inventory (Land Information Ontario) and was added to by the project team to create mapping and statistics for hydrologic calculations. Other sources of information resided with either the City of Quinte West or Lower Trent Conservation. These included the planning area mapping, floodplain mapping and hydraulic modelling of Mayhew Creek, and watershed studies.

The LiDAR mapping described in Section 3 provided a detailed topographic base for master drainage planning. All maps produced for this report are comprised of digital data in layers that can be combined both to illustrate features of interest in various combinations and to perform calcuations of area, length, slope, percentages and other measurements required for SWM.

Quinte Conservation obtained 3-D Analyst software for this analysis to create stream cross-sections from the LiDAR mapping and develop stage-storage relationships for potential SWM pond locations.

Natural Heritage Information Centre provides an on-line resource for information of. As well, Species at Risk mapping was also accessed to determine areas of Mayhew Creek that have any protected species.

A list of reference documents follows the report text.

6. Present and Future Land Use

6.1 Introduction and Planning Context

The primary utility of planning and land use designation input to this Master Drainage Plan is to assess existing runoff conditions, define how future proposed growth would impact present hydrology and to determine what stormwater management treatments would enable and effectively manage this growth.

The complete City of Quinte West planning description of the Telephone Road Development Area (TRDA) located on the western boundary of the Trenton Ward within the City of Quinte West is included as Appendix B to this report.

The TRDA, covering about 360 hectares over a linear distance of 3.7 kilometres, is located south of the Highway 401 corridor and is centered at the intersection of Telephone Road and Wooler Road in the City's Murray ward. The Telephone Road Development Area is shown on Map 6.1.

The TRDA was created as a result of the provision of municipal services to the General Mills facility located on the south side of Telephone Road at the western extent of the TRDA.

The effect of the extension of municipal services along Telephone Road, in addition to providing for the expansion of the industrial plant, created the potential for a new urban growth and settlement area within the City. This is in keeping with provincial Planning mandates.

In order to ensure efficient and orderly development of the new urban growth area, the City of Quinte West initiated a program in 2005 by which the urban growth area would be removed from the jurisdiction of the City of Quinte West Official Plan, which at this time was primarily a rural area official plan for the City of Quinte West. Instead, the urban growth area was included within the area of jurisdiction of the Trenton Ward Secondary Plan, to be governed by the urban development standards of that plan. In addition specific land use designations and policies were developed for the lands contained within the TRDA and accordingly, Official Plan Amendments were approved by Council in August 2005.

Prior to the OPA's detailed above, and the creation of the TRDA, lands were designated under four separate designations:

Agriculture - primarily occupied by the General Mills and Trenton Cold Storage facilities at the western boundary of the TRDA plus some orchard lands.

Rural - lands within the previous Rural designation cover a variety of land uses including agriculture, and related uses, low density residential, limited commercial and industrial uses, as well as forested areas and open grasslands.

Special Policy Area 1 - this designation referred to a specific parcel located in Part of Lots 9 and 10, Concession 2, and designated the lands for "Prestige Industrial". These lands have been re-designated through OPA 79 for a mix of industrial, commercial and residential uses. These lands are currently vacant.

Aggregate Reserve - this designation identifies lands with a reasonably high potential of containing commercial quantities of aggregate materials according to the Ministry of Natural Resources. This designation affects a 16 hectare parcel in the south of the TRDA. No extraction licenses have been issued on this property, and the extent of incompatible land uses within close proximity effectively sterilize future extraction potential.

The predominant form of existing development within the TRDA is that of low density, detached residential dwellings. Limited commercial development is located at the intersection of Wooler and Telephone Roads, with two institutional uses located to the east of Wooler Road.

There are a total of 459 residential dwellings within the TRDA. Of these 292 dwellings are located in the form of strip development along Telephone and Hellyer Roads and Orchard Lane. These developments were created through the Consent process prior to municipal amalgamation of the City of Trenton and Murray Township. The balance of the residential dwellings (167 units) are located within residential subdivisions, the bulk of which are located north of Telephone Road within the eastern portion of the TRDA. The existing lot fabric is illustrated on attached maps.

Due to the historic use of private water and sanitary services in the area, the majority of residential lots within the TRDA are situated on larger rural type lots. These larger lots may in some circumstances provide the potential for additional lot creation through severance, should municipal services be utilized.

Commercial land uses along Wooler Road near the intersection of Telephone Road include a gas station and convenience store, concrete trucking facility, a road-side market, a safety company and a number of vehicle sales operations.

6.2 Land Use Strategy – TRDA (Planning District 12)

The land use strategy for the TRDA as approved in 2005 under OPA 79 serves to recognize existing and future development within the context of a comprehensive planning strategy of compatible land uses.

To ensure that development is environmentally sensitive within Planning District 12, primarily the tributaries of Mayhew Creek and Tremur Lake, the City may require new development and/or re-development to provide environmental studies to identify environmental constraints and undertake further field work to determine impacts and offer mitigation measures to protect the environmental features. No development shall take place within 30 metres of the top of bank (or greater distance if a flood study is required) of the tributaries of Mayhew Creek and Tremur Lake as identified.

In areas of the Planning District where municipal services have been installed, any redevelopment and/or alteration of buildings currently on private services that result in an increase in habitable area or sanitary flow rates shall be required to connect into the appropriate sanitary sewer system.

The TRDA was placed within a new Planning District 12 that details and addresses the specific designations and requirements for new development located within the TRDA. Planning District 12 is divided into nine sub-districts as listed below (Appendix B has the detailed descriptions):

A. - primary industrial
B. - secondary industrial
C. - low density residential
D. - low density residential & commercial
E. - privately serviced Barry Heights residential subdivision
F. - public open space and recreational
G. - general commercial purposes (primary)
H. - general commercial purposes (secondary)
I. - industrial/ general commercial purposes

Note that stormwater management treatment planning breaks into two main categories from a hydrological and SWM planning standpoint – low density residential/ commercial (Sub-districts C, D, G, H) and industrial (Sub-districts A, B, I).

6.3 Approved and Additional Residential Land Supply:

Within the TRDA there currently exists one fully approved and registered Plan of Subdivision and three draft approved Plans of subdivision.

1) *Tremur Lake Subdivision* – 30 single detached residential lots. Approved and under construction.
2) *Wild Orchid Subdivision* – 28 single detached residential lots and 1 commercial lot. Draft approved.
3) *Orchard Lane Plan of Subdivision* – 188 single detached residential lots. Draft approved.
4) *Elks Lodge Plan of Subdivision* – 6 single detached residential lots. Draft approved.

The TRDA has sufficient designated lands to accommodate approximately 2,100 new residential units, subject to site-specific development constraints. Specific physical development constraints within the TRDA include the presence of CPR / CNR rail lines and associated rights of way and the Mayhew Creek watershed system, and lands affected by natural hazards and natural heritage features including but not limited to flooding, erosion, stream meandering slope stability wetlands and fish habitat.

Initiated primarily by the submission of the Orchard Lane draft plan application and the re-designation of lands on the western side of Orchard Lane (OPA 21) for residential use, the City has undertaken a consultant study for lands located to the north-east of the intersection of Wooler Road and Telephone Road.

This study will investigate the existing vehicular access capacity within this portion of the TRDA and review future opportunities and options for road access to service these designated lands. In addition the study will prepare initial servicing options and design for these lands. This study was initiated in February 2008 for completion by March, 2009. City Planning staff will ensure that this study and implementation of its findings will co-ordinate with the Mayhew Creek Watershed Master Drainage Plan study.

6.4 Transportation & Service Corridors

The TRDA has two primary transportation corridors, namely Telephone Road which runs east-west through the MDP study area, and County Road 40 which runs north-south providing connection to Highway 401 at intersection 522. Both Telephone Road and County Road 40 are classified as Arterial routes. Existing and future local residential streets run north and south from Telephone Road. Other than County Road 40 all local roads running north from Telephone Road terminate south of the 401 Highway. To the south of Telephone Road, County Road 40, Tate Road and 2nd Dug Hill Road provide connection to Highway 2 and beyond. Telephone Road and County Road 40 provide the main traffic arteries within the MDP study area. Recent traffic analysis conducted by the Thompson Rosemount Group (2009) identifies that primary road corridors and intersections within the Study Area are operating well within acceptable Level of Service standards.

Trunk municipal water main and sewer services exist on the Telephone Road corridor, originally installed to service the General Mills industrial plant at the western extent of the MDP study area. While existing residential and commercial development within the study area is primarily serviced by private individual water and sewer facilities, all new development within the TRDA is required to be connected to full municipal water and sewer service. Sewer servicing policy within the TRDA requires development to utilize a low flow sewer design system that meets a maximum daily flow rate of 225 liters/capita/day.

7. Hydrology and Hydraulics

7.1 Previous Hydrologic Modelling Studies

In their flood control study of Mayhew Creek between the Trent River and Tremur Lake, Chrysler & Lathem (1981) set up a hydrologic event model for the entire watershed and determined peak flows for the 5, 10, 25, 50 and 100-year design storms. The modeled peak flow at the outlet using the 100-year, 6-hour rainfall input for Kingston of 76.2 mm was 12.8 m^3/s.

Totten Sims Hubicki (1983) used a different hydrologic event model and Trenton IDF rainfall depths for two durations (12 and 24 hours), both distributed in time according to the SCS type II distribution to determine a peak flow at the outlet of 12.8 m^3/s.

7.2 Hydrologic Model Overview

Determination of the storage required to reduce peak post-development flows to existing conditions peak flows under specified rainfall inputs requires the use of a hydrologic simulation model of the event type. There are numerous candidate models of this type. XCG selected the model HEC-HMS (which was developed and is maintained by the U.S. Army Corps of Engineers) for the following reasons.

i. It is in the public domain.

ii. It is used widely in Canada and the United States.

iii. It is the successor to HEC-1, the first version of which was published in 1968 and subsequently extensively revised in 1973, 1981 and 1990, and as such has subjected to extensive testing by the hydrologic community.

iv. It incorporates algorithms that have been published and peer reviewed in technical literature.

Data Requirements

Data required for modelling can be classified as meteorological data, watershed & channel data and reservoir data, as defined below:

a. Meteorological data are essentially rainfall data, which are presented in the form of "Design Storms" and, in the case of Mayhew Creek, a historical storm that occurred in September 2004;
b. Watershed & channel data include physiographic data (drainage area, length and slope), soils data and land use data, all on a sub-catchment basis. Sub-catchments are delineated in a process known as "basin discretization" - in the case of Mayhew Creek, Quinte Conservation staff used GIS procedures to discretize the overall basin and determine sub-catchment data; and
c. Reservoir data include the locations of all reservoirs in the network and characteristics for each reservoir.

Three Conditions Modeled

Watershed data must be determined for three watershed conditions:

i. existing (2008) conditions,
ii. post-development conditions, and
iii. post-development conditions with stormwater management measures in place.

7.3 Design Storm and September 2004 Event

Design Storms

A design storm was developed in two steps for a 12-h storm duration for the 100-year return period.

i. Total rainfall depths were taken from the Atmospheric Environmental Service's updated "Rainfall Intensity – Duration – Frequency Values" for Trenton A, Ontario, station number 6158875 (see Table 7.1).

Table 7.1 Design Storm Rainfall Depths

Return period (years)	5	10	25	50	100
12-hour depth (mm)	48.9	55.2	63.2	69.1	74.9

**** Estimated by Environment Canada (IDF 1965 – 1997)***

ii. Hourly values of rainfall depth were determined by applying the peak 12-h rainfall distribution from the September 9th, 2004 event (see Table 7.2).

Table 7.2 Design Storm Temporal Distribution

Time Step (h)	1	2	3	4	5	6	7	8	9	10	11	12
Depth (%)	1.6	1.5	0.9	3.5	8.6	10.5	21.6	23.0	10.1	6.6	9.3	2.8

September 2004 Event

A large rainfall event occurred over eastern Ontario on September 9, 2004. Total storm depths recorded at three stations, as given by Klaassen & Seifert (2007) and the Environment Canada value for Trenton A are given in Table 7.3

Table 7.3 September 2004 Rainfall Event Depths

Location	Belleville	Wilton Cr.	Collins Cr.	Trenton A
Depth (mm)	109.2	107.0	137.4	110.8

Inspection of Table 7.3 shows that the event depths exceed the Environment Canada estimates for the Trenton A 100-year, 12-hour depth of 74.9 mm (see Table 7.1). In fact, they exceed the Environment Canada estimates for the Trenton A 100-year, 24-hour value of 84.4 mm. The September 2004 storm recorded at Trenton A and the 100-year, 12-h design storm are displayed in hyetograph form in Figure 7.1.

7.4 Basin Discretization

General Discretization Principles

The following general principles guided the configuration of the basin into sub-catchment, reservoir, channel and junction elements.

- **i.** Sub-catchment elements were provided to represent the watershed routing process for all sub-catchments obvious on the topographic map.
- **ii.** Sub-catchment elements were added when a drastic change in land use was anticipated.
- **iii.** Reservoir elements were added when a reservoir existed or was anticipated.
- **iv.** Channel elements were added to represent the delays in channels.
- **v.** Junction elements were added to link sub-catchment hydrographs or tributary hydrographs with each other or with the main branch.

Types of Elements and Parameters

Sub-catchment elements: An element refers to a component of the hydrologic event model. Elements incorporate algorithms that attempt to represent flow generation and routing processes. Sub-catchment elements (of area A, in km^2) represent two processes:

a) abstractions (or losses) from rainfall, and
b) routing of net water input through the sub-catchment

In this study, abstractions are modelled using the SCS curve number algorithm. For pervious areas, this algorithm has only one parameter, the curve number, CN. The values used for CN are those corresponding to antecedent moisture condition II (AMC-II), the average condition preceding annual floods. Values for CN were selected from tables developed by the US Soil Conservation Service, where CN depends on soil type and land use. For post-development conditions, the algorithm has an additional parameter: the percent of the total sub-catchment area that is impervious.

Watershed routing is modelled using the Clark unit hydrograph algorithm. This algorithm has two parameters, lag time and storage coefficient. An equation developed by Watt and Chow (1986) was used to estimate lag time using values for sub-catchment length and slope. The storage coefficient was estimated as 1.5 (lag time) for sub-catchments with <3% surface storage and 2 (lag time) for sub-catchments with >3% surface storage.

Reservoir elements: Reservoir elements, which represent constructed storage or detention ponds, are modelled using the modified Muskingum method. This method requires two relations: reservoir storage-elevation relation, and outflow structure hydraulic description. Information required for these two relations was provided by site visits by QC staff and XCG and by GIS interpretation of NTS mapping. These parameters apply to both existing and developed conditions.

Channel elements: Channel elements, which represent the process of channel routing, are modelled using the Muskingum-Cunge algorithm. This algorithm requires channel length, channel slope, Manning's n and a representative cross section. All parameters with the exception of Manning's n (estimated as 0.03) were obtained using GIS software and mapping interpretation. These parameters apply to both existing and developed conditions.

Junction elements: The outflow from a junction is equal to the sum of all inflows to the junction.

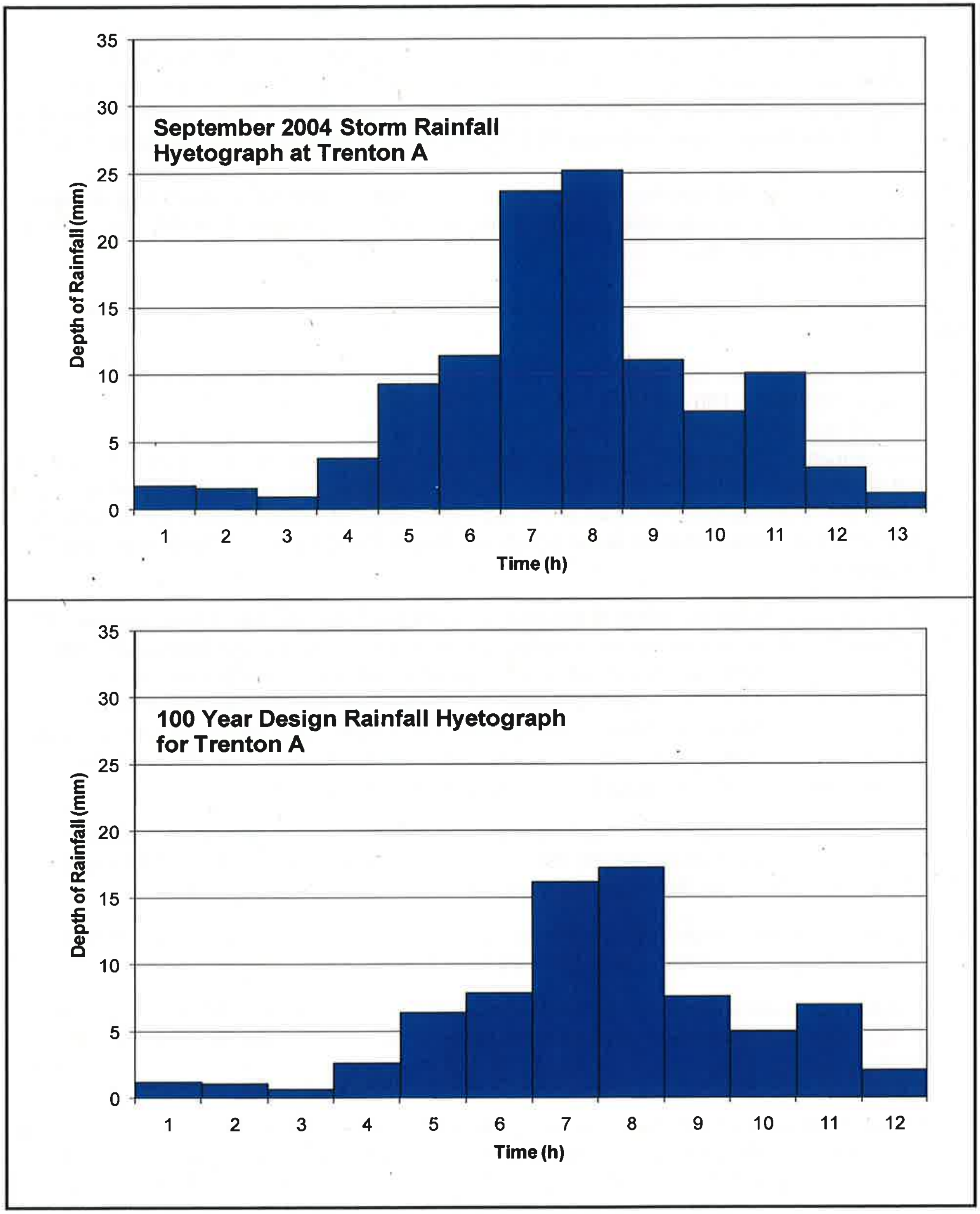

Figure 7.1 September 2004 Storm and 100-Year Design Storm

7.5 Existing Conditions Case – Basin Description

General description: The Mayhew Creek drainage basin (see Map 1.1) extends from near Smithfield and Brighton Provincial Wildlife Area in the west to the Trent River in the east. From the north it reaches Mount Zion and extends near County Road 2 in the south. Its drainage area at the Trent River is approximately 38 km^2, and includes land in the City of Quinte West.

Basin discretization: Sub-catchments were defined by points of interest. Contributing drainage areas to each point were calculated using GIS software and then confirmed/modified by XCG to represent actual conditions.

Drainage network: The Mayhew Creek watershed was split into the following five major drainage series:

1. The 100 series drains the southwest of the watershed to the future developing area (200 series). Within the 100 series are two dams with differing outlet structures. The first dam has two outlet structures – the first is a rectangular overflow orifice (measuring approximately 500 mm by 330 mm) and the second is a 450 mm culvert. Both are located at the outlet of sub-catchment 101. The second dam has a low flow outlet that is a 90-degree v-notch weir (approximate top width of 2.5 m); higher flows are passed over a grass spillway. This structure is located at the outlet of sub-catchment 104 (located on Glenburnie Farms property).
2. The 200 series drains the future developing area and has been split into a large number of sub-catchments to provide a more detailed flow analysis. There are two dams in the 200 series – the Tremur Lake Dam (located at the outlet of sub-catchment 204 and the Old Mill dam (located at the outlet of sub-catchment 205). The Tremur Lake dam is operated by two 8 ft stop logs. The Old Mill dam is not operated and it outlets over a stepped concrete weir structure. Also located in the 200 series catchments is the Mayhew Creek Water Survey of Canada gauge (02HK011) located at the outlet of sub-catchment 206.
3. The 300 series sub-catchments drain from the northwest to the downstream side of the Tremur Lake Dam. Sub-catchment 302 and a small portion of sub-catchment 301 (south of Higway 401) lie within the future development area.
4. The 400 series sub-catchments drain from the north into the pool caused by the Old Mill Dam. Sub-catchments 403, 404 and 405 all lie within the future development area.
5. The 500 series are downstream of the bulk of the future development (although some small development and redevelopment may occur in these areas) and eventually outlet to the Trent River.

Soils: The distribution of soil types is shown in Map 7.1. Data for this figure were taken from the *Soil Survey of Norththumberland County* (Gillespie et al. 1962) and then overlaid on the sub-catchment limits using GIS procedures. According to CCL (1981), "the watershed consists mainly of well-drained sand of the Pontypool type and sandy loam of the Brighton type. Essentially, the watershed can be classed as 'AB' type soils, which are well-draining".

Developed areas (existing conditions): Developed areas (under existing conditions) are generally restricted to the eastern edge of the basin in Trenton (see Map 6.1). Residential development is evident near Tremur Lake where several small subdivisions exist. Commercial development in the area is relatively small being comprised mostly of cold storage facilities.

The model schematic for existing conditions is shown in Figure 7.2.

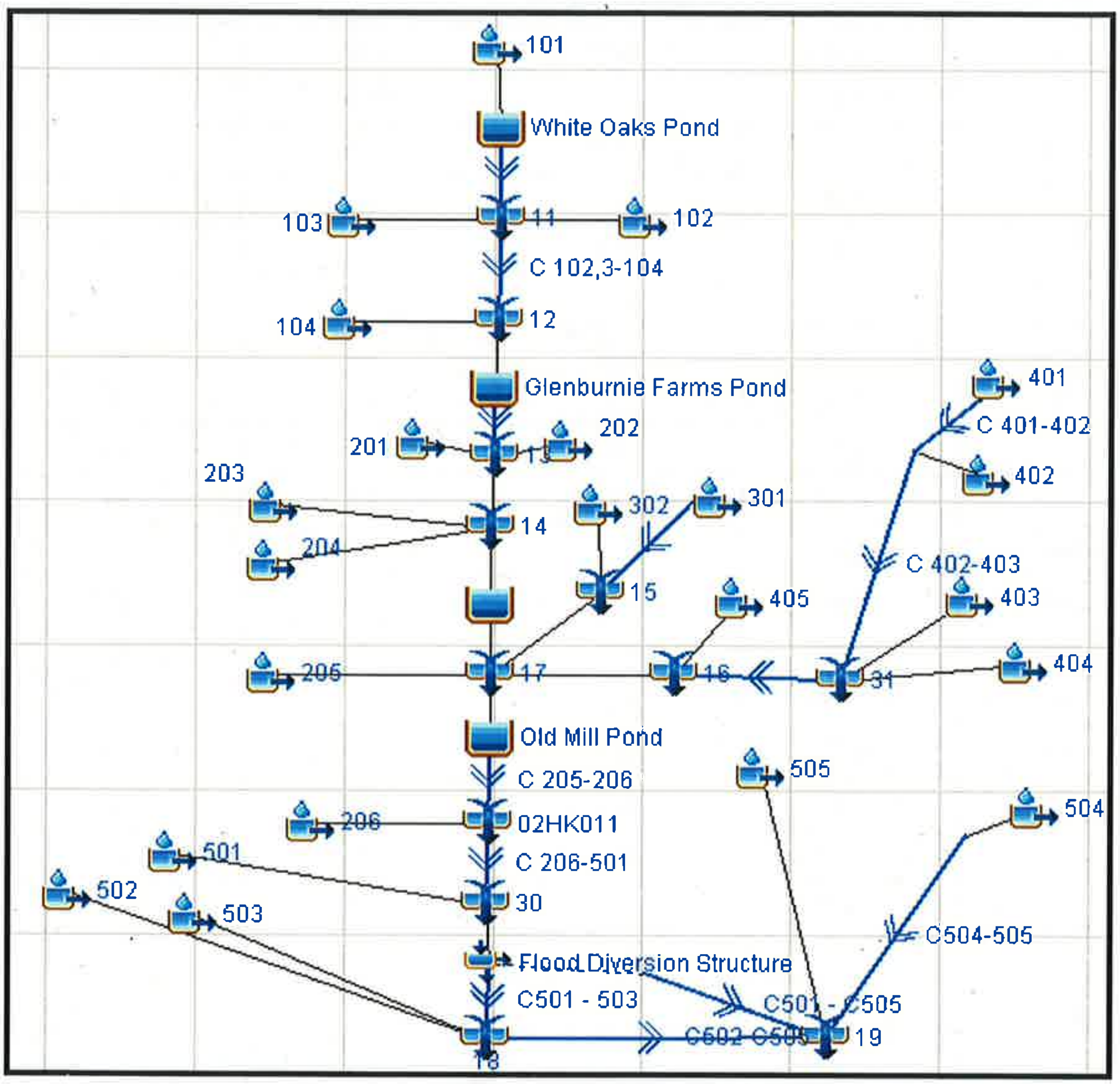

Figure 7.2 HEC-HMS Model Schematic for Existing Conditions

Sub-catchment Parameters

Initial estimates of the sub-catchment parameters for existing conditions (area, time to peak and curve number) were determined using topographical and soils data provided by GIS procedures. Final values, which are listed in Table 7.4, were determined by calibration using the September 2004 event.

Table 7.4 Sub-Catchment Parameters - Existing Conditions

Sub-catchment	Area (km^2)	Time to Peak (h)	Clark's R (h)	SCS Curve Number
101	3.16	6.25	12.5	54
102	1.62	1.5	3.0	69
103	5.82	3.0	6.0	73
104	1.11	13	16	61
201	1.80	0.5	1	68
202	1.20	4.75	9.5	65
203	1.08	2.25	4.5	60
204	1.72	6	12	68
205	0.41	2	2.5	65
206	0.18	1	1.5	66
301	3.91	1.5	3	62
302	0.61	3	6	62
401	6.60	1.5	3	68
402	2.45	0.75	1.5	70
403	0.24	0.5	0.75	73
404	0.47	0.5	0.75	70
405	0.38	0.5	0.75	60
501	1.02	1	1.5	68
502	1.11	1.5	2.25	63
503	0.10	0.25	0.5	62
504	2.13	2	3	71
505	1.05	3.5	5.25	62

The objective of the calibration was to provide a higher level of certainty for the parameter selection for use within the model. The initial stages of the calibration identified that there was a somewhat larger runoff volume than predicted by the model; to account for this difference the curve number was uniformly increased for all sub-catchments. With correct volumes the next issue was matching the timing. The Mayhew Creek drainage basin has many large swamps and reservoirs which significantly dampen peak flows. To account for this storage and reduced peak flow, lag times were multiplied by an adjustment factor based on percent lakes and swamps. The following relation was used for adjustment:

$$AF = \left(20\frac{A_s}{A} + 1\right)^{1.3}$$

where:

AF = Adjustment factor
A_s = Area of swamps and ponds (ha)
A = Area of the sub-catchment (ha)

The results of the calibration are summarized graphically below in Figure 7.3. The blue solid shows the modelled flow and the dotted black line shows the actual flow. In general the graphic shows a "good" fit and justifies the parameter selection for the model.

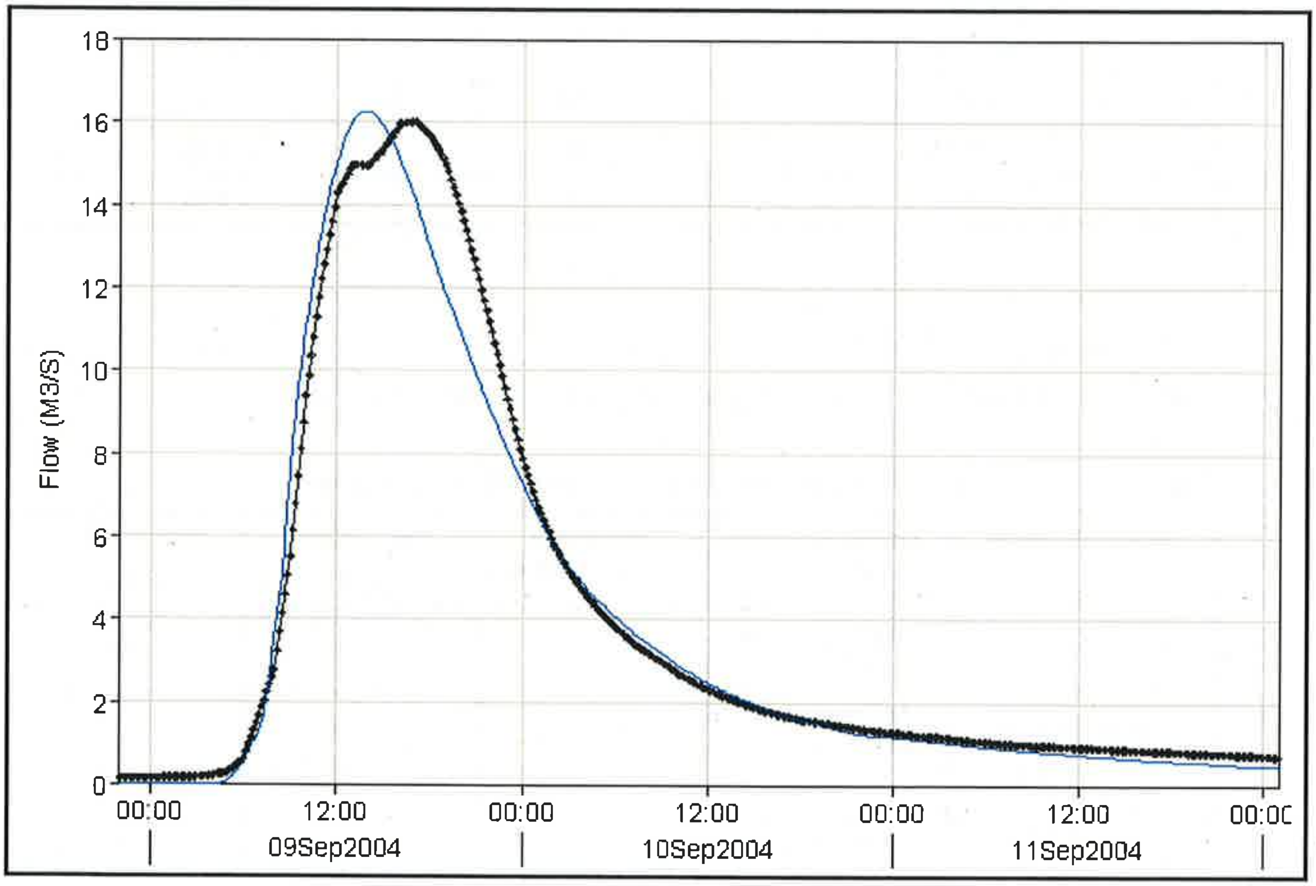

Figure 7.3 Comparison of Modelled to Actual flows for September 2004 Event

Channel Parameters

The channel elements are summarized in Table 7.5.

Table 7.5 Channel Parameters - Existing Conditions

Channel	Length (m)	Slope (m/m)
C101-103	2136	0.02
C102,3-104	1550	0.003
C104-202	1000	0.003
C205-206	400	0.005
C206-501	500	0.006
C301-302	950	0.01
C401-402	1200	0.004
C402-403	750	0.01
C403-405	550	0.003
C501-503	450	0.004
C501-505	1200	0.004
C502-505	900	0.002
C505-505	350	0.004

Reservoir Parameters

The reservoir characteristics for the 100-year storm are summarized in Table 7.6.

Table 7.6 Reservoir Characteristics for the 100-Year Storm

Reservoir Name	Outlet Structure	Maximum Storage (1000 m^3)	Peak Inflow (m^3/s)	Peak Outflow (m^3/s)
White Oaks Pond	Drop Inlet and Culvert	4.9	0.21	0.10
Glenburnie Farms	90° V-notch weir and bypass Spillway	79	4.40	2.52
Tremur Lake	Log Dam	173	3.29	2.08
Old Mill Pond	Concrete Dam	56.1	9.62	9.25

Sub-catchment Flows – Existing Conditions

Peak flows, at the outlet of each sub-catchment and at selected junctions, for the case of the 12-hour, 100-year rainfall input are given in Table 7.7. **These flow values should be considered benchmarks against which flows for post-development conditions are compared.**

Table 7.7 Sub-Catchment and Junction Flows - Existing Conditions

Sub-catchment	Sub-catchment Peak Flow (m^3/s)	Junction Node	Peak Outflow (m^3/s)
101	0.21		
102	1.09	11	4.38
103	3.37	11	4.38
104	0.08		
201	1.67		
202	0.30	13	2.76
203	0.31		
204	0.43	14	3.29
205	0.23	17	9.62
206	0.13	02HK011	9.34
301	1.66		
302	0.17	15	1.81
401	4.19		
402	2.19	C402-403	6.10
403	0.36	31	6.15
404	0.58		
405	0.21	16	6.81
501	0.79	30	9.92
502	0.57		
503	0.07	18	4.76
504	1.58		
505	0.31	19	12.28

Note: This table should be viewed with Figure 7.2.

7.6 Post-development Conditions Case

The basin and sub-catchment boundaries for the post-development conditions case are identical to those defined for the existing conditions case.

Planned Development

Planned development was defined by the Official Plan of the City of Quinte West. In summary, there is no significant change in land use anticipated for sub-catchments 101, 102, 103, 104, 401, 402, 502, 503, and 505. For the remainder of the basin, the Official Plan designates development and future land use that is significantly different than existing conditions. In general, the future land use that differs from existing is commercial/industrial, residential, or some combination of the two.

Sub-catchment Elements, Parameters and Flows

Model elements: Channel elements and reservoir elements in the existing conditions model were retained with no change in parameter values. The impact of changes in land use was modelled by changes in sub-catchment parameter values for relevant sub-catchments.

Sub-catchment elements and parameters: Parameters were determined as follows.

- **i.** Sub-catchments were divided into two categories: a) those for which a change in land use is anticipated according to the official plan and b) those for which no change is planned.
- **ii.** Parameters for category "b" sub-catchments were set equal to those used in the existing conditions model.
- **iii.** Parameter values for category "a" sub-catchments were revised as follows.
  - The abstractions sub model was revised to include a value for impervious area.
  - The time of concentration in the routing sub model was revised to reflect the effect of faster runoff from developed surfaces.

7.7 Post-development Conditions with Stormwater Management Case

Sub-catchment flows: The output from the HEC-HMS model for the case of the 12-hour, 100-year rainfall input under post-development conditions is given in Table 7.8.

Model elements: Channel elements and reservoir elements in the post-development conditions model were retained with no change in parameter values. The impact of stormwater management was modelled by adding a reservoir element for relevant (i.e. category "a") sub-catchments. The HEC-HMS model schematic for post-development conditions with stormwater management is shown in Figure 7.4.

Reservoir element parameters: Reservoir elements were modelled as linear reservoirs (i.e. reservoir storage is linearly related to reservoir outflow). For each reservoir element, required storage at maximum outflow was determined by numerically integrating the area between the inflow (i.e. post-development) hydrograph) and the outflow hydrograph with peak equal to the peak of the existing conditions hydrograph.

Sub-catchment storage and flows: The output from the HEC-HMS model (peak flows and storage) for the case of the 12-hour, 100-year rainfall input for post-development conditions with stormwater management is given in Table 7.8. Also tabulated for comparison purposes are the sub-catchment peak flows for existing conditions, which are given in Table 7.7. The storage values given are the total storage (in 1000 m^3) required to reduce post-development peak flows to peak flows under existing conditions.

Junction Flows: With two exceptions, flows at junction nodes for post-development conditions with stormwater management measures in place did not significantly exceed the values for existing conditions, which are given in Table 7.7. The two exceptions were junctions 13 and 14 where the post-development routed flows exceeded the existing conditions values by about 20 %. The cause of this increase was the coincidence of the routed flows from sub-catchments 201 and 202 with the outflow for Glenburnie Farms Pond. Further application of the HEC-HMS model revealed that the only feasible way to maintain existing peak flows at junction nodes 13 and 14 is to incorporate stormwater management measures in sub-catchment 201 such that the existing conditions hydrograph (resulting from the 100-year rainfall) is maintained.

7.8 Guidelines for Stormwater Management Calculations

Overview

In order to clarify the implementation of stormwater management storage facilities, detailed step by step guidelines are provided for:

- estimating pre-development peak flow for the case when only a portion of a sub-catchment is being developed;
- estimating post-development hydrographs for this case or for the special case when an entire sub-catchment is being developed; and
- estimating pond storage volume to ensure that post-development peak flows for the developed area do not exceed existing conditions peak flows.

In addition, two examples are provided in which portions of sub-catchments 204 and 405 are assumed to be subject to development. In these examples, calculations are provided for each step of the guidelines.

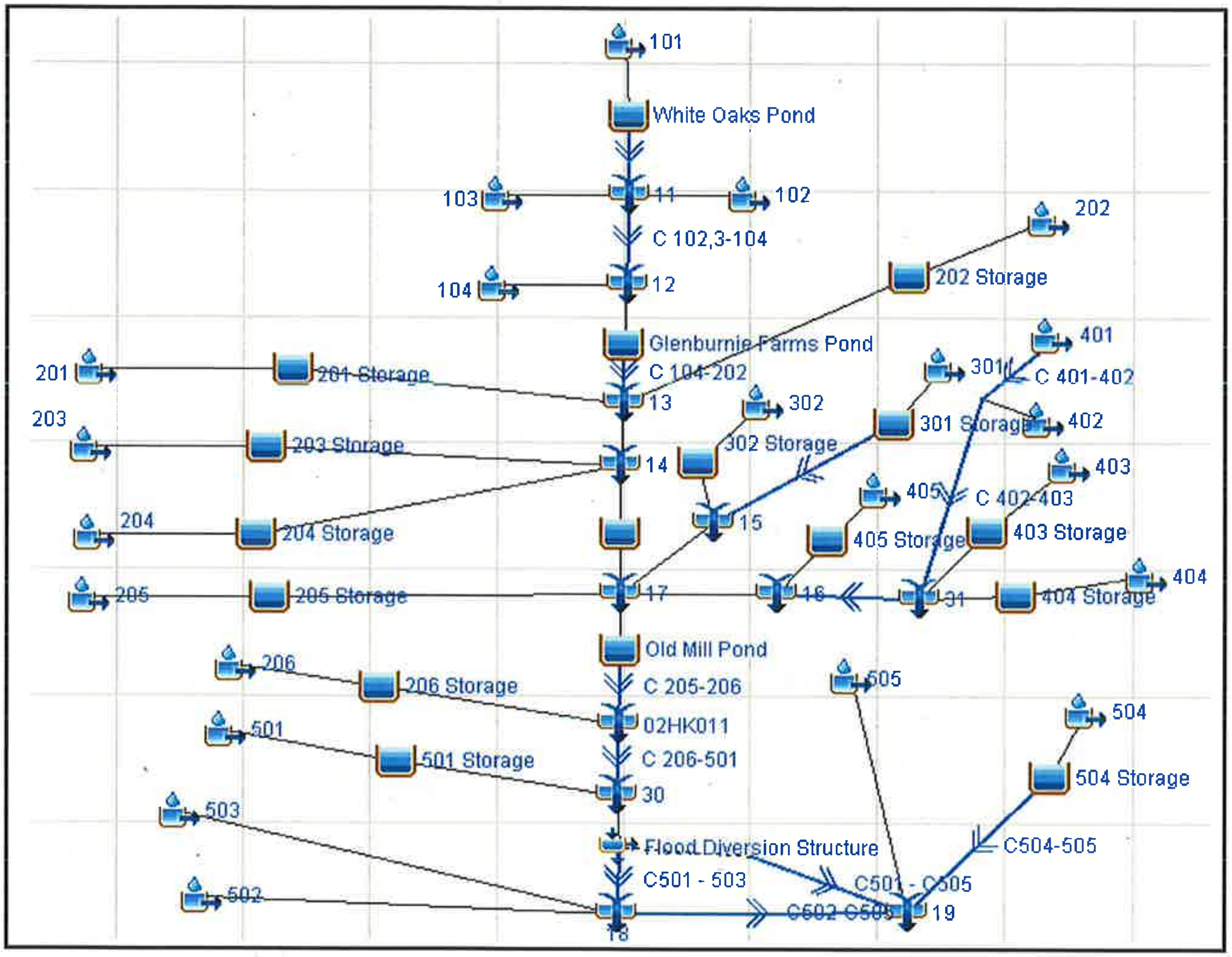

Figure 7.4 HEC-HMS Model Schematic for Future Conditions

*Table 7.8 Sub-Catchment Peak Flows**

Sub-Catchment	IMP (%)	Post Dev. Peak Flow (m^3/s)	Storage (1000 m^3)	Post Peak Flow with Storage (m^3/s)	Existing Peak Flow (m^3/s)
201	22	3.33	20.9	1.68	1.67
202	20	0.72	15.2	0.30	0.30
203	49	1.74	34.7	0.31	0.31
204	44	1.64	46.6	0.41	0.43
205	39	0.60	9.0	0.24	0.23
206	50	0.44	5.5	0.12	0.13
301	15	3.05	38.8	1.66	1.66
302	64	1.17	25.6	0.16	0.17
403	52	0.77	5.2	0.36	0.36
404	20	0.90	4.2	0.54	0.58
405	50	0.97	11.8	0.21	0.21
501	26	1.64	15.9	0.80	0.79
504	7	1.83	11.6	1.57	1.58

*Only for those sub-catchments where significant change in land use is anticipated

Calculation of Existing Conditions Peak Flow

In general, an entire sub-catchment will not be developed at the same time. The following steps are required in order to determine the existing conditions peak flow for the area of proposed development, A_d.

1. Identify sub-catchment number for proposed development
2. Obtain sub-catchment unit peak flow $\left(\frac{Q_p}{A}\right)$ from Table 7.10
3. Calculate area to be developed (A_d), in hectares.
4. Calculate existing conditions peak flow for proposed development.

$$Q_{ppre} = \left(\frac{Q_p}{A}\right)(A_d)$$

Note: A lower value for existing conditions peak flow would be acceptable if such value can be substantiated by field studies and site specific hydrologic modelling. In all cases, a value for existing conditions peak flow must be provided.

Calculation of Post-development Hydrograph

It is assumed that HEC-HMS or an equivalent hydrologic event model will be used. Accordingly, steps required to determine the parameters required for the abstractions submodel and for the watershed routing submodel are provided below.

1. Calculate the percent impervious area IMP of the proposed development.

$$\mathbf{IMP = 100\left(\frac{A_{imp}}{A_d}\right)}$$

2. Calculate the ratio of unconnected impervious area (R_{unc}) to the total impervious area.

   If it exceeds > 30% proceed to step 4 otherwise; go to step 3.

3. Calculate the post-development Curve Number (CN_{post}) by adjusting the sub-catchment pre-development Curve Number (CN_{pre} – see Table 7.10) to account for unconnected impervious areas:

$$CN_{post} = CN_{pre} + \left(\frac{IMP}{100}\right)(98 - CN_{pre})(1 - 0.5R_{unc})$$

   Proceed to step 5.

4. Obtain the post-development Curve Number by selecting (CN_{pre}) from Table 7.10 (assumption is that impervious areas are being modelled separately).

$$CN_{post} = CN_{pre}$$

5. Calculation of the time of concentration. Here AF is the adjustment factor; A_s is the area of swamps and ponds (ha); L is equal to the longest flow length (m); S is equal to the slope of the longest flow length (m/m).

$$t_{cpost} = t_{cpre}(-0.006A_{imp} + 1)$$

$$t_{cpre} = (AF)0.000326\left(\frac{L}{\sqrt{S}}\right)^{0.79}$$

$$AF = \left(20\frac{A_s}{A_d} + 1\right)^{1.3}$$

6. Calculation of Clark's *R.*

$$R = 1.5t_{cpost}$$

7. Calculate the post-development hydrograph using HEC-HMS or an equivalent hydrologic event model.

Estimation of Pond Storage Volume

1. On the post-development hydrograph, draw a straight line from the start of runoff at flow = 0 to a point on the recession limb where the flow is Q_{ppre}. Calculate the area under this curve (triangle) and record it as volume (V_{out}), in m^3.
2. Calculate the area under the inflow hydrograph to the existing conditions peak flow on the recession limb. Record this area as a volume (V_{in}), m^3.
3. Estimate Pond Storage Volume (SV), in m^3.

$$SV = V_{in} - V_{out}$$

Calculation of Quality Storage Volume

1. For a given value of IMP, determine Unit Total Quality Storage Volume (UQSV) from Table 3.2 in *MOE SWM Planning and Design Manual* (MOE, 2003) for Enhanced Control, which is provided in Appendix A.
2. Calculate Total Quality Storage Volume (TQSV) in m^3

$$TQSV = UQSV(A_d)$$

3. Calculate Extended Quality Storage Volume (EQSV) in m^3

$$EQSV = 40(A_d)$$

4. Calculate Permanent Pool Quality Storage Volume (PPQSV) in m^3

$$PPQSV = TQSV - EQSV$$

Sub-catchment-wide equivalent wet pond water quality storage volumes are given in Table 7.9; tabulated for each sub-catchment where a significant change in land use is anticipated are values for volumes of

a. total water quality storage,
b. permanent pool water quality storage, and
c. active water quality storage

Table 7.9 Sub-Catchment-wide Equivalent Wet Pond Water Quality Storage Volumes

Sub-Catchment	Total Water Quality Storage (m^3)	Permanent Pool Storage (m^3)	Active Storage (m^3)
201	18400	11200	7200
202	11500	6700	4800
203	19300	15000	4300
204	30000	23100	6900
205	6200	4500	1700
206	3200	2500	700
301	30100	14400	15700
302	12900	10500	2400
403	4400	3400	1000
404	4500	2600	1900
405	6700	5200	1500
501	11700	7600	4100
504	11100	8500	2600

Design Stormwater Pond

The next step is to design a stormwater pond to

i. satisfy quality storage requirements,

ii. meet the design guidelines of the Ministry of the Environment,

iii. ensure that the post-development peak flows do not exceed existing conditions peak flows under specified design storm conditions, and

iv. ensure that the design value of quantity storage per impervious hectare equals or exceeds the value given in Table 7.10.

Matching post-development peak flows to existing conditions peak flows is an iterative process wherein the outlet structure can be composed of weirs, orifices or both. Their location and set-up greatly affects the use of the storage. Full examples of calculating existing conditions and post-development peak flows, estimating storage and outlet structure sizing are provided in Section 11 for sub-catchments 204 and 405.

Table 7.10 Sub-Catchment Guideline Parameters

Sub-Catchment	CN_{pre}	Existing Conditions Unit Peak Flow (m^3/s/ha)	Required Storage per Impervious Hectare (m^3/ha)
101	54	0.00067	N/A
102	69	0.0067	N/A
103	73	0.0058	N/A
104	61	0.00072	N/A
201	68	0.0093	528
202	65	0.0025	633
203	60	0.0029	656
204	68	0.0025	616
205	65	0.0056	563
206	66	0.0072	611
301	62	0.0042	662
302	62	0.0028	656
401	68	0.0063	N/A
402	70	0.0089	N/A
403	73	0.015	426
404	70	0.012	447
405	60	0.0055	621
501	68	0.0077	600
502	63	0.0051	N/A
503	62	0.0070	N/A
504	71	0.0074	778
505	62	0.0030	N/A

8. Soils & Groundwater

The urban development of rural watersheds will result in an increase in impervious area due to hardening of surfaces with concrete, asphalt etc. This change in land use corresponds to greater runoff of surface water, and a decrease in infiltration to the underlying aquifers. Proper development of a watershed requires careful consideration of the hydrogeologic conditions in order to prevent unacceptable impact. Such impact can result from a change in the hydrologic regime of the watershed through reduced recharge, increased surface water runoff, flooding and decreased base flow in the stream. In an effort to maintain the natural hydrology of a developing area, watershed planning can consider sensitive areas of a watershed as well as implement effective storm water management solutions in consideration of the physical and ecological characteristics. Such solutions could include implementation of infiltration based storm water management measures in areas of suitable soil conditions.

The following is a description of hydrogeologic conditions in the Mayhew Creek watershed provided in order to assist with the development of a Master Drainage Plan. This includes a review of geology (bedrock and overburden) together with the hydrogeology as determined through a review of a variety of sources of information such as the Ontario Water Well Records, and the Trent Conservation Coalition Municipal Groundwater Study.

8.1 Geology

The landscape of the Mayhew Creek watershed was formed during the period when this region was covered by glaciers and subsequently inundated by sub glacial lakes. This activity has left a range of landscapes and soil types as illustrated by Map 8.1 (as mapped by the Ministry of Northern Development & Mines). The distribution of soils can be observed on Map 8.1 that generally shows the watershed to be bound by ridges of well-drained coarse sandy soil with finer sandy loam type soil in between these ridges which constitutes the greater majority of the Region. Shallow soil over bedrock along the eastern edge of the watershed near the Trent River is an exception to this generalization. The range of soil depth across the watershed provided by Map 8.2 (taken from the Trent Conservation Coalition groundwater study) indicates greatest soil depth at the west in the order of 100 to 125 metres above bedrock and tapering to the east in the order of 0 to 25 metres depth. A review of the records of wells drilled for residents within the watershed indicates the depth of soil above bedrock is typically in the order of 8 to 12 metres. Note that the majority of wells are drilled in the center portion of the watershed as opposed to the western boundary (see the location and distribution of water wells in the watershed on Map 8.4).

Beneath the overburden deposits lie two different types of limestone bedrock which have been mapped by the Ministry of Northern Development and mines as illustrated by Map 8.3 and described as the Lindsay and Verulam Formations. The easterly portion of the watershed is underlain by the Verulam formation and the westerly is the lower member of the Lindsay formation. These formations are the two upper most bedrock units (youngest) in the region, deposited as marine sediments during the period when this region was covered by an Ocean. Beneath these two bedrock units is a sequence of other limestone formations followed by the Precambrian basement bedrock. The upper bedrock surface has been contoured, as depicted on

Map 8.4, showing this surface as sloping to the south - southeast from elevations of 120 metres to 75 metres.

8.2 Groundwater

Rural residences within the watershed rely on private wells as a source of domestic water supply. From the records of these wells valuable information can be obtained about the underlying aquifers. For this study a review was completed of the records for 345 wells located within a 1 kilometre radius of the watershed boundary (please see Maps 8.3 & 8.5 for location of wells). Within this area it would appear that residents obtain supply from both overburden deposits of sand and gravel (55% of the total number of wells) and limestone bedrock (remaining 45% of wells). Both aquifers are interpreted as being unconfined (no significant overlying layers of low permeability) with occasional discontinuous lenses of silt and clay providing some areas of isolated protection. The location of these aquifers correspond with the bedrock and overburden geology mapping as bedrock wells are found throughout the eastern portion of the watershed and overburden wells at the west (see distribution of wells on Maps 8.3 & 8.5). Water is typically found in both of these aquifers at depths of less than 20 metres, and at depths of up to 90 metres in the western portion of the watershed given greater soil depth of this area. The yield of wells is suitable for domestic needs with flow rates up to 45 liters (10 gallons) per minute; however, higher flows were typically reported of the overburden aquifer.

Further information about groundwater conditions was obtained by plotting the elevation of the water table and depth to water table on two separate maps (Maps 8.4 and 8.5 respectively) followed by contouring of each surface using GIS. Map 8.4 illustrates the water table sloping to the south east and east corresponding with the direction of ground water flow. The depth to the water table as illustrated by Map 8.5 ranges from 0 to 70 metres with areas of greatest water table depth corresponding with areas of greatest soil depth along the watershed boundaries. Shallow water table depths are found throughout the central and eastern portions of the watershed. Such mapping can be used to generally interpret ground water recharge in the upland areas, with discharge occurring in lowland areas adjacent to watercourses.

8.3 Overview

From the review of hydrogeological information about the Mayhew Creek watershed the following conclusions can be made more specific to the area of the watershed that is planned for future growth:

- Sandy loam soils of good drainage characteristics are predominant throughout,
- Soil depth in this area is in the range 8 to 12 metres but in some areas greater,
- The elevation of the water table is typically at 70 to 90 metres (ranging up to 140 metres in the northwest corner of the region) with groundwater flowing to the southeast,
- The depth to the water table is in the range of 1 to 10 metres with many areas in the 1 to 5 metre category (particularly those close to surface water features).

To assist with future planning, Table 8.1 summarizes soil and groundwater depth conditions within individual catchments of interest located in the area of the watershed planned for future growth.

Table 8.1 Soil Description & Water Table Depth by Catchment

Catchment #	Soil Description (Major & Minor)	Water Table Depth (average in metres)
201	Mainly sand with minor silt, minor organic	4.5
202	Mainly sand with minor silt.	7.3
203	Mainly sand with minor silt.	6.7
204	Mainly sand with minor silt, minor organic & minor sand and gravel	5.1
205	Mainly sand with minor silt	2.9
206	Mainly sand with minor silt	3.7
301	Mainly sand with minor silt	10.2
302	Mainly sand with minor silt	7.3
403	Mainly sand with minor silt and sand & gravel	4.9
404	Mainly sand with minor silt and minor silty sand Till	14.6
405	Mainly sand with minor silt and minor sand & gravel	5.7
501	Mainly sand with minor silt	3.3
504	Mainly sand with minor silt	4.7
Please note soil descriptions are for portion of sub-catchment within planning area Average water table depths are for entire sub-catchment		

8.4 Recommendations

To mitigate the potential impacts of urban development on Mayhew Creek various methods of control exist to promote maintenance of the hydrologic cycle through groundwater recharge and base flow in Mayhew Creek. Conventional end of pipe facilities (storm water ponds) will be required for flood and erosion control and water quality improvement to accommodate drainage from roadways etc. that may contain high levels of suspended solids and other contaminants. Many options are available to reduce the volume of water draining to these facilities and promote ground water recharge for protection of the natural environment. These measures are generally suitable at the lot level where there may be relatively clean contaminant free runoff. This would include drainage from roof tops, foundation drains, and other impermeable surfaces but not roads due to high suspended solids content which could plug such systems and the presence of other potential contaminants which could impair ground water quality. Such possible mitigative measures could include:

- Reduced lot grading,
- Directing roof leaders to ponding areas,
- Directing roof leaders to soak away pits,
- Infiltration trenches,
- Pervious pipes,
- Grassed swales and vegetated filter strips,

- Pervious catch basins,
- Infiltration basins

Use of these storm water management best management practices requires suitable site conditions which include:

- Presence of permeable sandy to loam type soils with a minimum infiltration rate of 15 mm/hr,
- Greater than 1 metre of soil depth above bedrock,
- Greater than 1 metre of soil depth above the water table.

From an overview of the hydrogeologic conditions in the Mayhew watershed it would appear that there is significant potential for the use of lot level controls for infiltration of storm water. However, confirmation will be required through geotechnical assessment of individual developments as they occur. It is recommended that this be made a condition of all draft plan approvals for future development such that implementation of such measures be evaluated and implemented where feasible. Together with the use of such systems would be a program to educate the public and homeowners about the need, use and maintenance of lot level controls.

In addition to the above recommendations for promoting ground water recharge, it is recommended that provisions be made for consideration to the Source Water Protection Planning process. This process includes the mapping of significant ground water recharge areas which may exist in the Mayhew Creek watershed. This planning process may provide recommendations on potential restrictions on landuse and/or best management practices.

9. Ecology

9.1 Natural Areas

Two significant natural areas have been identified by Lower Trent Conservation within the Mayhew Creek watershed; the 'Mayhew Creek Headwaters' and the 'Murray Hills Headwaters Natural Areas'. The 'Mayhew Creek Headwaters' contains the best example of shoreline cliffs left by glacial Lake Iroquois, and a sand plain which extends to the south. This area contains a high diversity of native plants and plant communities, with a number of the communities being considered as rare in Ontario. An old growth Hemlock ravine, which is thought to be one of the oldest and most extensive examples in Ontario, is contained within the natural area. In addition, there are records of three rare plants, two of which are at their eastern most distribution within Ontario. One provincially significant bird species (Red-shouldered Hawk) has been observed within the area.

The 'Murray Hills Headwaters Natural Area' supports the most extensive known examples of intermediate mature deciduous forest on the shoreline cliffs of Lake Iroquois in Northumberland County. Map 9.1 locates the original and second growth forest cover. There are also a number of rare plant communities, including a small remnant dry prairie and a 'Spice Bush' ravine within the natural area. Although small, the prairie community is unusually high in diversity. The 'Spice Bush' ravine is considered to be its extreme north-eastern distribution within North America and is critically imperiled in its Ontario distribution. As also referenced in the *LTC November, 2000. Mayhew Creek State of the Watershed Report,* there are four provincially rare plants in the area, and one provincially rare bird species (Louisiana waterthrush).

9.2 Vegetation Communities

Due to the wide variety of environmental conditions in the watershed, a diverse assortment of vegetation communities are found in the study area. The dominant natural vegetation community within the watershed is mixed forest – deciduous and coniferous, typical of the Great Lakes/St. Lawrence Forest Region. Historical documents indicate the dominance of Oak and White Pine within the forest; however these species were targeted by European logging at the time of settlement. Although present in small patches, the Oak and Pine forests are a rarity within the watershed today. The watershed was estimated in the *LTC November, 2000 Mayhew Creek State of the Watershed Report* to contain 48 % forest cover, with a mix of lowland and upland deciduous, lowland and upland coniferous, and lowland plus upland mixed forest types; recent LTC analysis has determined a figure of 42 %. There is a 10.7 ha old growth Hemlock swamp and ravine slope located within the Mayhew Creek Headwaters Significant Natural Area. The other forest communities are primary the result of secondary growth (forests that have been previously disturbed).

In addition to the forest, there are several large patches of old field habitat, meadow and abandoned orchard communities, linked by fence line and hedgerow communities. Although there are no evaluated wetlands within the watershed, there are marsh, wooded swamp and swamp thicket communities within the drainage basin.

9.3 Fisheries

A detailed evaluation of the fisheries community within the Mayhew Creek watershed was completed in the 1970's with a summary of that work presented in the *LTC November, 2000 Mayhew Creek State of the Watershed Report.* In 2008 the fisheries community within Mayhew Creek and its tributaries was assessed at various road crossings throughout the watershed using a backpack electrofishing unit. Based on the fish community and additional field work collected during the 2008 season, the main channel of Mayhew Creek and some tributaries are considered to be a cold water stream system.

Mayhew Creek supports a wide range of fish species including temperature sensitive species and some species of sport fish. Although the fisheries assessments were restricted to road crossings (upstream and downstream of bridges and culverts), several species of fish were captured. In total, 30 species of fish were collected at the 12 assessment sites (see Map 9.2). With the exception of site MC-02 and MC-11 there were fish observed at all of the sites. The most diversity of species was observed at MC-01 which is located just upstream of the confluence with the Trent River. Fourteen species were collected at MC-01 with a total of 212 fish observed. This site also yielded the highest catch per unit effort (CPUE) which was approximately 1045 fish per hour of electro-fishing. Some of the species collected at MC-01 included *ambloplites rupestris* (rockbass), *oncorhynchus mykiss* (rainbow trout), *oncorhynchusw tshawytscha* (chinook salmon), *perca flavescens* (yellow perch), *rhinichthys cataractae* (longnose dace) and others. A complete inventory of the species collected at MC-01 and the other assessment sites can be found in Appendix C.

Of significant nature was the presence of juvenile salmonids collected at MC-01, MC-03, MC-04, MC-05, and MC-06 (see Map 9.2). The presence of juvenile salmonids is a good indication that these reaches provide suitable spawning and rearing habitat for these temperature sensitive species. Brook, brown and rainbow trout were observed at the aforementioned assessment sites however further assessments should be conducted to determine the extent of their ranges throughout the watershed. The 2008 observations were restricted to road crossings and may not give an accurate account of the presence/absence of all fish species in the watershed.

The Tremur Lake dam located at County Road 40 (Wooler Road) is a notable barrier that restricts the migration of fish species upstream. The areas assessed upstream of the Tremur Lake dam had a total of 12 different species of fish collected during the 2008 assessment. *Catostomus commersoni* (white sucker), *semotilus atromaculatus* (creek chub), and *culaea inconstanus* (brook stickleback) were the most abundant and represented approximately 40 % of all fish collected upstream of the dam. The assessment sites that were located in areas where the Tremur Lake dam did not influence the watershed exhibited a total of 26 species. Salmonid species were only found in areas north of and below the Tremur Lake dam, not influenced by the barrier.

Based on mapping provided by the Department of Fisheries and Oceans (DFO), the Mayhew Creek Watershed does not have any listed protected species at risk. The lower reach of Mayhew Creek (downstream of Tremur Lake dam) has been identified as having species of special concern and these species may be listed as protected in the future. Any proposed changes in the watershed may have to take into consideration the potential impacts to species at risk.

9.4 Wildlife

According to the Canada Land Inventory, the watershed as a whole generally has little capability of producing waterfowl due to the lack of permanent open water – Tremur Lake and Fox's Pond are locally important exceptions.

The large, forested natural areas (Mayhew Creek Headwaters and Murray Hills Headwaters) are an important feature for the abundant bird fauna which are known to migrate across Lake Ontario through Presqu'ile Provincial Park. Several types of common mammals are known to inhabit the watershed, with several locally significant White Tailed Deer wintering yards found in the headwaters. To date, herptofauna surveys have not been completed within the study area.

10. Water Quality Conditions

Some water quality sampling over various time periods has been completed and is interpreted in this section to provide an overview of the current conditions of the creek. More complete sampling results are included in Appendix C.

Water quality investigations undertaken specifically for this project include benthic sampling, temperature monitoring, and base flow measurements. Other work referenced includes the

Provincial Water Quality Monitoring Network (PWQMN), Pollution Prevention and Control Plan storm outfall sampling and fish sampling. The purpose of this section is to provide a context for defining the stormwater quality objectives for the area.

Findings from the fisheries investigation is included in the previous section, but is important to bear in mind since the presence of a healthy cold water fishery influences the water quality targets for stormwater management.

10.1 Historic Data

Water quality data for the watershed is limited. The Mayhew Creek State of the Watershed report contains sampling results for tests conducted between 1991 and 1995. These indicate that the average annual total phosphorus loading ranged from 0.022 to 0.036 mg/L. The total (Kjeldahl) nitrogen ranged from 0.44 to 0.55 mg/L during the same testing period. These values are similar to other watercourses in the Lower Trent region.

10.2 Benthic Investigation

Benthic macroinvertebrates (BMI) are bottom dwelling (benthic) organisms that can be seen with the naked eye (macro) and are without backbones (invertebrates). They include such organisms as aquatic insects, insects during their aquatic stages of the life-cycle, snails, clams, leeches and aquatic worms. BMI have varying tolerances to nutrient enrichment of phosphorus and nitrogen and their abundance are used as a base for assessing water quality in a stream.

Samples were collected using the 'kick and sweep' method at nine locations shown on Map 10.1. This method involves kicking the substrate and collecting the material that is stirred up by sweeping the net back and forth as the material floats downstream. Once the sample has been sorted, the BMI are identified and tallied.

The 'Hilsenhoff Biotic Index' (HBI) is used to evaluate the health of the stream and it is designed to reflect the nutrient status. The tolerance of each BMI is used in a weighted average calculation, together with the relative abundance of each benthic group, to be summed into a single value. A low HBI value (<6) indicates low nutrient conditions and a high HBI value (>6) indicates nutrient enrichment. Nine sampling sites were completed on Mayhew Creek and the HBI values ranged from 3.54 to 6.05, the average being 5.11, concluding that Mayhew Creek has a fair to above average nutrient status. The benthic field notes are included in Appendix C.

10.3 Provincial Water Quality Monitoring Network

The Provincial Water Quality Monitoring Network (PWQMN) measures water chemistry for the purpose of monitoring ambient (background) conditions. Mayhew Creek has two surface water monitoring stations that have been sampled for a set of water quality parameters that include basic chemistry, metals and nutrients, four to six times per year during the ice-free season. Results from 2002 to 2008 sampling seasons were available and were reviewed. Appendix C contains a more complete review of the PWQMN data, but a short summary is provided here.

The two stations (see Map 10.1 for locations) had concentrations of aluminum, cadmium, cobalt, lead, pH, and total phosphorous that were greater than the Provincial Water Quality Objectives (PWQO) from 2002 to 2008. They also had concentrations of hardness and manganese greater than the Ontario Drinking Water Standards (ODWS). Fraser Rd, the upstream station, also had concentrations of iron and turbidity that were greater than the PWQO. Parameters that were higher than the PWQO at the Front St station only were Total Kjeldahl Nitrogen (TKN) and zinc. Water quality is generally good and improves as you go upstream.

10.4 Water Temperature/Base Flow Measurements

Water temperature influences the composition of aquatic communities and is an indicator of groundwater discharge areas. Staff of Lower Trent Conservation deployed 12 temperature loggers into Mayhew Creek in an attempt to characterize the water temperature of each of the creek branches. Only five of the loggers were retrieved. Refer to Map 10.2 for locations of the loggers and a diagrammatic representation of the results. Two sites showed cold-water flows; two indicated cool-water and one revealed warm-water conditions. The lone warm-water site was downstream of a large wetland and Tremur Lake. Although the water temperature sampling period spanned only one summer season, the results show that Mayhew Creek could sustain cold to cool water communities.

The amount of water within a stream channel will also influence the makeup of aquatic communities. Baseflow measurements were also made in the summer of 2008 in mid-July to the end of August. Flows were measured using a 'Pygmy' flow meter during a summer season of above average precipitation. Of the 90 sites that were investigated, 16 had measureable flow, 39 were dry, 29 were inaccessible, and six were not measureable do to various reasons. Map 9.2 contains locations where monitoring of base flows occurred. The measured baseflow discharges ranged from 0.01 to 3.90 cubic metres per second.

Baseflow in branches of the creek where cool to cold water flows were recorded should be protected to maintain the temperature and flow characteristics. These are mostly the headwater portions of the watershed that are not slated for development with the exception of sub-catchments 203, 301, and 302. Development in those sub-catchments needs to be carefully planned to prevent water temperature changes and loss of baseflow.

Other branches with warm water characteristics that are scheduled for development should receive no less attention for protection of baseflow. Temperature affects from development can still have negative impacts on the stream and attention to this would still be important here. Since only one year of sampling was completed and since not all of the loggers were found, the results of this work contribute to a basic understanding of the creek and should not be relied upon for a definitive assessment of the creek. Further sampling over several years is recommended for increased reliability.

10.5 Storm Outfall Sampling results.

Stormwater discharge samples were taken in 2008 in various storm outfalls in municipalities fronting on the Bay of Quinte. These results were reviewed by XCG for the PPCP project and average event-based storm sewer Total Phosphorus concentrations are reported to be 0.2 mg/l. This is similar to sampling results from Kingston parking lots and lower that concentrations reported in Toronto (0.31 to 0.56). XCG references Schueler, 1987 in their interim report quoting a NURP average value of 0.46 mg/l. Trent River TP average annual concentration is 0.027 mg/l (XCG summary of PWQMN sampling).

While storm outfalls into Mayhew Creek were not specifically sampled for this project, by reference to neighbouring outfall results one can expect similar results for the discharges into Mayhew Creek of about 0.2 mg/l TP. These would be about one order of magnitude higher in concentration that the PWQO. The expected development is within the lower reaches of the creek where water quality and temperature are not as conducive

10.6 Resulting Water Quality Target

The water quality in Mayhew creek is good and the fishery data shows a healthy cold water fish community exists. Therefore, an Enhanced water quality target is required for the outfalls of the stormwater management facilities discharging to Mayhew Creek. This is consistent with the Bay of Quinte Remedial Action Plan Stormwater Management Guidelines which states a water quality target of Enhanced should be used for all Townships surrounding the Bay of Quinte.

11. Stormwater Management

As development proceeds in the study area it must do so in concert with management of stormwater runoff to mitigate water quantity and quality impacts. This section contains a more detailed discussion of each of the sub-catchments – their setting and growth potential as well as recommendation for numbers of and placement of treatment facilities.

11.1 Selection of Treatment Options

The individual description of each sub-catchment in this section, along with two detailed SWM calculation examples (in sub-catchments 204 & 405), provide SWM planning direction and guidance for the 25 prospective pond locations identified on Map 11.1.

Of these SWM ponds, 16 would service low-density residential/commercial development. The other 9 are identified for SWM treatment of designated industrial growth areas on a collective basis, in conjunction with on-site measures to locally reduce peak flows.

The onus is on the developer to utilize and extend this information at draft plan submission or formal approval stage to analyze and confirm appropriate SWM treatments, location, land requirements and ownership, pond configuration and geometry plus compatibility with guidelines in the Mayhew Creek Master Drainage Plan and relevant provincial and local policies and planning requirements.

Design of these facilities must recognize the sensitivity of the ecological and hydrogeological resources, both in the specific sub-catchment and downstream.

Off-line SWM ponds are the rule. In exceptional circumstances, where the developer can prove no negative ecological, fisheries or hydraulic impact (ie flooding or application of the HEC-HMS model to show no superimposition of downstream peaks that could worsen existing split-peak conditions), on-stream ponds may be considered.

The 25 identified prospective SWM sites can control the larger growth runoff areas. The size of SWM development capture is important - the larger the pond the better they work, favouring treatment of large or multiple developments over smaller developments; however, areas of infill and smaller development must be addressed mainly by lot level controls.

The key factors in determining what specific SWM treatment or combination of treatments is most appropriate for various areas within each sub-catchment include:

- the number and collective area of undeveloped single lots versus larger subdivision parcels requiring SWM control – many small individual properties that may be infilled for development at differing times in the future cannot be planned collectively as effectively as can larger development area blocks;
- low density residential & residential/ commercial designated lands have different SWM requirements than industrial designated lands for a couple of main reasons – first, industrial development may require hazard spill containment contingency treatment and second, flat-roofed industrial buildings can store and attenuate significant clean runoff as part of the SWM treatment;
- large contiguous tracts of either low density residential/ commercial development or industrial development in a given sub-catchment, whether presently owned by one or more adjacent landowners, can and should be treated for SWM in-so-far-is-possible at larger consolidated locations rather than at many individual locations – this is more difficult for industrial growth where the exact nature and timing of the future developments is not known;
- SWM treatments for low density residential/ commercial developments should be distinct from and not mixed with SWM for industrial development;
- recognition of existing and draft plan approved developments and the ability to blend new adjacent development growth SWM treatments or be compatible with those already in place or approved;
- avoidance of locating SWM facilities in significant natural areas – designs must be enhanced in favor of minimizing impacts and mitigating any habitat losses;
- recognition of the general pervious nature of the soils across the growth area and associated opportunity to infiltrate as much clean storm runoff as possible to maintain water tables and base flows.

Of the three general categories of SWM treatments – lot level control, conveyance facilities and downstream storage and outlet control – it is essential that all levels of government, environmental agencies plus the development community and the public maximize source controls as an important first-line and cost-effective upstream measure in the chain of more expensive downstream SWM conveyance and end-treatment facilities.

Many options are available to reduce the volume of storm runoff at the source and promote groundwater recharge for protection of the natural environment. These measures are generally suitable at the lot level where they may be relatively clean contaminant free runoff. This would include drainage from rooftops, foundation drains, and other impermeable surfaces; roads are excluded due to high suspended solids content which could plug such systems and the presence of other potential contaminants which could impair ground water quality.

Such possible mitigative measures could include reduced lot grading, directing roof leaders to ponding areas or soakaway pits, infiltration trenches, pervious pipes, grassed swales, vegetated filter strips, pervious catch basins and infiltration basins.

From an overview of the hydrogeologic conditions in the Mayhew watershed there appears to be significant potential for the use of lot level controls for infiltration of storm water. Confirmation will be required through geotechnical assessment of individual developments as they occur.

Impervious areas of residential development that include the street, driveway and front half of the house typically represent 30-35% of the subdivision area – storm runoff from these hardened surfaces must be conveyed to a SWM quantity control pond for peak reduction. For the remaining majority of landscaped and undeveloped areas, there is significant infiltration potential on an individual lot level control basis based on the predominance of sandy loam soils with good drainage characteristics and a typical water table depth of 1 to 10 metres across the growth area. Infiltration treatments should be a required integral part of development design.

Map 8.1 generally shows the watershed to be bound by ridges of well-drained coarse sandy soil with finer sandy loam type soil in between these ridges over the greater majority of the region. Infiltration-based storm water management measures should be considered in areas of suitable soil conditions. Infiltration is an important SWM element to consider - at the broad MDP level infiltration techniques should be integrated into the plan but should not be factored into the quantity control calculation. Detailed design level specific infiltration credit against SWM surface storage volume can be factored into the detailed design stage when accompanied by the appropriate geotechnical analyses.

For industrial development, an MOE Certificate of Approval will establish SWM requirements to be met. Roof storage of industrial developments will deal with initial abstraction.

Each pond must be designed to provide both quantity and quality control. Two detailed SWM calculation examples are included - Pond 204-C for industrial treatment in sub-catchment 204 & Pond 405-A for low density residential/ commercial treatment in sub-catchment 405.

11.2 Sub-Catchment Stormwater Management

The headwater sub-catchments located upstream (west and north) of the defined growth area are important primarily for calculating the pre-development Mayhew Creek mainstream and tributary flows entering the growth area, as described in Section 7. The 13 downstream sub-catchments within the growth area include all or parts of:

- 201 through 206;
- 301 & 302;
- 403 through 405; and

- 501 & 504.

Sub-catchments are numbered in the hydrology analysis from upstream to downstream along the mainstem and various branches of Mayhew Creek. For instance, per Map 1.1, sub-catchment 201 flows through 202, then 203, 204 and 205 in a downstream direction as branches of the 300, 400, & 500 series join in.

To provide assistance to designers and reviewers who will refer to this document, two sub-catchments, 204 and 405, are used as examples of how to apply the stormwater management recommendations contained herein.

The discussion of SWM strategies and treatments is completed below for each of the sub-catchments. These descriptions should be read in conjunction with the associated maps that are referenced by sub-catchment number and located at the back of the report.

Sub-Catchment 201

The east part of sub-catchment 201 is within the defined growth area, with the majority of the land north of Telephone Road designated for primary industrial land use. A large strip of this area is already developed north of Telephone Road, with significant future industrial growth designated south-east of the Telephone road & Fraser Road intersection and in a 180m wide strip north of Telephone Road and immediately west of the existing industrial development. All of this industrial development requires both SWM quantity and quality control, with optimum use of infiltration techniques to direct controlled flat roof storage discharge into groundwater infiltration galleries.

A strip of low density residential growth designation exists along the east boundary of sub-catchment 201, behind (north of) a few existing large developed lots on the north side of Telephone Road – **SWM pond 201-A** is proposed on or immediately north of the existing large developed lot that is located on the north side of Telephone Road and west of the northerly extension of Tate Road. This pond would be designed to treat all future low density residential growth runoff from the east end of sub-catchment 201.

A large proposed industrial growth area in sub-catchment 201, located north of Mayhew Creek and west of the existing industrial area at the extreme west limit of the study growth area is disaggregated on Map 11.1 into four drainages for pond siting - two located north of Telephone Road and separated by a small tributary and two located south of Telephone Road and separated by another small tributary stream. These four sites designated **SWM ponds 201-B, -C, -D, & -E** can control the large majority of storm runoff from the industrial area for SWM control and release.

The soils of this sub-catchment are mainly comprised of sand with minor silt of good natural drainage characteristics. A small deposit of peat is also found here and would not represent an area of good drainage. The average water table depth is 4.5 metres which in combination with good soil drainage may present suitable conditions for infiltration.

This sub-catchment also contains a large, mature, mixed wood forest south of Telephone Road. Field data collected during the field season of 2008 indicates that the northern tributary has a cold water base flow, while the southern tributary was dry. The fish species collected in the northern tributary indicated warm water conditions, however these species may have migrated upstream from the nearby marshes located downstream of the sample site. Due to the ecological connection between the forest and the watercourses (nutrient flow, groundwater base flow, stream bank shading, erosion resistance, in-stream structure, etc.), consideration should be given to retaining the existing forest or replanting equivalent cover.

Sub-Catchment 202

The designated growth area of sub-catchment 202 straddles the marsh headwaters of Mayhew Creek above Tremur Lake. All of the designated growth is industrial and most of this area is located within the mixed wood forest and immediately adjacent to Mayhew Creek and the riparian marshes.

Two SWM sites, **SWM ponds 202-A & 202-B,** are identified on Map 11.1 for industrial treatment nodes.

The soils in this catchment are comprised of sand with minor silt and an average water table depth of 7.7 metres. However, the portion of the catchment within the planning area is expected to exhibit a water table at less depth.

This sub-catchment contains a large, mature, mixed wood forest south of Telephone Road, the main channel of Mayhew Creek and associated riparian marshes. Field data collected during the field season of 2008 indicates that the upstream of Fraser Road, the creek has a cold water base flow; while sampling just above Tate Road indicated warm water temperatures and warm water fisheries. The cold upstream water is likely warmed by the exposure to direct sunlight (riparian cover of the main channel is marsh vegetation), and slowed water flows caused by the impoundment found just above Tate Road. Due to the ecological connection between the forest and the watercourses (nutrient flow, groundwater base flow, stream bank shading, erosion resistance, in-stream structure, etc.), consideration should be given to retaining the existing forest cover and increasing as part of the development process.

Sub-Catchment 203

Sub-catchment 203 is a complex network of tributary streams sourcing at the east-bound Highway 401 service center at km 420 and flowing south-east across Helyer Road and Telephone Road to discharge into Tremur Lake at the Morning Star Road allowance.

The soils of sub-catchment 203 are again mainly sand with minor silt of good natural drainage. The average water table depth is in the order of 6.7 metres indicating good potential for infiltration.

The headwaters areas are designated existing and future industrial growth, as northerly extensions of the sub-catchment 201 industrial strips. A pocket of Black Oak Woodland has been indentified within the Murray Hills Significant Natural Area directly south of the Highway 401.

Given the rarity of this plant community in Ontario, measures are required to preserve the natural features of this land when the designated industrial development proceeds.

East of the existing industrial development designation, downstream along sub-catchment 203 and split east-to-west by Helyer Road is at about 80 ha one of the two largest contiguous areas of future low density residential development land in the entire Quinte West growth area and significant SWM planning is required (the other combines three areas of sub-catchments 205, 206 &501 at the south-east part of the study area).

There are three tracts of forest identified in the low density residential growth area of sub-catchment 203 - one is in the upstream area and two are in the central area, one on each side of Helyer Road. The largest tract of forest cover is associated with the west side of the large drumlin at the extreme east boundary of sub-catchment 203. This forest block would be an excellent open space block, inclusive of the large forested east side of the drumlin and wetland to the south.

At the downstream end of sub-catchment 203, north of Telephone Road, there is a marsh area both sides of Helyer Road. Field sampling collected warm water tolerant fish species in the marshes which line the tributary, however base flow and temperature monitoring indicated a cool water regime.

Low density residential development in sub-catchment 203 will require several strategically located SWM treatments to not interfere with the branched on-stream flow system. Three proposed SWM pond locations, with **SWM ponds 203-A & 203-B** in the lower reaches plus **SWM pond 203-C** half-way up the development footprint, would enable capture of most of the development runoff; this, in conjunction with other SWM infiltration and other lot level controls, will meet the development, biological and groundwater preservation needs in sub-catchment 203.

Example Sub-Catchment 204 – Industrial SWM

Sub-catchment 204 straddles Mayhew Creek from the intersection of Telephone Road & Tate Road in the west and encompassing the old Trenton water supply pond east to Wooler Road.

The majority of developable residential parcels along the north part, against Telephone Road, are small and isolated and individual lot level SWM treatments are required.

Three centralized SWM facilities should be implemented for the two large blocks of proposed industrial land totaling about 80 ha south of Mayhew Creek in sub-catchment 204 – **SWM ponds 204-A & -B** between Tate and Morning star Roads and the third **SWM pond 204-C** just west of Wooler Road. The small industrial growth area to the north of Mayhew Creek will need individual treatment.

This sub-catchment exhibits mainly sand with minor silt however the southern edge of the watershed boundary is comprised of sand and gravel of very good drainage. The average water table depth is in the order of 5.1 metres and there is good potential for the use of infiltration practices.

This sub-catchment contains mixed forest and a portion of the marsh lining Tremur Lake, which are owned by the Municipality. The tributary flowing into Tremur Lake from the west was dry during the field sampling season. Due to the ecological connection between upland areas and the main channel of Mayhew Creek, the dry tributary should be protected and restored at the time of industrial development.

EXAMPLE 204 OVERVIEW

Sub-catchment 204 has the potential to have at least one large municipal facility installed for stormwater management. Map 7.2 displays sub-catchment 204 and the proposed location of a pond. Preliminary estimates suggest that the pond could service an area equal to 42 hectares. The proposed development under the official plan shows that 82% of the area would be developed as industrial and the remainder would be not zoned or used for open space. It was determined that some of the non-industrial lands (Areas 2 and 3 on Map 7.2 could be feasibly conveyed to a central facility that would be constructed in Area 1. The facility was sized to receive all of Areas 1, 2, and 3.

Using the methodology above the existing conditions and post-development flows and the pond storage volume can be calculated.

Calculate Existing Conditions Peak Flow

1. Sub-catchment number is 204.
2. From Table 7.10, $\left(\frac{Q_p}{A}\right)$ for sub-catchment 204 is 0.0025 $m^3/s/ha$.
3. $A_d = 42$ ha.
4. $Q_{ppre} = 0.0025(42) = \mathbf{0.105}$ m^3/s.

Post-development Hydrograph

1. For this example, it is assumed that industrial areas are 80% impervious and that open space/no zoning areas are unchanged. The impervious area was calculated as:
   $A_{imp} = (42x0.82x0.8) + (42x0.18x0) = 27.6$ ha
   IMP = 27.6/42 = 66%
2. Since IMP > 30 go to Step 4.
3. Skip this step.
4. From Table 7.4 $CN_{pre} = 68$; therefore $CN_{post} = 68$.
5. From Map 7.2 the approximate flow length (L) is 717 m with a slope (S) of 0.028 (m/m); there is not a large damping expected for wetlands AF = 0. Using the following equation

$t_{cpre} = (AF)0.000326\left(\frac{L}{\sqrt{S}}\right)^{0.79}$ = 0.24 h. Based on the amount of impervious area the t_{cpost} was calculated as $t_{cpost} = t_{cpre}(-0.006A_{imp}+1) = 0.15$ h.

6. Clark's R was calculated as $R = 1.5t_{cpost} = 1.5 \times 0.15 = 0.22$ h.
7. The above input parameters were entered into HEC-HMS using the design rainfall described in Chapter 7. The following post-development hydrograph (Figure 11.1) was produced with a peak flow of 1.54 m^3/s.

Estimate Pond Storage Volume

1. Figure 11.1 shows an orange line being drawn from the beginning of runoff to the existing conditions peak flow on the recession limb of the post-development hydrograph then down to zero. The area under the orange curve is approximately 2,350 $m^3 = V_{out}$.
2. The area under the inflow curve to the existing conditions peak flow on the recession limb in Figure 11.3 was calculated as approximately 23,000 $m^3 = V_{in}$.
3. The approximate required storage volume is then 23,000 – 2,350 = 20,650 m^3.
4. Generally speaking, the approximation obtained in 3. underestimates the required storage. As a rule of the thumb the underestimation is on the order of 5 – 10 %. For this example the storage was increased by 7% (new estimated storage is approximately 22,000 m^3).

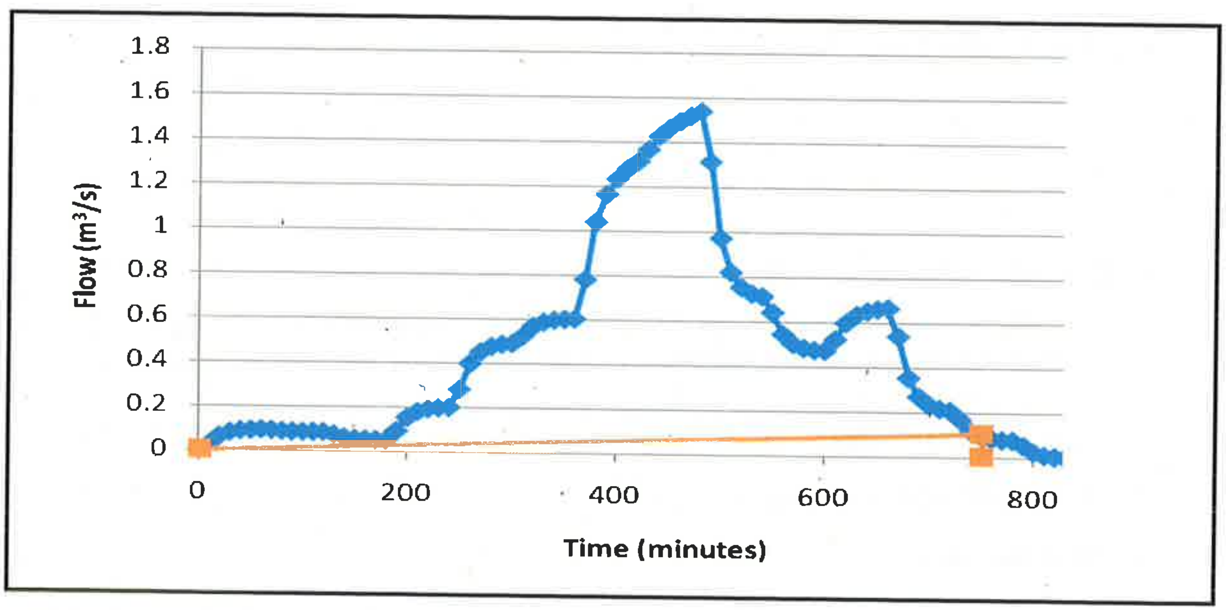

Figure 11.1 Post-development Hydrograph and Example of Storage Calculation

Design Pond Outlet Characteristics

For ease of this example, the side slopes on the pond are assumed to be vertical. If it is assumed that the water quantity storage is not to exceed 1 m, then the surface area of the pond would be 22,000 m^2. As the minimum required outflow is small, a regular broad-crested weir is inappropriate. For this application the pond will be drained by a 200 mm orifice. Using the orifice equation with a coefficient of 0.62 the following stage-storage-discharge table is made (see Table 11.1). Note: A weir would need to be installed to convey flows greater than those generated by the 100-year storm.

Table 11.1 Stage-Storage-Discharge Relation

Stage (m)	Storage (1000 m^3)	Discharge (m^3/s)
0	0.0	0.000
0.25	5.5	0.043
0.5	11.0	0.061
0.75	16.5	0.075
1	22.0	0.086
1.25	27.5	0.096

When the post development hydrograph was routed through this pond, it was found that the resultant peak flow did not exceed the existing conditions peak flow of 0.105 m^3/s (see Figure 11.2).
Note that the final pond design must also satisfy MOE water quality criteria. In some cases, meeting the minimum detention criteria will require an increase in pond area.

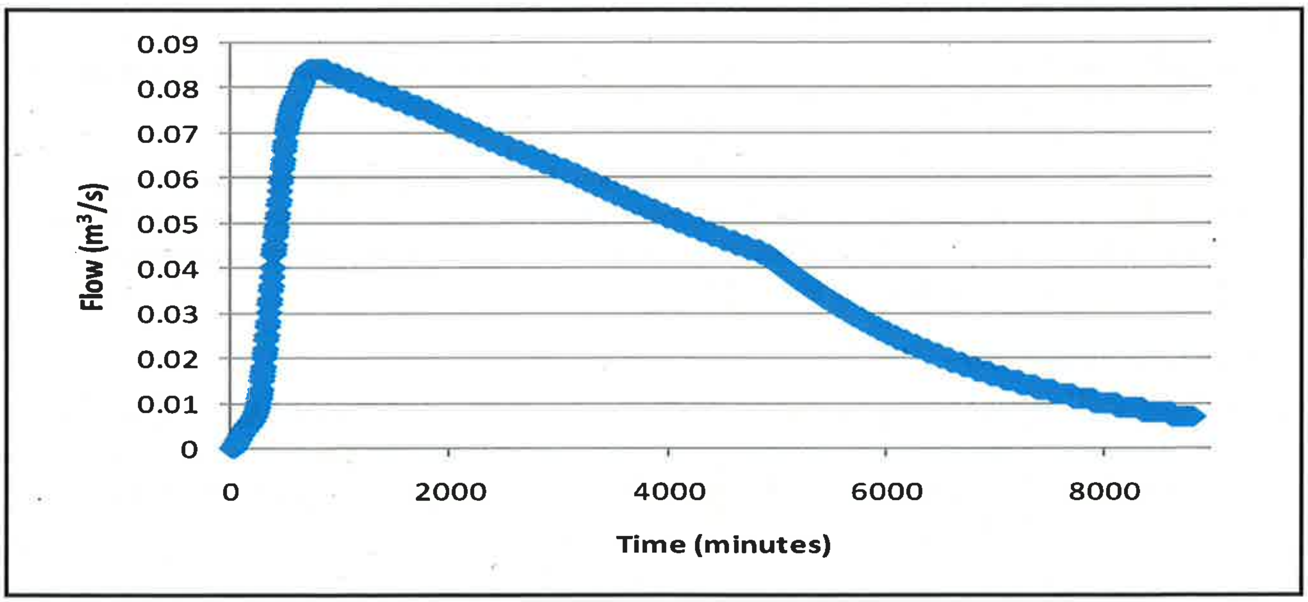

Figure 11.2 Post-development Hydrograph with Control

As a final check, the storage per impervious hectare is 22,000/27.6 = 797 m^3/ha. This value exceeds the average value for the sub-catchment 204 (616 m^3/ha) and hence, no further increase is required.

Sub-Catchment 205

Sub-catchment 205 is an area of about 26 ha of designated low density residential development located east of Wooler Road, south of Fox Pond, north of the CNR and about 400m wide from west to east. Given the north-easterly slope of this area, the north-east corner near Tremur Lake is a natural location for pond **SWM-205A**.

This sub-catchment is comprised of mainly sand with minor silt. The water table is shallow with an average depth of 2.8 metres which may present a restriction for infiltration capacity.

The sub-catchment contains a large second growth forest block, forest plantation, and marshes associated with Tremur Lake. Due to the ecological connection between upland areas and the main channel of Mayhew Creek, as much forest cover should be retained as possible. In addition, the natural buffer between the Tremur Lake marshes and future development should be restored at the time of development.

Sub-Catchment 206 (see 501)

A contiguous low density residential designation of about 18ha is proposed straddling sub-catchments 206 & 501. The low boundary between the sub-catchments allows the development of a single pond location as is discussed under pond **SWM pond 501-A** in sub-catchment 501, just west of 2nd Dug hill Road, to service development from both areas. Easterly controlled SWM release could be either north via the 2nd Dug Hill west road ditch or by cross-culvert directly east to Mayhew creek.

Sand with minor silt is the predominant soil type and the water table is shallow at an average of 3.7 metres, potentially restricting the use of infiltration.

Catchment 206 contains the main channel of Mayhew Creek, however the riparian area is already heavily developed thus there is little opportunity for restoration. Catchment 501 is also developed, however there is an existing deciduous swamp which should be protected from further development (see sub-catchment 501).

Sub-Catchment 301

Sub-catchment 301 located immediately south of Highway 401 and west of Wooler Road has some low density residential development and industrial/ commercial development proposed along it's south edge, against sub-catchments 203 & 302. The central and northern areas are mainly forested and wetlands.

The proposed residential development can be accommodated in **SWM pond 301-A** located east of Helyer road and upstream of the large on-stream wetland. Proposed industrial development will require individual SWM treatments to meet the water quality and local biological constraints.

The portion of this catchment within the planning area is underlain by sand with minor silt. The average water table depth is in the order of 10.2 metres, however it is anticipated that within the planning are that this depth would be more in the range of 1 to 5 metres.

A pocket of Black Oak Woodland has been indentified within the Murray Hills Significant Natural Area directly south of the Highway 401. Given the rarity of this plant community in Ontario, measures are required to preserve the natural features of this land when the designated development proceeds. In addition, the catchment contains a large forest and swamp complex, through which flow tributaries of Mayhew Creek. Fish collections during the field season indicated a cool water regime within the each of tributaries.

The portion of this catchment within the planning area is underlain by sand with minor silt. The average water table depth is in the order of 10.2 metres, however it is anticipated that within the planning area that this depth would be more in the range of 1 to 5 metres.

Sub-Catchment 302

Sub-catchment 302 is located west of Wooler Road and north of Telephone Road. A couple of low density residential growth areas are located at the west end with commercial areas west from Wooler Road.

The sand with minor silt soil type is predominant in this area with an average water table depth of 7.34 metres, suggesting good potential for infiltration.

Much of the sub-catchment is covered in forest and two large wetlands. A large drumlin in the west-center will make the proposed residential development problematic for SWM. As mentioned in the sub-catchment area 203 description, this drumlin would be a prospective excellent open space block implemented in accordance with the City of Quinte West Parks Masterplan, July 2007. This includes the large forested east side of the drumlin and wetland to the south. Field sampling collected cool water base flow and cool water fish species in the tributary which traverses the catchment.

Two SWM pond locations **SWM ponds 302-A & -B** are identified to treat the residential development blocks. **SWM pond 302-C** is situated to capture much of the runoff from the south-east side of the large drumlin feature identified for commercial development

There is potential to add a fourth pond location **(SWM pond 302-D)** on sub-catchment 302 on the east side of the elongated wetland to treat potential commercial development near County Road 40; proximity to the wetland will require that environmental approval agencies can be satisfied with the design and possible mitigation requirements.

Lot level controls will be needed to control remaining development in this sub-catchment.

Sub-Catchments 403 & 404

Sub-catchment 403, running south from Highway 401 just east of the Wooler Road interchange and west of Orchard Lane for about 500 metres, is proposed for industrial/ commercial and residential development.

The soils of this sub-catchment include sand with minor silt as well as a silty sand till. The average water table depth is deep at 14.6 metres. Sub-catchment 403 was not accessible for baseflow and fisheries measurements, however, 402 just upstream was flowing. Sub-catchment 404 was dry.

The 400 series sub-catchments are of specific interest for coldwater fisheries protection as this branch does not have a barrier to fish migration. Development along the stream channel should have a high regard for protection of the water quality and temperature. The marshes which line the tributary should be protected from development and the restoration of the riparian buffer should be considered at the time of development.

A common **SWM pond 403-A** should be developed west of the lower end of the stream, just out of the wetland boundary. Residential development east of the stream in sub-catchment 403 can be controlled along with the adjacent residential part of sub-catchment 404, west of Orchard Lane, at **SWM pond 403-B** at the 403/ 404 sub-catchment boundary.

Example Sub-Catchment 405 – Low Density Residential/ Commercial SWM

Sub-catchment 405 is chosen as an example per the Section 7 analytical procedure of how the hydrological analysis is applied to the pre- and post-development condition and how preliminary SWM analysis is applied to siting and sizing pond facilities.

Sub-catchment 405 is bounded on the west by County Road 40 (Wooler Road) and Webb Road and on the south by Telephone Road. Orchard Lane bisects the sub-catchment north to south. The south-east boundary traverses south of the draft plan approved Smits subdivision, traversing a large drumlin and remaining north of the existing subdivision centered along Crestview Lane. The north sub-catchment 405 perimeter bisects the Smits subdivision and runs west to Wooler Road. Collectively, all of the land within sub-catchment 405 is within the Barry Heights Sub-division area.

East of Orchard Lane the 187 lot Smits development has received draft plan approval, with two SWM ponds located immediately east of Orchard Lane controlling outflow to Tributary 4. Other than a couple of infill lot development sites located on Applecrest Lane, a cul-de-sac running north from Telephone Road and abutting the south end of the Smits development, there is no additional future sub-catchment 405 development located east of Orchard Lane requiring SWM - these few individual infill development lots require to be controlled for SWM at the individual lot level via infiltration treatments for roof and foundation discharge, etc.

Tributary 4 flows south towards Telephone Road, paralleling and about 50 – 75m to the west of Orchard Lane. Most of the individual lots along this strip on the west side of Orchard Lane and backing onto Tributary 4 are already developed and there is little opportunity for collective SWM treatment for the remainder. Therefore, these individual lots require to be controlled for SWM at the individual lot level via infiltration treatments for roof and foundation discharge, etc.

A large block of developable low density residential land exists west of Tributary 4 and north of Webb Road. It is proposed per Maps 7.3 & 11.1 to develop an off-stream SWM pond facility called **SWM pond 405-A** immediately west of the lower reach of Tributary 4 approaching Telephone Road. This pond would capture and treat storm runoff from 9.4 ha of residential development lands prior to release to Mayhew Creek.

The soils found here are mainly sand with minor silt. However fluvial sand and gravel is also found near the water course. The average water table depth is in the order of 5.6 metres.

This sub-catchment is a productive coldwater fishery and development along the stream channel should have a high regard for protection of the water quality and temperature. The marshes which line the tributary should be protected from development and the restoration of the riparian buffer should be considered at the time of development.

EXAMPLE 405 OVERVIEW

Sub-catchment 405 has the potential to have at least one large municipal facility installed for stormwater management. Map 7.3 displays sub-catchment 405 and the proposed location of a pond. Preliminary estimates suggest that the pond could service an area equal to 9.4 hectares. The proposed development under the official plan shows that 83% of the area would be developed as low density residential and the remainder would be for industrial/commercial use. Using the methodology above, the existing conditions and post development flows and the pond storage volume can be calculated.

Calculate Existing Conditions Peak Flow

1. Sub-catchment number is 405.
2. From Table 7.10, $\left(\frac{Q_p}{A}\right)$ for sub-catchment 405 is 0.0055 $m^3/s/ha$.
3. A_d = 9.4 ha.
4. Q_{ppre} = (0.055)(9.4) = 0.052 m^3/s.

Post-development Hydrograph

1. For this example, it is assumed that residential areas are 50% impervious and that commercial/industrial areas are 80% impervious. The impervious area was calculated as:

   A_{imp} = (9.4x0.83x0.5) + (9.4x0.17x0.8) = 5.17 ha

   $$IMP = \frac{5.17}{9.4} \times 100 = 55\%$$

2. Since IMP > 30 go to Step 4.

3. Skip this step.
4. From Table 7.4 CN_{pre} = 60; therefore CN_{post} = 60.
5. From Map 7.2 the approximate flow length (L) is 424 m with a slope (S) of 0.028 (m/m); there are no swamps/ponds in this area so AF = 0. Using the following equation $t_{cpre} = (AF)0.000326\left(\frac{L}{\sqrt{S}}\right)^{0.79}$ = 0.16 h. Based on the amount of impervious area the t_{cpost} was calculated as $t_{cpost} = t_{cpre}(-0.006A_{imp} + 1)$ = 0.11 h.
6. Clark's R was calculated as R = $1.5t_{cpost}$ = 0.15 x 0.11 = 0.16 h.
7. The above input parameters were entered into HEC-HMS using the design rainfall described in Chapter 7. The following post-development hydrograph (Figure 11.3) was produced with a peak flow of 0.28 m^3/s.

Estimate Pond Storage Volume

1. Figure 11.3 shows an orange line being drawn from the beginning of runoff to the existing conditions peak flow on the recession limb of the post-development hydrograph then down to zero. The area under the orange curve is approximately 1,050 $m^3 = V_{out}$.
2. The area under the inflow curve to the existing conditions peak flow on the recession limb in Figure 11.3 was calculated as approximately 4,100 $m^3 = V_{in}$.
3. The approximate required storage volume is then 4,100 – 1,050 = 3,050 m^3.
4. Generally speaking, the approximation obtained in 3. underestimates the required storage. As a rule of the thumb the underestimation is on the order of 5 – 10 %. For this example the storage was increased 7% (new estimated storage is approximately 3250 m^3).

Design Pond Outlet Characteristics

For ease of this example the side slopes on the pond are assumed to be vertical. If it assumed that the water quantity storage is not to exceed 1 m, then the surface area of the pond would be 3,250 m^2. As the minimum required outflow is small, a regular broad-crested weir is inappropriate. For this application the pond will be drained by a 150 mm orifice (the minimum recommended). Using the orifice equation with a coefficient of 0.62 the following stage-storage-discharge table is made (see Table 11.2). Note: A weir would need to be installed to convey flows greater than those generated by the 100-year storm.

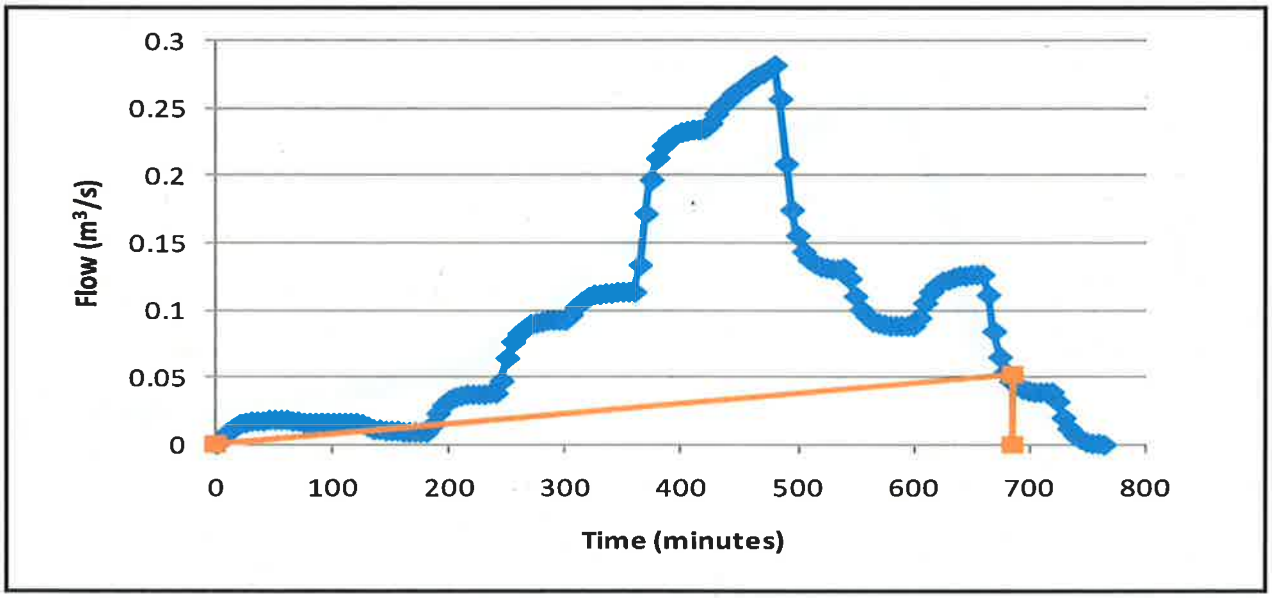

Figure 11.3 Post-development Hydrograph and Example of Storage Calculation

Table 11.2 Stage-Storage-Discharge Relation For Example Pond 405

Stage (m)	Storage (1000 m^3)	Discharge (m^3/s)
0	0.0	0.000
0.25	0.8	0.024
0.50	1.6	0.034
0.75	2.4	0.042
1.00	3.3	0.049
1.25	4.1	0.054

When the post development hydrograph was routed through this pond, it was found that the resultant peak flow did not exceed the existing conditions peak flow of 0.052 m^3/s (see Figure 11.4).

Note that the final pond design must also satisfy MOE water quality criteria. In some cases, meeting the minimum detention criteria will require an increase in pond area.

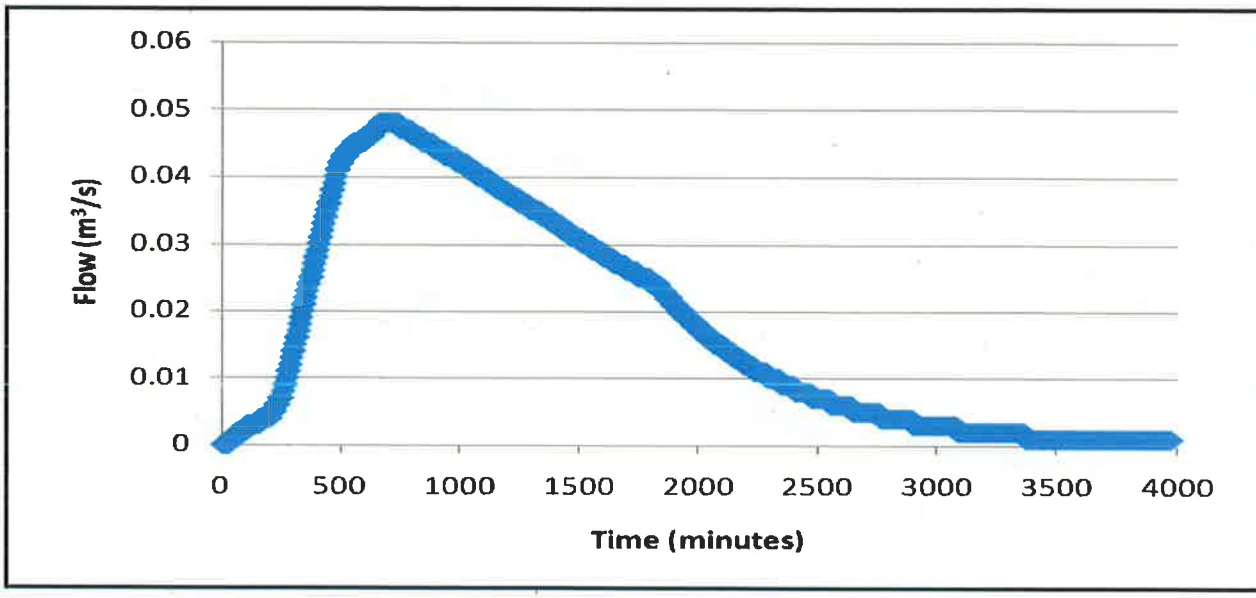

Figure 11.4 Post-development Hydrograph with Control

As a final check, the storage per impervious hectare is 3,250/5.17 = 629 m^3/ha. This value exceeds the average value for the sub-catchment 405 (621 m^3/ha) and hence, no further increase is required.

Sub-Catchment 501

Two prospective residential/ commercial SWM pond locations are identified in sub-catchment 501 near the mouth of Mayhew Creek. Drainage area includes the triangle of land bounded by 2nd Dug Hill Road, Telephone Road and the railway to the south, plus some additional drainage from the west and north.

Pond **SWM-501A** was identified in the discussion of adjacent sub-catchment 206. A small infill residential growth area on the west side of Harcourt Road and north of Telephone Road. Another small adjacent area on the east side of Harcourt, can be treated at pond **SWM-501B** on the west side of Harcourt.

Although catchment 501 is heavily developed, there is an existing deciduous swamp which should be protected from further development.

Sub-Catchment 504

Sub-catchment 504 is located at the south-east corner of Highway 401 and Harcourt Road. The proposed small (~5 ha) industrial area can be serviced by a **SWM pond 504-A** located in a small existing wet spot on the intermittent stream.

A second small residential growth block south of Hillcrest Drive can be controlled at **SWM pond 504-B**.

This sub-catchment exhibits mainly sand with minor silt and the average water table depth is in the order of 4.6 metres.

Sub-catchment 504 contains three isolated pockets of forest cover, and one larger forest block which connects a marsh complex with a riparian corridor lining the tributary. As much of the larger forest block should be retained as possible.

12. Implementation

The ultimate goal of the Master Drainage Plan (MDP) is to identify and implement stormwater management (SWM) policies, strategies, guidelines and treatments that will improve stormwater quality entering the Bay of Quinte. SWM must not only reduce water quality loading from future development but also maintain pre-development flow conditions along the system in recognition of fish passage and habitat requirements, hydraulic obstructions, downstream flooding and erosion concerns.

The report defines the general SWM guidelines and approach, with ultimate responsibility on the development community to define the appropriate blend of SWM measures, to secure pond locations and to develop designs.

Following the general SWM principles established by the Ontario Ministry of Environment in their 2003 *Stormwater Planning Management Planning and Design Manual* plus guidelines defined in this MDP report, developers are responsible at draft plan stage to undertake sufficient SWM analysis to review and compare SWM alternatives, define the feasibility of their preferred option and submit a SWM report to support their draft plan application.

Once draft plan conditions are formalized by the City, in consultation with the Conservation Authority, the developer must complete a final SWM design supported with related detailed technical studies (ie. geotechnical, ecological, floodline) as may be required to clear draft plan conditions and achieve SWM approval for their development to proceed.

Information provided in the first 11 sections of the report, along with the support maps and appendices, establish the watershed setting from a physiographical, natural and ecological resources, land use and urban growth, hydrological, water quality, groundwater and general stormwater management perspective. This forms the baseline for defining existing environmental features and protection requirements and establishing SWM requirements on a sub-catchment basis to accommodate future growth.

The MDP report develops the theoretical 'perfect scenario' with pond sizing and location rules-of-thumb developed on a storm runoff basis using the HEC-HMS hydrologic model, high resolution contour mapping developed from laser-controlled LiDAR helicopter photography, 3-D Analyst software used to create stream cross-sections from the detailed mapping and definition of stage-storage outflow relationships for potential SWM pond locations. Example quantity control calculations illustrate the SWM flow/unit area pond sizing methodology to be applied on a sub-catchment basis.

SWM quality control design cannot be dealt with in detail at the Master Drainage Plan level - instead, it is allowed for by adding a safety factor volume of 200 m^3/ha [calculated by using a 400 m^3/ha value for an impervious area / 0.8 = 500 m^3/ha, due to the area not flowing through the pond]. With this simple storage volume per area allocation method, the total volume of necessary cubic metres of storage for water quality control per sub-catchment will be committed now. This total volume will be allocated over time as development occurs thereby reducing the remaining residual sub-catchment volume towards zero as sub-catchment development approaches full capacity.

12.1 City Implementation Requirements

Recommendation 1 - The City will adopt this MDP report as a companion document to the Official Plan, to provide SWM and other water resources engineering and planning guidance to ongoing City planning and development review.

Recommendation 2 - The City will work to define and conduct the appropriate public/ landowner/ stakeholder SWM information and education process, with Mayhew Creek MDP team support and input. This will emphasize the use and maintenance of lot level controls.

Recommendation 3 - The City, in conjunction with the Conservation Authority, should explore incentives and support for developers and private landowners to increase the use of lot level controls (ie roof runoff rail barrel subsidies, assistance with infiltration education and treatment design).

Recommendation 4 - To deal with situations where a developer may be directed for reasons of topography or the property fabric to contribute payment towards a common off-site SWM treatment, the City will work with the Conservation Authority to develop an appropriate funding formula - a cost allocation method is preferred over a cash-in-lieu approach.

Recommendation 5 - The City will develop a SWM contribution formula with a level of contribution sufficient to build a reserve.

Recommendation 6 - The City will work with the Conservation Authority to estimate SWM capital costs and long-term maintenance costs and to establish a cost apportionment schedule.

Recommendation 7 - The City should require a minimum 2-year maintenance holdback from developers to ensure the final pond meets functional requirements.

Recommendation 8 - The City requires submission of a minimum 20-year maintenance cycle by the developer, including sufficient funding commitment from the developer to do periodic monitoring and carry out maintenance work. This requires a sediment build-up calculation to be developed, including a built-in safety factor. This will be determined in conjunction with the Conservation Authority.

Recommendation 9 - Using this MDP report as a starting point, the City may want to undertake a study to analyze and prioritize potential sites by cost, SWM effectiveness, potential growth sequencing, etc.

Recommendation 10 - The total growth area approach may require that the City needs to consider staging of certain SWM treatment ponds, depending on the projected speed of growth.

Recommendation 11 - The City needs to adopt an ongoing review mechanism to amend pond locations as growth develops.

Recommendation 12 - The City should implement a 30-metre Environmental Protection buffer along main channels and all tributaries within the Urban Growth Area as part of the development review process.

Recommendation 13 - To ensure that development is environmentally sensitive within Planning District 12, primarily the tributaries of Mayhew Creek and Tremur Lake, the City should require new development and/or re-development to provide environmental studies where deemed necessary to identify impacts and offer mitigation measures to protect the environmental features.

12.2 LTC Implementation Requirements

In 1984/85, flood control works were implemented in the lower reaches of Mayhew Creek to divert a portion of the Timmins flood event from the main channel. Whereas the scope of this MDP study does not include floodplain analysis or expanding the existing floodline mapping base, this information can have a bearing on the siting of development and associated SWM facilities. Additional updated floodplain limits definition is needed.

Recommendation 14 - Lower Trent Conservation, working in cooperation with the City, should plan and budget to update the quarter-century old lower Mayhew Creek floodplain analysis.

Recommendation 15 - The LTC should continue the fisheries monitoring process undertaken for the MDP to update the last survey done in the 1970's.

Recommendation 16 - In order to defend buffer criteria, LTC with City input should budget to implement an ecological monitoring strategy to establish a multi-year ecological data set, utilizing the Ontario Stream Assessment Protocol and including benthic, surface water quality grab samples, and electrofishing of all the channels within the urban growth area

Recommendation 17 - LTC in conjunction with the Ministry of Natural Resources should utilize the Provincial Wetland Evaluation Methodology to investigate the significance of the wetland complex found above and below Tremur Lake and other wetlands in the Mayhew Creek growth area.

Recommendation 18 - Above and beyond its normal monitoring and ecological planning responsibilities and development review input, Lower Trent Conservation should take the lead in maintaining, running and updating the HEC-HMS model in the future.

Recommendation 19 - Depending on the proposed scope of development and complexity of required SWM analysis, the LTC will confer with the City and decide if and to what extent a developer may be required to assess more than one design storm and associated multiple durations and curve shapes (Chicago, SCS, etc).

Recommendation 20 - The LTC should undertake herptofauna surveys to establish important habitat locations relative to potential SWM sites.

Recommendation 21- The LTC in conjunction with the City of Quinte West should define a natural heritage system for Mayhew Creek based on the Natural Heritage Strategies and further Ecological Land Classification surveys. This system should be used in conjunction with the MDP to ensure that the location and design of proposed SWP does not impair the connectivity and function of the natural features and functions in the Mayhew Creek subwatershed.

12.3 Developer Implementation Requirements

Developers, in consultation with the Conservation Authority and Municipality, must consider many key factors as listed in Section 12.1 to determine what specific SWM treatment or combination of treatments is most appropriate for various areas within each sub-catchment.

Developers are responsible to follow the SWM guidelines in this MDP report as approved in accordance with accepted MOE stormwater management planning and design in preparing SWM submissions and designs to accompany development applications to the City of Quinte West and Lower Trent Conservation. In recognition of the many SWM design criteria itemized in Section 12.2.2, the Developer must:

- satisfy quality storage requirements,
- meet the design guidelines of the Ministry of the Environment,
- ensure that the post-development peak flows do not exceed existing conditions peak flows under specified design storm conditions, and
- ensure that the design value of quantity storage per impervious hectare equals or exceeds the value given in Table 7.10.

Full examples of calculating existing conditions and post-development peak flows, estimating storage and outlet structure sizing are provided in Section 11 for sub-catchments 204 and 405.

Developers must analyse four watershed conditions - existing (2008) conditions, post-development conditions, post-development conditions with stormwater management measures in place and the large rainfall event that occurred over eastern Ontario on September 9, 2004 – and provide options for review of the City and Conservation Authority (see Section 7).

Peak flows developed by the HEC-HMS model at the outlet of each sub-catchment and at selected junctions should be considered benchmarks against which flows for post-development conditions are compared.

Developers must ultimately be charged for procuring SWM sites, be responsible for designing and developing the approved treatment facilities and for ongoing maintenance and performance monitoring cost until facilities are assumed by the City.

Developers are required to discuss SWM options in general with the City and Conservation Authority prior to undertaking detailed analysis, modeling (if necessary) and design.

Submission of as-built drawings and sign-off of the completed SWM works by a qualified Water Resources Engineer are an integral part of the process to ensure that the approved SWM treatment is constructed and performing according to plan and are required prior to the release of associated performance securities.

The residential and commercial SWM ponds have different design requirements than industrial SWM ponds; industrial ponds will need extra information to satisfy MOE & possible MISA requirements.

Recommendation 22 - Developers must apply Level 1 stormwater management criteria to all new development.

Recommendation 23 - Developers are responsible for the design of SWM facilities and ensuring the proposed development does not produce peak flows exceeding the benchmark flows at the nodes shown in Table 7.7.

Recommendation 24 - Developers must base their SWM pond designs on off-line ponds. In exceptional circumstances, where the developer can prove no negative ecological, fisheries or hydraulic impact (ie flooding or application of the HEC-HMS model to show no superimposition of downstream peaks that could worsen existing split-peak conditions), on-stream ponds may be considered.

Recommendation 25 - The developer will be required to pay for TSS water quality sampling for a two-year post-development SWM construction period to ensure the facility is functioning within design parameters and if not, undertake appropriate re-design and reconstruction and pay for all associated costs.

Recommendation 26 - Industrial developments will require the installation of oil/grit separator technology (ie Stormceptor) systems for SWM quality control unless they can specifically illustrate viable alternatives.

Recommendation 27 - Developers in the Webb-Telephone-Wooler Roads triangle need to work with the City to determine the need for an oil/grit separator versus alternative quality control ponds or other treatments to enable growth in this area.

Recommendation 28 - Developers SWM analyses will be required to demonstrate no downstream conveyance constraints below prospective SWM ponds, focusing specifically on designs that minimize the warming of receiving water and associated negative impacts to aquatic life.

Recommendation 29 - Until such time as historical floodplain analyses are updated, the LTC and City may require developers to undertake their own local floodplain analysis associated with their proposed developments.

Recommendation 30 - Geotechnical analysis and evaluation of infiltration potential by the developer is a required condition of all draft plan approvals for future development, with infiltration measures maximized and implemented as part of the SWM plan insofaras feasible.

Recommendation 31 - Developers should optimize the use of lot level controls and may receive SWM credit for integrating lot level controls into their SWM plans.

Recommendation 32 - It is proposed that rear yard swales be considered as a form of temporary storage and conveyance, depending on soils and water table information plus other factors relating to topography and proposed over-all subdivision SWM design.

Other practical lot level controls include foundation drains, capturing roof runoff in cisterns or barrels, reduced lot grading, directing roof leaders to ponding areas, directing roof leaders to soak away pits, infiltration trenches, pervious pipes, vegetated filter strips, pervious catch basins and infiltration basins.

Recommendation 33 - Facility designs must contain a landscape plan showing a planting strategy using native species that will promote shading and reduce temperature effects.

Recommendation 34 - Cold water streams, seeps, intact forest cover, well vegetated riparian zones and wetlands should be identified at the application stage by the developer and protected accordingly.

References

CCCL/ Crysler Lathem. December, 1981. ***Mayhew Creek Flood Control Report.***

ECOS Garatech. 1994. ***Potter Creek Subwatershed Plan***. Report submitted to the Moira River Conservation Authority.

Gillespie, J.E., Wickland, R.E. and Richards, N.R. 1962. ***Soil Survey of Hastings County***. Canada Department of Agriculture and Ontario Agriculture College, Report No. 27 of the Ontario Soil Survey.

Klaassen, J. and Seifert, M. 2007. Extreme Rainfall in Ontario: ***The Summer 2004 Storms Study***, Meteorological Service of Canada, Environment Canada.

Lower Trent Conservation, November, 2000. ***Mayhew Creek State of the Watershed Report***.

Marsalek, J. 2001. ***Review of Stormwater Source Controls in Urban Drainage.*** In Advances in Urban Stormwater and Agricultural Runoff Source Controls. Kluwer Academic Publishers, London.

Marshall Macklin Monaghan. 2006. ***Master Drainage Plan and Stormwater Management Plan – Tributary 1 and 2 to Potter Creek.***

MOEE. 1994. ***Stormwater Management Planning Practices and Design Manual***. Ontario Ministry of Energy and Environment, Toronto.

MOE. 2003. ***Stormwater Management Planning and Design Manual***. Ontario Ministry of the Environment, Toronto.

QRAP. 1993. ***Bay of Quinte Remedial Action Plan Stage 2 Report.***

SCS. 1972. ***National Engineering Handbook***. Section 4 (Hydrology), Soil Conservation Service, U.S. Department of Agriculture, Washington, DC.

Watt, W.E. and Chow, K.C.A. 1985. A General Expression for Basin Lag Time. ***Canadian Journal of Civil Engineering***, 12(2), 294-300.

WEF ASCE. 1992. ***Design and Construction of Urban Stormwater Management Systems***. ASCE Manuals and Reports of Engineering Practice No. 77, WEF Manual of Practice FD-20, ASCE, New York, NY.

WEF ASCE. 1998. ***Urban Runoff Water Quality Management***. WEF Manual of Practice No. 23, ASCE Manual and Report on Engineering Practice No. 87, WEF, Alexandria, VA.