URBANTECH®

SUBWATERSHED STUDY
AND STORMWATER MASTER PLAN OVERVIEW REPORT

UPPER WEST SIDE SECONDARY PLAN

CITY OF HAMILTON

PREPARED FOR:
Upper West Side Landowners Group

Urbantech File No.: 17-556

NOVEMBER 2023

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BACKGROUND

In June 2011, the City of Hamilton published the Airport Employment Growth District (AEGD) Phase 2 Subwatershed Study and Stormwater Master Plan (prepared by Dillon Consulting and Aquafor Beech Limited). The Study Area encompasses multiple parcels and spans several watersheds and is generally bound by:

- Fiddler's Green Road to the west;
- White Chuch Road to the south;
- Upper James Street to the east; and,
- Twenty Road West to the north.

This study was preceded by a Phase 1 study, which dealt with land use planning / characterization of existing conditions and the overall planning framework.

Since the release of the 2011 AEGD SWS, there have been changes to the applicable environmental legislation, policies and guidelines as well as the City of Hamilton Urban boundary and intended land use . Consequently, an update to the AEGD SWS findings to reflect these changes and to support the updated Secondary Plan being submitted to Council.

This SWS update has been developed concurrently with updated infrastructure and planning studies, update to environmental feature evaluations and changes to the Natural Heritage System (NHS) based on:

- additional comprehensive field studies;
- analyses based on the current applicable legislation, policies and guidelines; and,
- work completed and submitted to the agencies to date regarding the proposed urban boundary expansion

This AEGD SWS update and the updated Secondary Plan also incorporate:

- revisions to the body of the 2011 AEGD SWS
- changes to the Land Use Plan

Only those sections of the 2011 AEGD SWS that required updating are included in this document. As such, this update must be read in conjunction with the original 2011 SWS document. To facilitate integration for the reader, different fonts are used for the original / unchanged text versus any additions, revisions, or replacements. The reader will be required to refer to the 2011 AEGD SWS to obtain the relevant information for those subsections, figures and tables that have not been revised. Furthermore, the scope of this update is limited to the lands bounded by:

- Glancaster Road to the west;
- Dickenson Road to the south;
- Upper James Street to the east; and,
- Twenty Road West to the north

These lands are part of the Twenty Mile Creek watershed and therefore no changes are proposed to any other watersheds described in the original June 2011 AEGD SWS. Refer to Figure 1 for details.

GENERAL

The Airport Employment Growth District (AEGD) encompasses approximately 2,800 hectares of land (excluding the Greenbelt) located in the west end of Glanbrook, extending between Garner Road / Twenty Road West in the north and Carluke Road East / White Church Road in the south, Fiddler's Green Road in the west and Upper James Street in the east. The first stage of development in the urban area expansion comprises 660 net hectares of land. The Airport Employment Growth District is guided by this Secondary Plan and has been designed to provide for a major business park development which effectively integrates with and complements the existing John C. Munro Hamilton International Airport, effectively integrates with the residential development abutting Garner Road / Twenty Road, recognizes and allows for certain existing land uses to continue until such time that they are redeveloped, as well as respects and enhances the prominent natural areas throughout the Secondary Plan area.

The Airport Employment Growth District is intended to offer a range of employment and employment-related land uses in the context of an eco-industrial park. In general, this eco-industrial park concept provides for prestige business park (PBP), airport related business (ARB), light industrial (IND) and airside industrial (AI) development which has an environmental footprint that is managed through a range of urban design and sustainable design techniques. It also allows for the land use and character of surrounding lands to be protected.

The Airport Employment Growth District provides the opportunity to create a new employment node which improves live-work ratios in the City and helps meet provincial employment targets. It supports the airport as important infrastructure and as an economic driver, supports long-term prosperity, and contributes to quality of life for Hamilton. Prestige business park uses are directed to the Secondary Plan's major transportation corridors where urban design approaches help support the transition between prestige business park uses and any nearby residential and agricultural/rural land uses. Light industrial uses are directed to interior lands where they can abut natural areas and prestige business park uses. Airside industrial uses, which require direct "airside" access to the airport, are located adjacent to the existing and future runway aprons of the John C. Munro Hamilton International Airport. Airport related businesses, which allow for businesses and services to travelers, are planned in close proximity to the airport. The plan protects natural features and provides for a limited range of employment-related commercial uses that serves employees of the Secondary Plan area. Fundamental to this entire process, was the commitment to the development and implementation of an eco-industrial park concept that would result in a state of the art industrial-commercial development.

Note that while the proposed land use continues to include employment lands within the white-belt area, the northerly half of the subject lands are now proposed to be residential as shown on the attached Secondary Plan.

The overall planning for the AEGD project includes the development of an overall land use plan and individual component infrastructure studies covering transportation, water and wastewater and stormwater management/natural heritage systems planning. In part, the end products of this planning exercise are a framework for the development of the AEGD lands through 2031 that is consistent with municipal and provincial policy and a set of planning documents and urban design guidelines that outline how development and associated infrastructure will be constructed to meet the growth objectives, while protecting human and natural environmental values. In addition, the master plans and capital elements of the infrastructure study components were developed to satisfy the requirements of the Municipal Class Environmental Assessment process for master plans. While the land use planning and infrastructure studies comprehensively address planning, development and environmental protection within the Study Area and are sensitive to the future needs of the Airport and its future land requirements, these lands are excluded from the Growth Management Study.

The Municipal Class Environmental Assessment process has been followed for all of the AEGD Infrastructure Master Plan Studies. The study has been carried out according to the guidelines set out in A.2.7 Master Plans of the Municipal Engineers Association (MEA) Class Environmental Assessment.

Approach #2 of the Master Planning process from the Municipal Engineers Association (MEA) document was used as a guide for the AEGD Infrastructure Plan Studies. This approach involves the preparation of a Master Plan document at the conclusion of Phase 1 and 2 of the Municipal Class EA process. The Master plan would provide the basis for the future investigations for the specific Schedule C project indentified within it. The coordinated EA Approach #2 is accompanied by master plans for transportation, water and wastewater, and stormwater management. The simultaneous preparation of these planning documents can reduce the social, environmental and economical impacts of the preferred alternatives, as land use is not yet finalized. This was a well-suited planning approach for the overall AEGD Study.

The use of Approach #2 for the preparation of the AEGD Infrastructure Master Plans provides a broad context for need and justification. The assessment within the master plan satisfies Phases 1 and 2 of the Class EA process for Schedule B projects.

Phase 1 of this process provided a description of the existing conditions associated with each of the component studies as well as outlining the current planning framework in which the AEGD project has been developed. Phase 1 studies are reported in two separate documents:

- Phase 1 Land Use Planning Report

- Phase 1 Infrastructure Component Report

These are stand alone documents that are not included as part of these Phase 2 studies.

PART A – PHASE 2 SUBWATERSHED STUDY

1.0 OVERVIEW / INTRODUCTION

This study is somewhat unique in terms of the planning process to come up with a recommended plan and infrastructure components. Where typically a Subwatershed Study would be prepared in advance of and separate from, the Growth Management Study or Secondary Planning Study, thus establishing the Natural Heritage system and stormwater/groundwater management framework within which the secondary plan would be developed (see Figure 1.0); in this case, the two studies have been completed in a fully integrated, yet iterative process, which has allowed for the concept of an eco-industrial park concept to be more fully explored, while at the same giving more consideration to subwatershed study components. This has also led to the development of a Stormwater Master Plan that is also more integrated between the environmental components of the subwatershed plan and the planning and infrastructure elements of the land use plan because of the need to utilize LID measures extensively in the overall plan.

This fully integrated and iterative approach also provides for greater opportunity for public involvement, a key component of this project and is fully consistent with an adaptive environmental management approach.

Part A of the following report outlines the remaining phases of the Subwatershed Study and Part B addresses the Stormwater Master Plan Study. The Subwatershed Study outlines the environmental master plan for the study area, while the Stormwater Master Plan follows the Class EA process and describes the process leading up to the preferred alternative. In addition, the Stormwater Master Plan identifies the environmental criteria that need to be addressed in order for development to proceed.

Key findings/recommendations from the Phase 1 studies are as follows:

Natural Heritage System – Terrestrial

The Study Area Contains a Significant Terrestrial Natural Heritage System to be Protected and Enhanced:

• 434 ha (1072 acres) of Significant Natural Heritage Core Area both within and outside the Greenbelt Natural Heritage System.

• The Greenbelt Natural Heritage System extends in a north/south finger beyond the Core Areas.

• In all areas of the Greenbelt Natural Heritage System, significant policy restrictions are in place both in the Greenbelt Plan and the Rural OP including requirements for an EIS for adjacent land.

• Approximately 6.5% of the study area is forest cover.

• 20 patches that are at least 4 ha with the largest being 27 ha. These will be protected as part of the Core Areas, while the remainder are identified as linkages.

• Consideration should be given to identifying, preserving and enhancing wildlife linkages as well as final confirmation of the core natural heritage features in the study area.

• Significant Natural Heritage System can Provide a Parkway Setting

Natural Heritage System – Aquatic

The Area Contains Some Sensitive Aquatic Features:

• The study area is part of the headwaters of four watersheds.

• The drainage features appear to be intermittent. However, there are several features that may provide seasonal fish habitat.

• A range of warmwater fish species are likely typically present.

• At this time, cold/cool and warm water streams (critical and important fish habitat), as well as some intermittent or marginal habitat features have been identified as aquatic constraints that require protection in the form of fisheries buffers/setbacks as development proceeds.

• Some of these features may be allowed to be altered in terms of their location, although they still would be maintained as natural features.

• All Drainage Features are Sensitive to Water Quality and Sediment Impacts

• Enhanced or level 1 stormwater treatment from a water quality/fish habitat perspective is required for all tributaries.

• Both the Welland and Twenty Mile Creeks in the study area and immediately downstream are nutrient rich, moderately contaminated by bacteria and have elevated chloride levels.

• Airport and agricultural operations contribute to the elevated levels. Airport operations also contribute to elevated levels of glycol and other deicing compounds on a seasonal basis.

Groundwater

• The entire study area falls within the Source Protection Areas of the Hamilton, Grand River and Niagara Peninsula Conservation Authorities. There are both Significant Groundwater Recharge Areas and High Groundwater Susceptibility Areas within the Study Area as a result of the presence of aquifers supporting domestic water supplies, hydrologic connections to surface waters used as water supplies and local transport pathways that increase the potential for aquifer contamination. Multiagency committees have been established to prepare Source Water Protection Plans to provide policy, regulation and guidelines for activities within Source Protection Areas.

• Groundwater infiltration is generally low to moderate as a result of the relatively impermeable soil conditions (extensive veneer of glaciolacustrine silt and clay - Hydrologic C soils) found within the study area.

• Achieving pre-development water balance conditions will be a challenge due to the low to moderate permeability of the soils, and will require the application of a novel approach

• Groundwater does not have a major role in sustaining natural features such as wetlands and drainage features

• The majority of drainage features are intermittent and lack a significant baseflow from groundwater discharge

Stormwater Management

The following are general recommendations with respect to stormwater management within the study area:

• Generally there needs to be an emphasis on "lot level" and conveyance control measures, consistent with the industrial character of the lands and a predisposition to maintain a rural road cross section in most areas, as the headwater drainage features in the study area are too shallow to provide outlets for conventional stormwater management facilities.

Replacement for above bullet:

Lot level and conveyance control measures are proposed for industrial land uses. Where possible, lot level measures will be implemented on private residential lots. As there will be a residential component to the plan for the scoped study area as well, the original AEGD study recommendations for a rural ROW section are no longer valid and a conventional major / minor storm drainage system will be required. The drainage features in the study area are not too shallow to provide useful outfalls – drainage will be directed to appropriate outfalls and portions of the site will be filled to provide cover over services.

• Due to the sensitivity of downstream areas to water quality impacts (fisheries, erosion susceptibility, ESA/wetland features, and Great Lakes Areas of Concern), all proposed development will require level 1 or enhanced stormwater treatment.

• Numerous headwater features exist within the study area and a preliminary mapping of features to be protected based on floodplain and fisheries requirements has been identified. A number of features have been classified as marginal fish habitat as they provide indirect or support habitat. Additional studies and site visits with Conservation Authority staff will be necessary to finalize whether these features require protection, or whether they may be replaced with components of the stormwater management system such as LID source and conveyance measures., consistent with replicating the flow conveyance/water quality attenuation functions of indirect habitat. It is important to note that most features, except those currently identified as warm or cool water streams (or important/critical fish habitat), may be altered in terms of their location, although they may still have to be maintained as natural features.

• From a stormwater management perspective, centralized facilities, where they are feasible, will require about 5% of the developable land area.

• Because the lands are gently undulating to flat, the floodplains tend to be very wide and shallow along the watercourses, and occupy a significant land area.

• A water budget approach is recommended to maintain the existing hydrologic cycle in new developed areas. Because much of the lands in the study area have a low potential for infiltration, innovative source and conveyance control measures will be necessary, perhaps even in combination with end-of-pipe measures. This is in keeping with the Eco-Industrial development concept being considered for these lands and recent changes to the City standards associated with the CLI ECA process, in which retention of the 90th percentile rainfall is encouraged. This is also consistent with a "comprehensive urbanization approach" recommended in the City of Hamilton's Stormwater Management Strategy (Aquafor Beech, 2007). Suitable stormwater management facilities may include:

- rain barrels
- rainwater harvesting
- slab-on-grade development
- rain gardens
- biofilters
- soakaway pits
- pervious pavement
- perforated storm sewers
- grassed swales/ditches
- “end-of-pipe” controls for water quality control, erosion control, flood control and/or to promote infiltration:
  - stormwater management ponds
  - constructed wetlands
  - centralized infiltration facilities
  - erosion and sediment controls during construction.

- Other important measures for consideration include:
  - Revegetating riparian corridors along drainage features
  - Revegetating riparian areas around stormwater management facilities

The feasibility of these measures must be confirmed at the block plan / functional servicing stage based on hydrologeological studies, land use, and City design guidelines.

2.0 ADDITIONAL BASELINE STUDIES

2.1 STREAM CLASSIFICATION SYSTEM

2.1.1 STREAM CLASSIFICATION SYSTEM

2.1.2 FISH HABITAT CLASSIFICATION

2.2 SURFACE WATER DRAINAGE PATTERNS

2.2.1 BIG CREEK

2.2.2 SULPHUR CREEK

2.2.3 TWENTY MILE CREEK

Twenty Mile Creek drains from the Glanbrook area towards Lake Ontario. Existing land uses are primarily rural, however, this watershed will see future urban development in approximately 21% of the watershed area.

Approximately 1100ha (1131.5ha) of the study area are located within the headwaters of Twenty Mile Creek watershed. The east portion of John C Munro Hamilton International Airport is located within this portion of the study area. Numerous headwater tributaries drain the airport lands and lands directly adjacent to the airport. These tributaries flow southerly away (downstream) from the airport to the confluence with Twenty Mile Creek which then drains to Lake Ontario (at Jordan harbor) downstream of the study area.

2.2.4 WELLAND RIVER

2.2.5 GENERAL DESCRIPTION OF SURFACE WATER FEATURES

The majority of the headwater drainage features within the study area have been altered/improved for agricultural drainage or crop cultivation purposes and exist as agricultural drains, swales through cultivated fields, roadside ditches and natural drainage features (where they have been variously preserved by woodlot/wetland features or unproductive soils). The majority of these features have drainage areas less than 50 ha and all have drainage areas less than 125 ha.

In addition to these drainage features, there are numerous man-made ponds, created on agricultural, golf course and rural residential lands within the study area.

Essentially there are no engineered stormwater drainage systems within the AEGD as the majority of the lands are rural. The exceptions to this are the Hamilton International Airport lands, and the Highway 6/403 interchange. The Airport has a stormwater management system internal to the airport lands that also discharges via a number of stormwater management facilities/swales into adjacent headwater tributaries of Twenty Mile Creek and the Welland River; Highway 6 provides stormwater treatment at several discharge points along its length where it crosses headwater features of Sulphur Creek and Big Creek.

The existing road network is a rural system with roadside ditches, including the village of Mount Hope. Urban curb and gutter road systems, stormwater facilities and support infrastructure exist in communities adjacent to the study area on the north side along Garner Road and Twenty Road (i.e. St. Elizabeth Village SWM Ponds). At present the existing stormwater management facilities are under private management.

2.2.6 DRAINAGE MOSAIC

The pattern of the movement of surface runoff (overland flows) within the Hamilton Airport Employment Growth District is illustrated for each study area on Figure 2.7. These exhibits illustrate distinct parcels of land (catchments) each draining to a watercourse.

The drainage mosaic consists of 10 catchments within the Sulphur Creek Watershed Area, 11 catchments within the Welland River Watershed Area and 13 catchments within the Twenty Mile

Creek Watershed Area. This drainage mosaic was used for the hydrologic modeling work to determine hydrologic characteristics on a catchment basis.

NOTE: Big Creek was not partitioned into catchments, nor set up for HSPF modeling since the majority of the lands, approximately 330ha (330.2ha), are entirely within the Additional Study Area (post 2031). The exception to this is the approximately 12ha at the corner of Garner Rd East and Fiddlers Green Rd – see Section 5.5 the Council Directed Additional Lands. Development on these Council Directed Additional Lands within the Big Creek subwatershed will be subject to site-specific (lot level) controls and SWM criterion established based on the modeling results obtained from the other watersheds (these SWM criteria can be applied based on dominant soil types). Prior to Development in the remainder of the Big Creek Subwatershed, modeling should be undertaken and this study revisited given the time lapse anticipated between completion of the subwatershed study and Stormwater Master Plan and potential future development (post 2031).

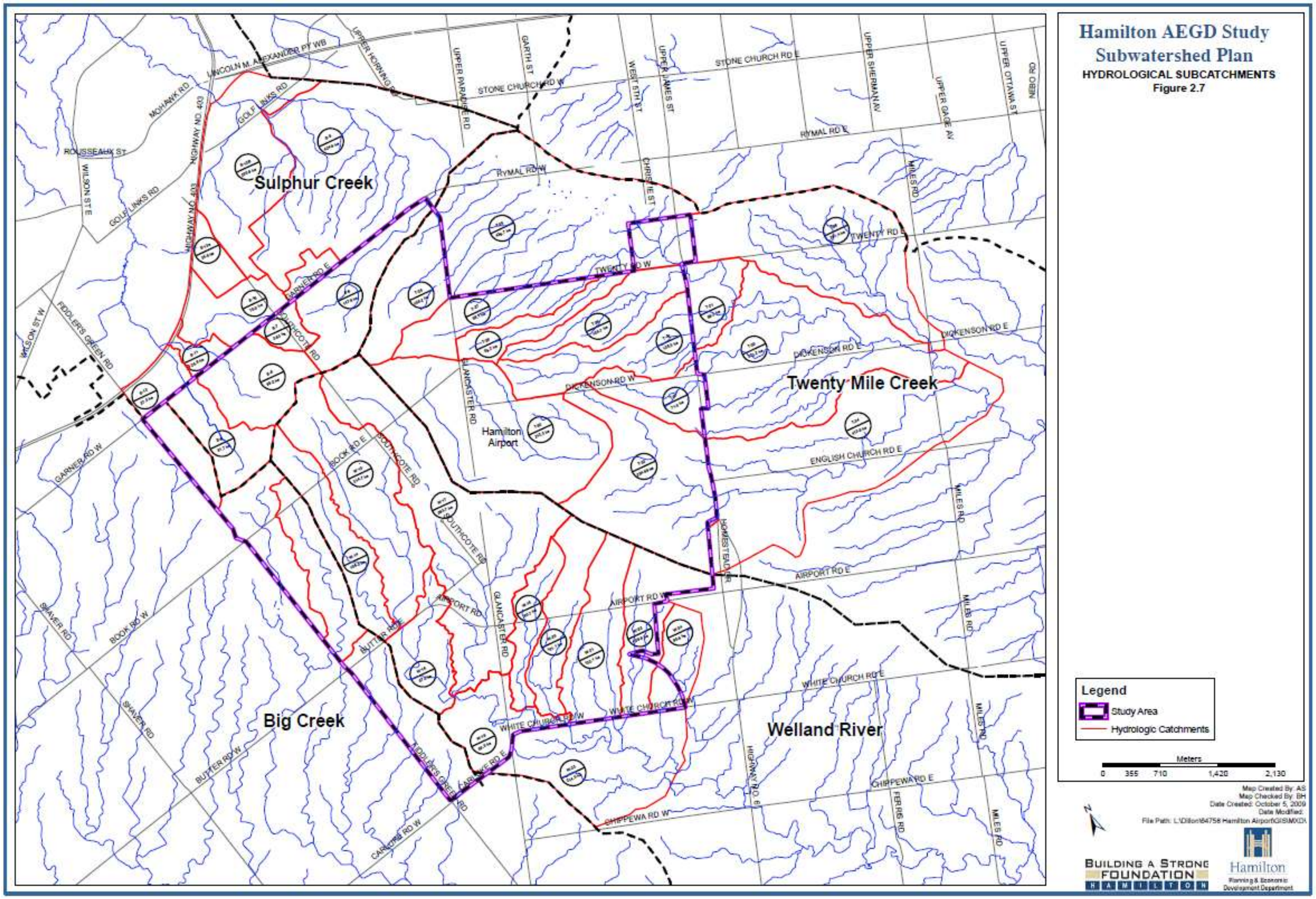
2.2.7 CATCHMENT CHARACTERISTICS FOR EXISTING CONDITIONS

The study area catchments range in size from 26.2 ha to 439.7 ha, and are characterized by gently rolling topography with average catchment land slopes ranging from 0.1% to 0.8%. The average percent of the existing conditions land uses within each of the three watersheds is illustrated in Table 2.1

Drawing STM-1 illustrates the existing drainage boundaries within the scoped study area.

Table 2.1: Existing Conditions Land Use Distribution Reported as Percent of Total Area

Watershed	Area (ha)	Existing Conditions Land Use Distribution (%)							
		Woodlot	Row Crop	Pasture	Residential	Commercial	Roads and other impervious	Total Pervious	Total Impervious
*For the catchments located with the study area (as illustrated in **Figure 2.7**)*									
Sulphur Creek	*355.0*	*8*	*67*		*14*	*8*	*4*	*85*	*15*
Welland River	*1,295.3*	*16*	*52*	*13*	*13*	*2*	*3*	*88*	*12*
Twenty Mile Creek	*1,131.5*	*13*	*49*	*26*	*8*	*1*	*2*	*92*	*8*
Total Area of Hydrologic Modeling (Study Area and downstream area included in assessment)									
Sulphur Creek	*1,152.5*	*10*	*41*	*4*	*26*	*8*	*11*	*71*	*29*
Welland River	*1,570.2*	*17*	*56*	*11*	*14*	*2*	*3*	*89*	*11*
Twenty Mile Creek	*2,718.8*	*14*	*53*	*14*	*16*	*2*	*4*	*87*	*13*


Hamilton AEGD Study
Subwatershed Plan
HYDROLOGICAL SUBCATCHMENTS
Figure 2.7
Sulphur Creek
Twenty Mile Creek
Big Creek
Welland River
Hamilton Airport
Legend
Study Area
Hydrologic Catchments
Meters
0 355 710 1,420 2,130
BUILDING A STRONG FOUNDATION HAMILTON
Hamilton
Planning & Economic Development Department

2.3 WATER QUALITY

2.3.1 GENERAL

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2.5.3 GROUNDWATER RECHARGE AND DISCHARGE

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2.5.5.1 SIGNIFICANT GROUNDWATER RECHARGE AREAS

2.5.5.2 GROUNDWATER SUSCEPTIBILITY AREAS

2.5.6 CONCLUSIONS

3.0 ISSUES, OPPORTUNITIES AND CONSTRAINTS

There are a number of issues, opportunities and constraints associated with the study area from a natural environment and water management perspective, as follows:

• Headwaters of 4 different watersheds with flat topography and relatively low to moderate permeability soils

• The AEGD lies within the boundaries of all three of the City's (and the CA's) Source Protection Areas that includes areas designated as Significant Recharge Areas and High Groundwater Susceptibility Areas. These areas are classified based on climate, soils, water table and local aquifer characteristics, as well as local domestic water wells and potential groundwater use for domestic purposes.

• Airport restrictions on open water and bird populations make wet ponds for stormwater management infeasible

• Generally low permeability soils present a challenge for implementing groundwater infiltration techniques in end-of-pipe applications. However, the use of dispersed/decentralized source and conveyance controls (provided they are properly sized and engineered) largely removes permeability limitations and may provide an opportunity to better manage pre-development hydrology and water balance criteria.

• Flat terrain and small headwater features create large floodplains and result in nuisance flooding conditions

• Small drainage features are very susceptible to impacts of increased runoff and may be too shallow to provide outlets for stormwater management facilities

• Eco-industrial park concept is well suited to a LID SWM approach

• Groundwater functions are generally not as significant as in other areas in supporting wetlands and watercourses

• Fish habitats are generally seasonal or warmwater and lack permanent baseflow, riparian vegetation, receive excessive sediment loads and have poor instream habitat conditions

• Wetlands are generally absent within the study area, but large wetland features exist downstream on Twenty Mile Creek and Welland River

• The Greenbelt lands provide for a significant area of natural features and agricultural lands to be preserved which provides an opportunity to have a significant terrestrial linkage from the Welland River valley to nearby significant woodlots

• Existing stormwater facilities in communities adjacent to the study area on the north side along Garner Road and Twenty Road accept surface flows from within the study area and are presently managed privately without the City possessing legal access for inspection, maintenance or upgrade (See Part B- Section 5.1.1).

• Meet, to the extent possible based on soil / groundwater conditions, the retention targets established in the CLI ECA document.

• As requested by City staff, a suitable flow / volume should be maintained to existing drainage features north of the scoped study area (i.e along Twenty Road West). This should be quantified through future studies (i.e. functional servicing report), but it is assumed that the full range of design / flood flows up to the 100-year storm do not need to be replicated to the existing features, but rather the frequent events. This may conflict with the requirement noted above regarding the CLI ECA retention targets.

4.0 SUBWATERSHED GOALS AND OBJECTIVES

4.1 GOALS

4.2 OBJECTIVES

4.2.1 COMMUNICATION AND EDUCATION

4.2.2 WATER QUANTITY

- Manage flooding and erosion risks to human life and property to within acceptable limits
- Maintain, enhance or restore stream processes to support human uses, agricultural needs and natural habitats
- Manage flows to reduce erosion and sediment impacts on habitats and property
- Protect groundwater water resources in order to support ecological and human use functions

- Retain the 90th percentile flow to the extent possible or manage it in the hierarchy established in the City's CLI ECA agreement.

4.2.3 WATER QUALITY

4.2.4 AQUATIC COMMUNITIES AND HABITATS

4.2.5 TERRESTRIAL COMMUNITIES

5.0 FUTURE LANDUSE AND POTENTIAL IMPACTS

The development of land use options for the Airport Employment Growth District was completed and represented the first part of the planning process for the Phase 2 Secondary Plan. These options were the first step in evaluating alternative approaches to place employment and other related uses in the AEGD area. Three land use options were drafted and evaluated: Light Industrial Business Park, Prestige Business Park and Hybrid Business Park/Light Industrial, with the Hybrid Business Park being selected as the preferred option for development.

In Phase 2, the preferred alternative was refined and has become the basis for completing the Phase 2 infrastructure reports, including the integrated Subwatershed/Stormwater Master Plan. The preferred plan provides a growth strategy for development around the airport that includes planning to the year 2031 (Secondary Plan Area) to meet provincial growth management objectives, as well as providing an additional employment reserve area for potential growth beyond 2031 (Additional Study Area). Figures 5.0 and 5.1 illustrate the preferred plan and the staging, respectively.

The Secondary Plan Area land use plan was further broken down into two phases as follows:

Phase 1: growth that can occur without additional expansion of water and wastewater infrastructure

Phase 2: growth that will require new water and wastewater infrastructure

The following provides an overview of the four employment land use categories:

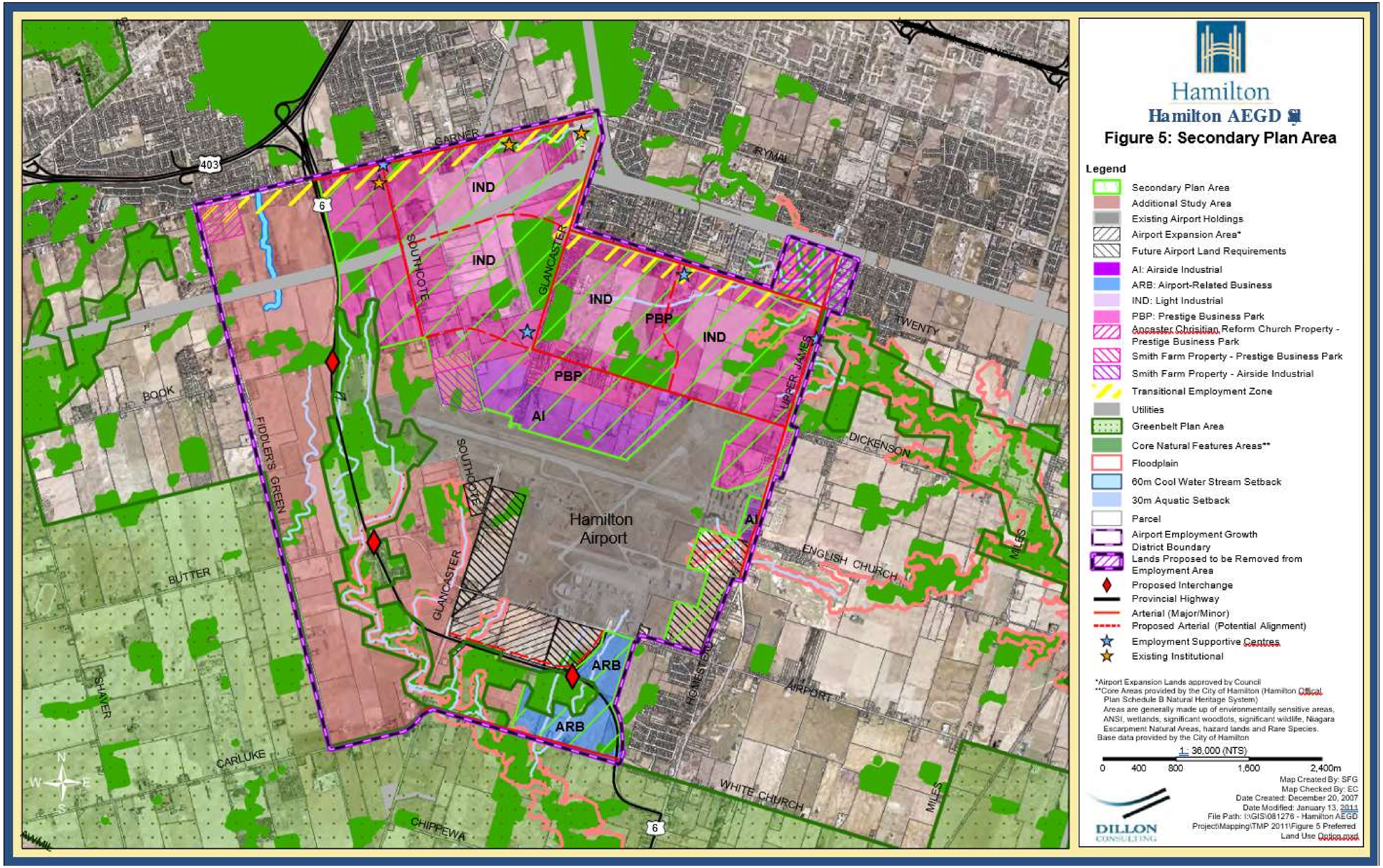
1. Airport Related Business (ARB);

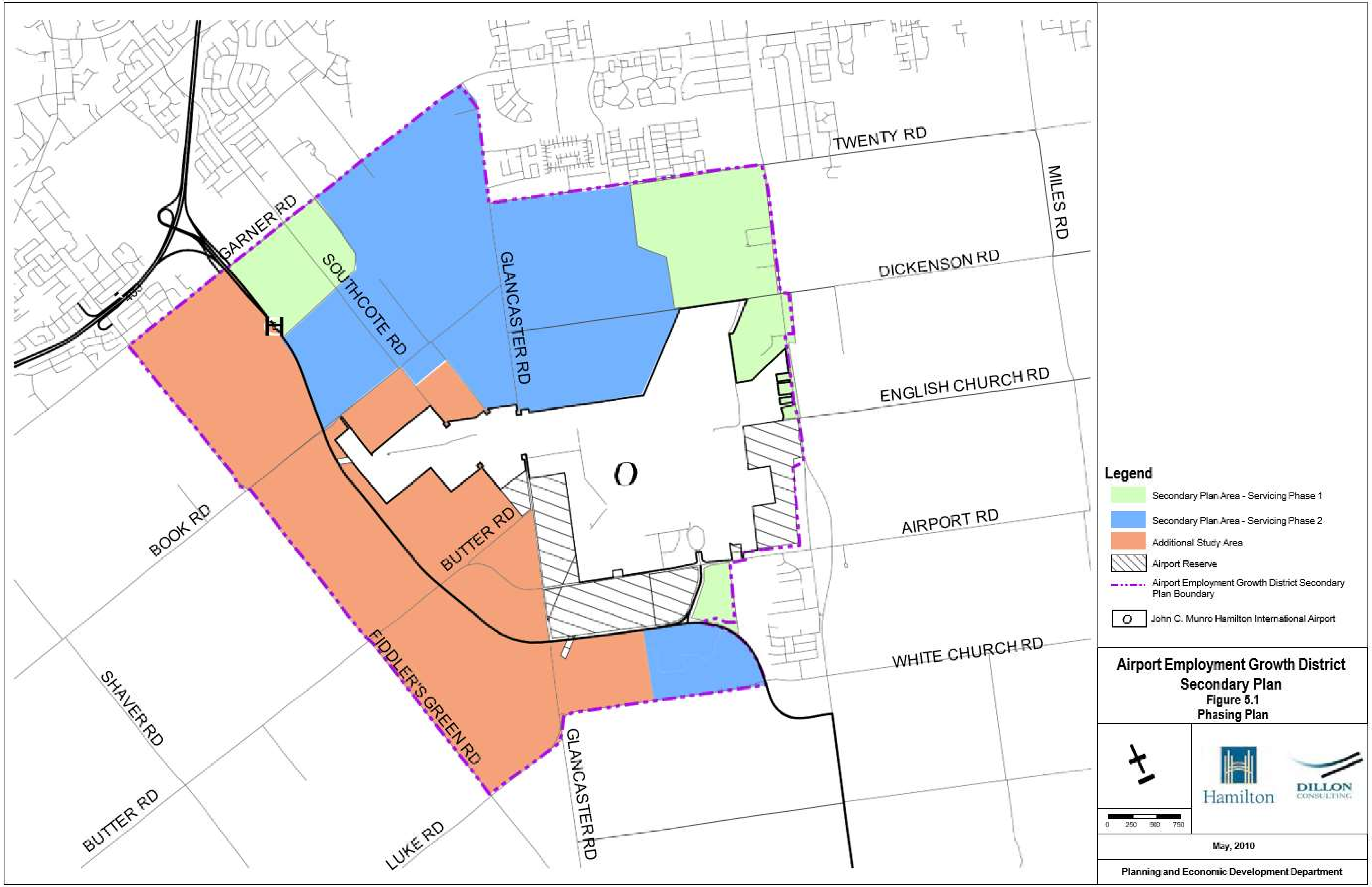
2. Airside Industrial (AI);

3. Light Industrial (IND); and

4. Prestige Business Park (PBP)

In addition to the above uses, residential land use is now proposed for the north portion of the scoped study area as shown on the proposed (updated) Secondary Plan land use figure. Note that the former AEGD Secondary Plan shown in Figure 5 is now superseded by the updated Secondary Plan (prepared by CLS). Similarly, the phasing shown in Figure 5.1 must be updated at the functional design stage to reflect timing of infrastructure, land ownership / participation and associated timing of development.


Hamilton
Hamilton AEGD
Figure 5: Secondary Plan Area
Legend
Secondary Plan Area
Additional Study Area
Existing Airport Holdings
Airport Expansion Area*
Future Airport Land Requirements
AI: Airside Industrial
ARB: Airport-Related Business
IND: Light Industrial
PBP: Prestige Business Park
Ancaster Christian Reform Church Property - Prestige Business Park
Smith Farm Property - Prestige Business Park
Smith Farm Property - Airside Industrial
Transitional Employment Zone
Utilities
Greenbelt Plan Area
Core Natural Features Areas**
Floodplain
60m Cool Water Stream Setback
30m Aquatic Setback
Parcel
Airport Employment Growth District Boundary
Lands Proposed to be Removed from Employment Area
Proposed Interchange
Provincial Highway
Arterial (Major/Minor)
Proposed Arterial (Potential Alignment)
Employment Supportive Centres
Existing Institutional
*Airport Expansion Lands approved by Council
**Core Areas provided by the City of Hamilton (Hamilton Offical Plan Schedule B Natural Heritage System)
Areas are generally made up of environmentally sensitive areas, ANSI, wetlands, significant woodlots, significant wildlife, Niagara Escarpment Natural Areas, hazard lands and Rare Species.
Base data provided by the City of Hamilton
1: 36,000 (NTS)
0 400 800 1,600 2,400m
Map Created By: SFG
Map Checked By: EC
Date Created: December 20, 2007
Date Modified: January 13, 2011
File Path: I:\GIS\081276 - Hamilton AEGD Project\Mapping\TMP 2011\Figure 5 Preferred Land Use Option.mxd
DILLON CONSULTING
IND
PBP
AI
ARB
Hamilton Airport
GARNER
RYMAL
TWENTY
DICKENSON
ENGLISH CHURCH
AIRPORT
WHITE CHURCH
CHIPPEWA
CARLUKE
BUTTER
BOOK
SHAVER
FIDDLER'S GREEN
SOUTHCOTE
GLANCASTER
UPPER JAMES
HOMESTEAD
MILES
403
6


TWENTY RD
MILES RD
GARNER RD
SOUTHCOTE RD
GLANCASTER RD
DICKENSON RD
ENGLISH CHURCH RD
AIRPORT RD
BOOK RD
BUTTER RD
WHITE CHURCH RD
FIDDLER'S GREEN RD
SHAVER RD
BUTTER RD
LUKE RD
GLANCASTER RD
Legend
Secondary Plan Area - Servicing Phase 1
Secondary Plan Area - Servicing Phase 2
Additional Study Area
Airport Reserve
Airport Employment Growth District Secondary Plan Boundary
John C. Munro Hamilton International Airport
Airport Employment Growth District
Secondary Plan
Figure 5.1
Phasing Plan
0 250 500 750
Hamilton
DILLON CONSULTING
May, 2010
Planning and Economic Development Department

5.1 AIRPORT RELATED BUSINESS (ARB)

The ARB lands, located adjacent to the HIA, will have direct access to the airside and will be focused for businesses that require airside access, such as freight-forwarders, regional integrator operations (i.e. FedEx, UPS) and on-site customs brokers. This designation allows a broad range of employment uses, including light industry, warehousing, wholesale trade, distribution, outdoor storage, office, transportation, communication and utilities, among other uses. All will need to demonstrate the need for airside access to locate on these properties. This designation will have minimum standards for urban design (relative to the prestige areas) and will require a high level of sustainable design.

In addition, this designation allows Employment Support uses that primarily support industry, businesses and employees within the employment area, such as commercial schools, amenities (e.g. health services, recreational facilities, open spaces, offices, entertainment, convenience commercial, gym and restaurants), financial establishments, personal services and labour association halls. It also allows accessory uses, such as smaller offices and retail.

5.2 LIGHT INDUSTRIAL (IND)

The IND designation allows a broad range of employment uses, including light industry, warehousing, repair service, wholesale trade, office, distribution, transportation, communication and utilities, among others. This designation will have minimum standards for urban design (relative to the prestige areas) and will require a high level of sustainable design.

In addition, it allows Employment Support uses that primarily support industry, businesses and employees within the employment area, such as Employment Support to the primary use, commercial schools, amenities (e.g. health services, and recreational facilities, open spaces, offices, entertainment, convenience commercial and gyms), financial establishments, restaurants, commercial rental establishments, personal services and labour association halls. It also allows accessory uses, such as smaller offices and retail. Controlled outdoor storage is permitted within this area.

5.3 AIRSIDE INDUSTRIAL (AI)

AI designation will be focused on clustering accommodation; food and catering services; convention centres; research & development; offices; business/financial services; automobile rental; taxi terminals; and, Employment Support and supporting services, among other uses.

These areas are set to have high quality urban design standards, sustainable development standards and the incorporation of amenities supporting employment (i.e. retail, offices, gym, services and restaurants). No light industry, warehousing, distribution, or outdoor storage is permitted.

5.4 PRESTIGE BUSINESS PARK (PBP)

Areas designated as PBP are set to have a high quality urban design and sustainable development standards. Businesses in PBP areas will integrate the natural sensitive features into their landscaping while providing all employees with opportunities for recreation and active transportation.

The focus of the PBP designation is on business/financial services, research and development, offices, prestige/light industrial, warehousing, wholesale trade, transportation, communication and government services, among other uses. Outdoor storage is only permitted within this area subject to strict design guidelines.

In addition, this designation allows Employment Support uses that primarily support industry, businesses and employees within the employment area, such as commercial schools; amenities (i.e. health services, recreational facilities, open spaces, offices, entertainment, convenience commercial, gym and restaurants); financial establishments; personal services; and, labour association halls. It also allows accessory uses, such as offices and retail.

5.5 COUNCIL DIRECTED ADDITIONAL LANDS

The Council Directed Additional Lands (CDAL), as the name suggests, were added by Hamilton City council at the request of the property owners and the public and as such are not part of the Secondary Plan Area. These lands were however part of the AEGD study area and were included in the subwatershed study analysis and mapping. The Recommended Subwatershed Plan detailed in Section 6.0, applies to the Council Directed Additional Lands (CDAL).

The CDAL lands are comprised of the following properties (Figure 5); each designated a land use as per the four employment land use categories detailed above:

1. The Ancaster Christian Reform Church (15.8ha): designated as Prestige Business Park (PBP), see Section 5.4.

2. The Smith Farm (approx. 22ha)

• Smith Farm (North Portion – 6.4ha): designated as Prestige Business Park (PBP), see Section 5.4.

• Smith Farm (South Portion – 15.4ha): designated as Airside Industrial (AI), see Section 5.3.

5.6 FUTURE LANDUSE AND POTENTIAL IMPACTS: CONCLUSIONS

A number of potential opportunities and constraints from the development of this land use plan were addressed through the iterative planning process in addressing natural heritage and water resources systems as the land use plan was being developed including:

• A natural heritage system was identified by protecting significant woodlots and other significant features, as input to the development of the land use plan. This included protecting 30 m buffers around these core features

• The presence of a large Greenbelt Area within the study area was recognized and planning of land uses around this area in part provided a logical separation between Phase 1 and Phase 2 development

• The eco-industrial park concept is ideally suited to the implementation of LID Stormwater Management approaches and measures, which are also the SWM approach of choice because of airport restrictions on open waters.

At the completion of the integrative planning and adaptive management process, a number of potential impacts remain to be addressed:

• A number of smaller woodlots remain on the landscape as linkages that were not protected as part of the core areas

• The relatively high density and potential to create large impervious areas within the development areas has potential to impair or eliminate many of the numerous headwater drainage features and the need to develop a protected system of stream corridors, important in sustaining hydrology, water quality, flood management and fish habitats both within and downstream of the study area.

These issues are discussed in more detail in the following section.

6.0 RECOMMENDED SUBWATERSHED PLAN

6.1 SUBWATERSHED PLANNING GUIDELINES

6.2 NATURAL HERITAGE PLAN

6.3 GROUNDWATER MANAGEMENT PLAN

6.3.1 PROVINCIAL POLICY STATEMENT

6.3.2 SIGNIFICANT GROUNDWATER RECHARGE AREAS

6.3.2.1 CONTAMINANT MANAGEMENT

6.3.3 HIGH GROUNDWATER SUSCEPTIBILITY AREAS

6.3.3.1 POTENTIAL SOURCE PROTECTION PLAN CONCEPTS

6.3.3.2 CONTAMINANT MANAGEMENT

6.3.3.3 EMERGING CHALLENGES

6.3.3.4 ADDITIONAL RECOMMENDATIONS

6.4 SURFACE WATER MANAGEMENT PLAN

The Surface Water Management Plan is shown in Part B Figure 3.3. Part B of this document addresses, in detail, the Surface Water Management component of the Subwatershed Plan.

This plan has been updated to reflect the proposed land use – refer to Figure STM-2 for details.

Management of water resources within the study area will address flooding; erosion, sedimentation and stream morphology; and water quality. The naturally low gradient, channelized, headwater drainage network that dominates the surface drainage of the study area currently results in regular nuisance flooding conditions. Lack of riparian cover and high sediment delivery to these features, results in localized sedimentation and leads to a reduction in substrate diversity (instream habitat) and an increase in nutrient enrichment. Generally these features are not erosion prone, because of their low stream power and the high sediment load they receive. Other factors affecting water quality include both agricultural and airport runoff. A number of management actions are recommended to address surface water problems:

• Develop a comprehensive Stormwater Master Plan and guidelines to address impacts of future land uses as they pertain to the four (4) watersheds of the study area (see Part B)

• Implement a stewardship program targeting existing agricultural operations to reduce sediment transport and delivery to watercourses through a combination of programs including:

- Implementing nutrient management plans on farm operations

- Utilizing sediment control practices such as conservation tillage and cover cropping practices
- Encouraging the planting of buffer strips along drainage features to reduce sediment delivery to these features
- Continue to support initiatives by the airport to reduce water quality and quantity impacts by:
- Monitoring offsite water quality to identify problem areas
- Implement an EMS program on Airport lands to manage potential sources of surface water contamination
- Identify opportunities to mitigate the effects of uncontrolled airport runoff on receiving waters

• Encourage the adoption of a similar approach to stormwater management within the airport and areas required to meet its future land requirements

6.5 MONITORING REQUIREMENTS

7.0 FUTURE STUDIES

Before development can proceed:

• Existing stormwater facilities in communities adjacent to the study area on the north side along Garner Road and Twenty Road accept surface flows from within the study area and are presently managed privately without the City possessing legal access for inspection, maintenance or upgrade (See Part B- Section 5.1.1).

Direction regarding maintaining suitable flows and/or volumes to these facilities should be sought by the City and the owners of the existing facilities. In general, it can be assumed that flows discharged to these outlets / downstream facilities should be less than or equal to existing conditions, to mitigate conveyance-related constraints.

• Areas identified as highly vulnerable/ susceptible (Figure 6.2) will require additional Hydrogeological investigations prior to proceeding with development.

• EIS studies will be completed adjacent to all areas identified in the Natural Heritage Plan (Figure 6.0)

• Stormwater Management Plans will be completed consistent with the recommendation of the Stormwater Master Plan, including addressing the treatment of watercourses, addressing water budget requirement through effective implementation of LID measures and the finalization of the Class EA related to end of pipe dry ponds. This will include meeting the CA's regulations with respect to watercourses.

Next steps/ studies that may need to be completed:

• Generally, the following recommendations are put forward to reduce the potential to increase groundwater susceptibility and to be consistent with the current initiatives under the Source Protection Program:

- The City should undertake a review of all wells in the study area to determine their current location and status (in use or abandoned) and that any wells remain after servicing is available, that these be properly decommissioned as noted above.
- Any existing abandoned or unused wells that can be identified now should be decommissioned as soon as possible.
- Wells should be abandoned as directed under O.Reg. 903 as both municipal water and municipal sewage become available concurrently and as development proceeds.

• Areas identified as highly vulnerable/ susceptible (Figure 6.2) will require additional Hydrogeological investigations prior to proceeding with development and implementation of infrastructure

• The protection of greenbelt lands and the proposed natural heritage system should be recognized as providing a significant role in protecting water balance and sustaining local groundwater recharge.

• Contaminant management plans should be prepared for all high risk land uses

• An EMS system and groundwater monitoring program is recommended for the Airport to reduce potential groundwater contamination impacts

• The monitoring program for the existing groundwater monitoring well should be reviewed to ensure that the data collected reflects the future needs of the area with respect to future growth. This may include additional baseline water quality monitoring and the implementation of additional short term wells established as part of hydrogeological studies for proposed development.

8.0 AEGD IMPLEMENTATION DOCUMENT

PART B – STORMWATER MASTER PLAN

2.0 CLASS EA PROCESS

Class Environmental Assessments are a method of dealing with projects which display the following important common characteristics (Municipal Engineers Association, 2007):

• Recurring;

• Usually similar in nature;

• Usually limited in scale;

• Have a predictable range of environmental effects; and

• Responsive to mitigating measures.

Projects which do not display these characteristics would not be able to use the planning process set out in the document entitled “Municipal Class Environmental Assessment” and therefore must undergo an individual environmental assessment.

This study was carried out under Schedule B of the Municipal Class Environmental Assessment for Master Plans, and is subject to the requirements of the Environmental Assessment Act. This Class Environmental document therefore reflects the following five key principles of successful planning under the Environmental Assessment Act.

• Consultation with affected parties early on, such that the planning process is a cooperative venture;

• Consideration of a reasonable range of alternatives;

• Identification and consideration of the effects of each alternative on all aspects of the environment;

• Systematic evaluation of alternatives in terms of their advantages and disadvantages, to determine their net environmental effects;

• Provision of clear and complete documentation of the planning process followed, to allow "traceability" of decision-making with respect to the project.

2.1 POTENTIAL STORMWATER MANAGEMENT OPTIONS

The principles of ecological design are fundamental to eco-industrial parks (EIPs), and influence the entire development cycle, from development planning to infrastructure design (including stormwater management), to zoning, and ultimately, to individual businesses' lot plans, building designs, and operations.

Infrastructure design within the AEGD reflects the change in the way in which the public and policy makers regard the natural environment. This change, embodied within the principles of eco-industrial design has led to considerable alterations in the planning, design and construction of employment areas and the infrastructure necessary to sustain them. In keeping with the principles of eco-industrial design and the gravitation towards an ecosystem–based approach to stormwater management, this approach has replaced the now outdated land use and infrastructure planning driven solely by rapid conveyance and public safety objectives.
The eco-industrial/ecosystem-based approaches integrate the concepts of community and development sustainability with the requirements of the natural system within which the development will ultimately exist. Naturally this has changed the way stormwater concerns are approached, designed and managed, specifically the change in the philosophy from one of stormwater management to rainwater management (GVRD, 2005). Furthermore, the techniques identified for stormwater management within the AEGD are intended to be implementated as part of treatment train approach, whereby stormwater Best Management Practices (BMP) controls are applied in succession along the stormwater flow path. In keeping with the EA process, principles, and objectives, five (5) techniques for stormwater management within the AEGD were identified. These options include:

1) Do Nothing;

2) Low Impact Development (LID) Source Controls;

3) Conveyance Controls;

a. Rapid Conveyance Controls (conventional curb and gutter piped systems)

b. Low Impact Development (LID) Conveyance Controls

4) End-of-Pipe controls; and

5) Stream Restoration.

A detailed description of each stormwater management is provided below:

2.1.1 DO NOTHING

This measure involves developing the AEGD lands without stormwater management.

This alternative would result in a substantial increase in runoff, flooding, erosion and also water quality degradation both within the AEGD and in downstream lands

2.1.2 LOW IMPACT DEVELOPMENT (LID) SOURCE CONTROLS

This technique involves addressing SWM using lot level controls/source controls. Source controls are physical measures that encourage the infiltration of water into the ground and reduce stormwater runoff. These systems would be integrated into the design of commercial/industrial developments and can include:

- Rainwater Harvesting (RWH);
- Green Roofs;
- Downspout Disconnection;
- Soakaway Pits,
- Bioretention and Special Bioretention:
- Compost Amendments;
- Tree Clusters;
- Filter Strips; and
- Permeable Pavement.

(From L to R: Special Bioretention, Downspout Disconnection, Permeable Pavement & Green Roofs)

The suite of 13 landscape-based, decentralized, lot-level, micro-control Best Management Practices (BMPs) are collectively known as Low Impact Development (LID). There are many definitions that have been developed in an attempt to define Low Impact Development, with the most widely accepted definition being that used by the United States Environmental Protection Agency (EPA, 2007):

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

LID techniques mimic natural systems as rain travels from the roof to the stream by applying a series of practices across the entire development site before discharge to receiving water body.

Real-world LID designs typically incorporate a series of LID BMPs in a ‘treatment train’ approach to provide integrated treatment of runoff from any and all sites, as exemplified in Figure 2.0.

Figure 2.0: Landscape Based Stormwater Management Strategy

LID practices are considered at the earliest stage of site design, are installed during construction and sustained in the future as a low maintenance natural system. Each LID practice incrementally reduces the volume of stormwater on its way to the receiver. In doing so, LID practices are applied to meet stormwater management targets for water quality, geomorphic and water balance objectives.

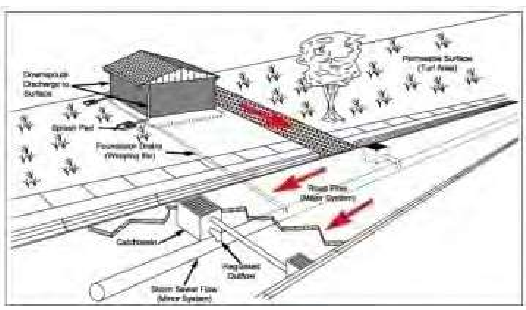
LID practices, together with traditional BMP’s can be applied to achieve an overall stormwater management system which provides better performance, is more cost effective, has lower maintenance burdens, and is more protective during extreme storms than conventional stormwater practices alone. The basic idea is that each LID practice is a bead on a string running from the roof to stream, with each bead providing successive storage, attenuation and water quality benefits.

It should also be noted that LID practices may be beneficial in order to meet objectives beyond the field of stormwater management such as energy/water conservation, reduce-reuse of materials, ozone protection and reduction of the effects of 'Urban Heat Island'. For more details regarding refer to the Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC-2010)

2.1.3 CONVEYANCE CONTROL

Conveyance controls are linear stormwater transport systems that are generally located within the road right-of-way. Conveyance controls can be divided into two general categories:

1) Rapid Conveyance Systems – primary function is conveyance. Traditional curb and gutter piped systems or concrete lined channels are typical of these types of systems.




(From L to R: Conceptual Curb and Gutter, Concrete Lined Surface Channel)

2) LID Conveyance Systems – while still providing conveyance, these features encourage infiltration of water into the ground, improve water quality and reduce runoff. Included in this category are practices such as bio-filters, bio-swales, grassed channels and subsurface perforated pipe systems.




(From L to R: Vegetated Channel, Subsurface Perforated Pipe, Bio-swale & Grass Channel)

2.1.4 END-OF-PIPE

End-of-pipe measures involve addressing SWM using conventional stormwater facilities such as wet ponds, wetlands and dry ponds at the end of the flow conveyance system. These facilities are utilized for any combination of erosion, water quantity and quality control applications.

(From L to R: Wet pond, Wetland & Dry Pond)

2.1.5 STREAM RESTORATION

This stormwater management measure involves the replanting of floodplain and native stream side vegetation to improve stream corridor functions and water quality, slowing runoff, moderating stream temperatures, reducing erosion while improving aquatic and terrestrial habitat conditions. It also includes the reconstruction of the stream's natural characteristics including morphology of the channel and its floodplain which may also improve fish habitat.

(From L to R: Created Channel, Wetland Feature, Linear Wetland, & Naturalize Corridor)

2.2 ENVIRONMENTAL ASSESSMENT (EA) EVALUATION PROCESS

To manage the complexity and constraints inherent within the AEGD study area as they pertain to stormwater management and to ensure a transparent selection process (as part of the Class EA) that considers all possible design alternatives, a two-phased evaluation process has been used. The two-phased approach (Figure 2.1) is composed of a screening level assessment followed by a detailed assessment. Subsequent steps involved the evaluation of the preferred alternative in the context of potential implementation considerations within the AEGD.

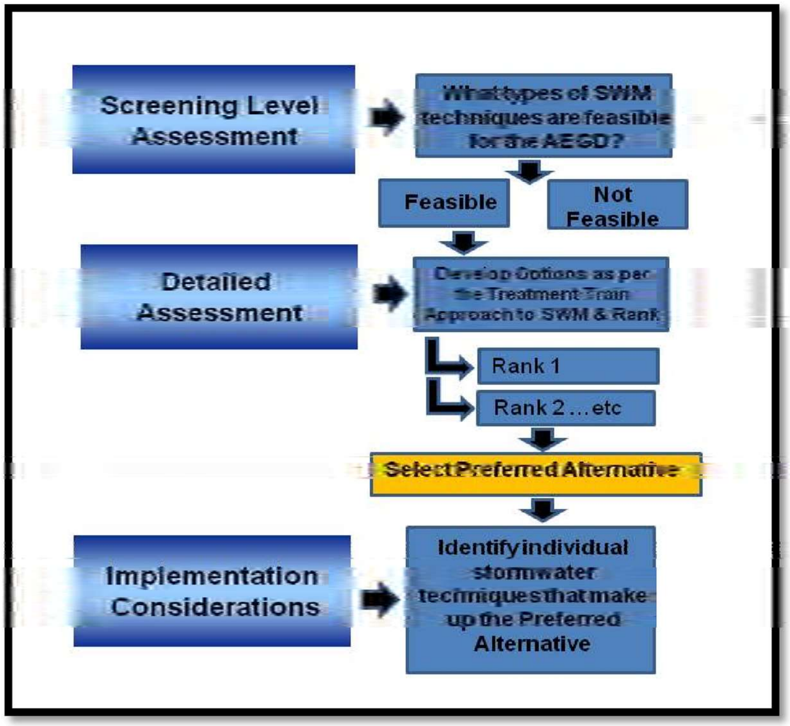


Figure 2.1: Environmental Assessment (EA) Evaluation Process Flow Chart

2.2.1 PHASE 1: SCREENING LEVEL ASSESSMENT

The screening level assessment is intended as a coarse screening tool, used to identify those techniques that are feasible (and infeasible) for use in the AEGD and therefore which SWM techniques are to be carried forward to the more detailed assessment phase. To this end, nine (9) screening level assessment criteria have been developed based on the primary stormwater management objectives within the AEGD study area. The primary criteria include:

1) Technical feasibility;

2) Ability to meet targets for Flooding;

3) Ability to meet targets for Water quality;

4) Ability to meet targets for Erosion;

5) Ability to meet targets for Water balance;

6) Cost effectiveness;

7) Consistency with Eco-Industrial design approach;

8) Public acceptance; and

9) Regulatory agency approval – municipal, provincial, Federal and respective Conservation Authority.

A detailed description of the individual screening level assessment criteria and measures for assessment are provided in Table 2.0. In order to apply the primary criteria, a matrix detailing the screening level assessment (Phase 1) was developed and is presented in Table 2.1.

Table 2.0: Description of the Primary Criteria used in Screening Level Assessment (Phase 1)

<table>
<tr><th>Criteria</th><th>Description of Criteria</th><th>Measures for Assessment</th></tr>
<tr><td>Technical Feasibility</td><td>• Ability of the SWM technique to be constructed given the known constraints (see Section 1.3).</td><td rowspan="9">Assessment of the individual stormwater management techniques will range from Excellent to Poor in its ability to meet the identified criteria.

Stormwater management techniques that fail to meet primary criteria will be deemed to be an unacceptable stormwater management option for the AEGD and will <u>not</u> be carried forward to the detailed assessment (scored NA – Not acceptable).</td></tr>
<tr><td>Ability to meet targets for Flooding</td><td>• Ability of the SWM technique to meet flood control criteria. Technique must control peak outflows to pre-development rates for design storms with return period up to 100yrs.
• Cannot increase flooding risks to infrastructure and private property.</td></tr>
<tr><td>Ability to meet targets for Water quality</td><td>• Ability of the SWM technique to meet water quality criteria as per the 2003 MOE Stormwater Management Manual.</td></tr>
<tr><td>Ability to meet targets for Erosion</td><td>• Ability of the SWM technique to control water course erosion in accordance with the 2003 MOE Stormwater Management Manual.</td></tr>
<tr><td>Ability to meet targets for Water balance</td><td>• Ability of the SWM technique to maintain the pre-development water balance and prevent adverse changes to site hydrology.
• At a minimum, the technique must maintain the pre-development groundwater recharge.</td></tr>
<tr><td>Cost effectiveness</td><td>• Cost effectiveness of the SWM technique is in relation to the overall benefit and the collective criteria.</td></tr>
<tr><td>Consistency with Eco-Industrial design approach</td><td>• Ability of the SWM to be integrated within the Eco-industrial design approach adopted for the AEGD, specifically in regards to stormwater management as listed in Section 1.2.</td></tr>
<tr><td>Public acceptance</td><td>• General public acceptance of the individual stormwater management technique.</td></tr>
<tr><td>Regulatory agency approval</td><td>• Ability of the SWM to meet the requirements of Municipal, Provincial, Federal agencies and the respective Conservation Authorities.</td></tr>
</table>

Table 2.1: Phase 1- Screening Level Assessment Matrix for Stormwater Management Techniques within the AEGD

	Technical Feasibility	Flooding	Water Quality	Erosion	Water Balance	Cost Effectiveness	Consistency with Eco- Industrial Design	Public Acceptance	Regulatory Agency Approval	Overall
Do Nothing	E	NA	NA	NA	NA	E	P	P	NA	**NA**
LID Source Control	E	P	E	E	E	P	E	G	E	**E**
Conveyance										
Rapid Conveyance	E	F	P	P	P	E	NA	E	F	**NA**
LID Conveyance	E	F	G	G	G	G	E	G	E	**G**
End-of Pipe										
Wet pond	E	E	G	F	P	E	G	E	NA	**NA**
Wetland	E	E	E	G	E	P	G	G	NA	**NA**
Dry Pond	E	E	F	G	F	G	G	G	G	**G**
Stream Restoration	E	P	G	E	G	P	E	G	E	**G**
	E=Excellent, G= Good, F = Fair, P=Poor, NA = Not Acceptable									

Phase 1 – Screening Level Assessment Recommendations

- Stream Restoration and EOP (Dry Ponds) techniques together with LID Source and LID Conveyance Controls provide benefits in regards to the individual primary criteria and are more consistent with the Eco-Industrial design approach and the protection of headwater drainage features and therefore are deemed feasible and carried forward to the Detailed Assessment.
- Due to air travel safety concerns the use of open water end-of pipe facilities such as Wet Pond and Wetland are not acceptable techniques, and therefore are not carried forward to the Detailed Assessment.
- Due to the inability of the Do Nothing technique to meet flooding, water quality, erosion, water balance and therefore the inability to meet regulatory agency approvals, the technique is not carried forward to the Detailed Assessment.
- Due to the inconsistency of Rapid Conveyance system (traditional Curb and Gutter) with the principles and objectives of Eco- industrial design and its inability to satisfactorily address environmental criteria without the use of wet ponds, the technique is not carried forward to the Detailed Assessment

2.2.2 PHASE 2: DETAILED ASSESSMENT

The SWM techniques carried forward from screening level assessment (Stream Restoration and end-of-pipe Dry Ponds, LID Source and LID Conveyance Controls) have been used to develop eight (8) SWM alternatives for the AEGD. The eight alternatives are made up of both individual approaches (i.e. LID source control alone) and combinations of approaches (consistent with the MOE 's treatment train approach to SWM). The eight (8) SWM alternatives include:

1. Dry ponds end-of-pipe controls Only;

2. LID Conveyance Controls Only;

3. LID Source Controls Only;

4. Combination of LID Source Controls and LID Conveyance Controls;

5. Combination of LID Source Controls and Dry pond end-of-pipe Controls;

6. Combination of LID Source Controls, LID Conveyance Controls and Dry pond end-of- pipe Controls;

7. Combination of LID Conveyance Controls and Dry pond end-of-pipe Controls:

8. Stream Restoration Measures (Note- this alternative is common to all others as it will be implemented regardless of which alternative is preferred).

The Detailed Assessment is a much more rigorous and thorough assessment of each alternative, based on a set of 21 selection criteria. The criteria developed to satisfy the SWM objectives were used to score the alternative and select/identify the preferred alternative.

The twenty-one (21) SWM Assessment Criteria developed for the Phase 2 Detailed Assessment include:

<u>Physical and Natural Environment Criteria</u>

• Ability to meet targets for Water balance and mitigate impacts to surface drainage and groundwater, soils and geology;

• Ability to meet criteria for flooding, water quality and erosion;

• Impact on terrestrial and aquatic habitat: Connectivity, Diversity and Sustainability

Social, Economic and Cultural Environment Criteria

•Impact on existing and proposed development, including agricultural land uses;

• Aesthetic value;

• Integration with Eco-Industrial design approach and compatibility with proposed land-use;

• Potential benefit to community and public acceptance;

• Coordination with proposed roadway design; and

• Built Heritage/ Cultural and Archaeological Heritage.

Technical Criteria

• Level of service- proven effectiveness;
• Regulatory agency acceptance (Municipal, Provincial, Federal and CA);
• Policy and by-law requirements;
• Impact on existing infrastructure;
• Constructability; and
• Available and suitable surface outlets.

Financial Criteria

• Capital costs;
• Operation and maintenance costs;
• Impact on property value; and
• Phasing considerations.

A description of the individual Phase 2- Detailed Assessment criteria and measures for assessment are provided in Table 2.2- 2.5. Applying the primary criteria, a matrix illustrating the Detailed Assessment (Phase 2) of the eight (8) SWM Alternatives for the AEGD is presented in Table 2.6.

Table 2.2: Description of the Physical and Natural Environment Criteria used in the Phase 2

Criteria	Description of Criteria	Measures for Assessment
Ability to meet targets for Water balance	• Ability of the SWM alternative to mitigate undesired impacts to the pre-development water balance and prevent adverse changes to site hydrology (surface drainage, groundwater, soils and geology). • At a minimum, the technique must maintain the pre-development groundwater recharge.	Scoring ranges from 4 if the potential to mitigate changes to the pre-development water balance is high, to 1 if the potential to mitigate water balance changes are low and post-development changes are anticipated.
Ability to meet targets for Flooding	• Ability of the SWM alternative to meet flood control criteria. Alternative must control peak outflows to pre-development rates for design storms with return period up to 100yrs. • Cannot increase flooding risks to infrastructure and private property.	Scoring ranges from 4 if the potential to meet flooding criteria is high, to 1 if the potential is low and downstream flooding is anticipated.

Ability to meet targets for Water quality	• Ability of the SWM alternative to meet water quality criteria as per the 2003 MOE Stormwater Management Manual.	Scoring ranges from 4 if the potential to meet water quality criteria is high, to 1 if the potential is low and water quality impacts are anticipated.
Ability to meet targets for Erosion	• Ability of the SWM alternative to control water course erosion in accordance with the 2003 MOE Stormwater Management Manual.	Scoring ranges from 4 if the potential to erosion criteria is high, to 1 if the potential is low and erosion impacts are anticipated.
Impact on terrestrial and aquatic habitat: Connectivity, Diversity and Sustainability	• Potential for the SWM alternative to mitigate impacts to terrestrial and aquatic habitat. • Ability for the SWM alternative to provide opportunities for connectivity, diversity and sustainability for terrestrial and aquatic habitats.	Scoring ranges from 4 if the potential to mitigate impacts to terrestrial and aquatic habitat and provide additional opportunities for connectivity, diversity and sustainability is high, to 1 if the potential is low and impacts are anticipated.

Table 2.3: Description of the Social and Cultural Environment Criteria used in the Phase 2 Detailed Assessment

Criteria	Description of Criteria	Measures for Assessment
Impact on existing land uses (including agricultural)	• Potential for the SWM alternative to be integrated with the existing land uses (including agricultural) within the AEGD study area.	Scoring ranges from 4 if the potential for land use integration is high, to 1 if the potential is low.
Aesthetic value	• Potential for the SWM alternative to provide an aesthetic benefit to the existing and proposed community.	Scoring ranges from 4 if the SWM alternative has potential aesthetic value, to 1 if the potential is low.
Integration with Eco-Industrial design approach and compatibility with proposed land-use;	• Ability of the SWM to be integrated within the Eco-industrial design approach adopted for the AEGD, specifically in regards to stormwater management as listed in **Section 1.2**. • Potential compatibility of the SWM alternative with the proposed land- uses.	Scoring ranges from 4 if the potential for integration with the principles and objectives of Eco- industrial design is high, to 1 if the potential is low. Scoring also influenced by the appropriateness of SWM with respect to the proposed land-uses.

Potential benefit to community and public acceptance;	• Potential benefit to the community with respect to integration into natural areas, passive use areas, pedestrian and bike trails, as well as general public acceptance of the SWM alternatives within such areas.	Scoring ranges from 4 if the potential for integration in public areas and public acceptance is high, to 1 if the potential for integration and public acceptance is low.
Coordination with proposed roadway design per the AEGD Transportation Master Plan.	• Potential for the proposed SWM alternative to be integrated into the proposed standard roadway cross- sections within the AEGD per the AEGD Transportation Master Plan.	Scoring ranges from 4 if the potential for integration with the proposed roadway design is high, to 1 if the potential for integration is low.
Built Heritage/ Cultural and Archaeological Heritage	• Potential impacts of the proposed SWM alternative on Built Heritage/ Cultural and Archaeological Heritage significant areas/features within the AEGD identified in the Figure 6.4 and Section 6.0- Stage 1 Archaeological Assessments of the Hamilton AEGD: Land Use Report (May 2008) Potential Impacts are high throughout the AEGD study area as per the Hamilton AEGD: Land Use Report (May 2008) and Figure 6.4. A major predictor of pre-contact archaeological	Scoring ranges from 4 if the potential for impacts to identified Built Heritage/ Cultural and Archaeological Heritage sites impact is low, to 1 if potential impacts are high. Note: Based Hamilton AEGD: Land Use Report (May 2008), all facilities were assessed as having a high potential impacts (Scored a 1 in Table 2.6).

Table 2.4: Description of the Technical Criteria used in the Phase 2 Detailed Assessment

Criteria	Description of Criteria	Measures for Assessment
Level of service- proven effectiveness	• Degree to which the SWM alternative has been proven effective through scientific literature, implementation and/or monitoring.	Scoring ranges from 4 if the SWM alternative has been proven effective, to 1 if the alternative is unproven.
Regulatory agency acceptance	• General level of acceptance of the SWM alternative by the various regulatory agencies (Municipal, Provincial, Federal and CA)	Scoring ranges from 4 if the SWM alternative is generally accepted by the various regulatory agencies, to 1 if the alternative is generally not accepted.
Policy and by-law requirements	• Degree to which the SWM alternative will be impacted by or contradict existing policy and by-law requirements	Scoring ranges from 4 if there is no interference with existing policy and by-law requirements, to 1 if significant interference with existing policies existing.
Impact on existing infrastructure	• Potential impacts on existing infrastructure (services, roads, etc)	Scoring ranges from 4 if the potential impacts are high, to 1 if the expected impacts are low.
Constructability	• Degree of difficulty in constructing the SWM alternative given the existing site conditions and constraints.	Scoring ranges from 4 if the general constructability is high, to 1 if it is low.
Available and suitable surface outlets	• Degree of difficulty in locating and engineering a suitable stormwater outlet given existing surface water feature constraints (headwaters, low slope, sluggish systems).	Scoring ranges from 4 if the potential for a suitable outlet is high, to 1 if the potential is low and locating a surface outlet may not be possible.

Table 2.5: Description of the Financial Criteria used in the Phase 2 Detailed Assessment

Criteria	Description of Criteria	Measures for Assessment
Capital costs	• The relative cost of constructing the SWM alternative.	Scoring ranges from 4 if the relative construction cost is low, to 1 if the relative cost is high.
Operations and Maintenance Costs	• The relative cost of operating and maintaining the SWM alternative	Scoring ranges from 4 if the relative cost of maintenance is low, to 1 if the relative cost is high.
Impacts on property value	• Potential impacts (positive or negative) to local property value, based on aesthetic benefits, potential land-use synergies and general economic incentives. • Criteria based on peer reviewed literature relating to property value including: ○ Urban trees, proximity to natural environment (Speirs, 2003) and woodlots (Kim and Johnson, 2002), inclusion of and landscaping and trees (Anderson and Cordell, 1988), as well as observed and reported buyer preference to properties adjacent to naturalized and LID SWM techniques (Guelph, 1998-Present; Dixon, J.M., et.al., 2005)	Scoring ranges from 4 if the potential benefit to property value is high, to 1 if the potential benefit is low.
Phasing Considerations	• Degree to which the SWM alternative can be effectively implemented as per the proposed phasing plan, See AEGD Subwatershed Study -Figure 5.0: AEGD Secondary Plan, Phasing Plan.	Scoring ranges from 4 if the potential to implement to SWM alternative as per the phasing plan is high, to 1 if the potential is low

Table 2.6: Phase 2- Detailed Assessment Matrix for Selecting the Preferred Stormwater Management Alternative for the AEGD

		Physical and Natural Environment					Social and Cultural Environments						Technical Criteria					Financial Criteria				
Alternative #		Water Balance	Flooding	Water Quality	Erosion	Terrestrial & Aquatic Habitat	Existing Land Uses	Aesthetic Value	Consistency with Eco-Industrial Design	Benefit to Community & Public Acceptance	Coordination with proposed roadway design	Cultural heritage and archaeological	Level of service-proven effectiveness	Policy and by-law requirements	Impact on existing infrastructure	Constructability	Available and suitable surface outlets	Capital costs	Operations and Maintenance Costs	Impacts on property value	Phasing Considerations	**Aggregate Score**
1	Dry Pond end–of-pipe Only	1	4	2	4	2	3	2	4	2	3	1	4	1	4	4	3	4	4	2	3	58
2	LID Conveyance Controls Only	2	1	3	3	4	4	3	4	2	4	1	4	1	2	3	3	3	2	4	4	58
3	LID Source Controls Only	4	1	4	4	4	4	4	4	3	4	1	3	1	3	2	4	1	1	4	4	61
4	LID Source Controls and LID Conveyance Controls	4	2	4	4	4	4	4	4	3	4	1	4	2	3	3	4	2	1	4	4	67
5	LID Source Controls and Dry pond end-of-pipe controls	4	3	4	4	4	4	3	4	3	3	1	4	2	3	4	3	3	2	3	4	67
6	**LID Source, LID Conveyance Controls and Dry pond end- of-pipe controls**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**1**	**4**	**2**	**3**	**3**	**3**	**2**	**2**	**4**	**4**	**72**
7	Conveyance Controls and Dry pond end-of-pipe controls	2	4	2	4	3	4	3	4	3	4	1	4	3	3	3	3	3	3	3	4	65
8	Stream Restoration Measures (Riparian Plantings)*	2	2	4	4	4	4	4	4	4	3	1	4	4	3	1	4	4	1	4	4	71

***Note-Alternative number 8- Stream restoration is common to all others as it will be implemented regardless of which alternative is preferred**

Phase 2 – Detailed Assessment Preferred Alternatives

- The preferred SWM alternative for the AEGD study area is Alternative 6- LID Source Controls in combination with LID Conveyance Controls and end-of-pipe Dry Ponds facilities, along with Stream Restoration Measures, consistent with the Ministry of the Environment's Treatment train approach to stormwater management. Proposed stream restoration measures are to consist of riparian planting in accordance with the AEGD Subwatershed Plan (Figure 6.0: Recommended Natural Heritage System) and the recommended stormwater master plan.
- Low Impact Development (LID) source and conveyance controls provide aquatic habitat protection, water quality, erosion, and water balance control, while dry-ponds provide flood protection (Note: with Alternatives #2 and #3- LID Conveyance Control Only and LID Source Control Only respectively, the potential to provide flood protection is low (score =1) and downstream flooding is anticipated, therefore Alternative #6 includes Dry ponds for flood protection). Stream restoration provides the additional benefits of improved stream corridor functions, moderating stream temperatures and improving aquatic and terrestrial habitat conditions. The complexity of the existing surface drainage systems and resources, requires site specific, integrated solutions, such as those included in the LID suite of techniques, that can adequately deal not only with water quality, but also infiltration, erosion and natural features concerns.

The following sections detail the implementation consideration of the preferred alternative (Alternative 6- LID Source Controls in combination with LID Conveyance Controls and end-of-pipe Dry Ponds) for the AEGD.

3.0 RECOMMENDED STORMWATER PLAN

3.1 BACKGROUND

3.2 OVERVIEW OF LOW IMPACT DEVELOPMENT (LID) SOURCE CONTROLS

3.2.1 RAINWATER HARVESTING

3.2.2 GREEN ROOFTOPS

3.2.3 DOWNSPOUT DISCONNECTION

3.2.4 SOAKAWAY PITS

3.2.5 BIORETENTION

3.2.6 SPECIAL BIORETENTION

3.2.7 SOIL COMPOST AMENDMENTS

3.2.8 TREE CLUSTER

3.2.9 FILTER STRIPS

3.2.10 PERMEABLE PAVEMENT

3.3 OVERVIEW OF LOW IMPACT DEVELOPMENT (LID) CONVEYANCE CONTROLS

3.3.1 DUAL DRAINAGE CONCEPT: DESIGN OF MINOR AND MAJOR SYSTEMS

As part of the 'Dual Drainage Concept', whereby stormwater drainage is managed using a combination of a:

• minor system, removing surface runoff from more frequent storms and deliver it to receiving waters ;and

• major system, consisting of overland flow routes (roads, drainage swales etc) and end- of-pipe stormwater management facilities;

LID conveyance controls are intended to function as the minor system for the AEGD. As such the LID conveyance controls should be designed as a minor system in compliance with the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips- 2007). Other design considerations during site planning may include the following:

• LID conveyance systems (see Section 3.3.2) should convey flow from the ROW and adjacent development areas from the upstream end to the centralized dry pond (SWM facility;

• LID conveyance systems (see Section 3.3.2) should be designed to accommodate/ convey flows underneath driveways (using culverts/ perforated pipes etc.)

• LID conveyance systems are to have the capacity to accommodate flows from the outlets from adjacent development (pipes, open channels, Other LID conveyance controls)

• LID conveyance techniques should be combined or stacked (perforated pipes, gravel storage areas, infiltration/filtration media, enhanced landscaping) to provide additional water quantity/quality benefits.

- The LID conveyance control measures may only be feasible in selected areas of the development, where soils and groundwater elevations permit. Furthermore, these measures may not be feasible within conventional residential development areas in which an urban ROW (i.e. curb & gutter vs. rural section) is required.

The AEGD, as with all developments, will require a major system - the overland route the excess runoff will follow when the minor system capacity is surpassed or is inoperable. The major system exists whether it is deliberately designed or not, therefore it is vital in the initial planning stages, to recognize the need for a continuous grade to convey runoff in excess of the minor system capacity to a free outlet.
Major system capture in to the minor system may be required to avoid major system discharge across larger ROWs and to ensure adequate capture of flows into the minor system (vs. discharge onto external ROWs).

The major system includes such features as natural and constructed open channels, streets and roadways, drainage easements and stormwater management facilities. The major system should be designed in compliance with the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips- 2007).

3.3.2 LID CONVEYANCE OPTIONS

3.3.3 GRASS CHANNELS

3.3.4 DRY SWALES

3.3.5 SUBSURFACE PERFORATED PIPE EXFILTRATION SYSTEMS (SOAKAWAY PIT VARIANT)

3.4 END-OF PIPE DRY PONDS ASSESSMENT

3.5 LID BMPS IN RELATION TO AEGD LAND-USES

3.5.1 CRITERIA FOR EVALUATION

3.5.2 IDENTIFICATION OF APPROPRIATE LID TECHNIQUES FOR THE PRIMARY AEGD LAND USES

3.5.2.1 HIGH RISK LAN USE

3.6 STREAM RESTORATION MEASURES – RIPARIAN PLANTING

3.7 ECONOMICS OF LID SOURCE AND CONVEYANCE CONTROLS

4.0 ENVIRONMENTAL CRITERIA DEVELOPMENT

4.1 HYDROLOGIC AND HYDRAULIC MODELING

The hydrologic response of the study area under the existing and proposed land use conditions has been characterized using hydrologic modeling computer software. Computer modeling simulations and spreadsheet analysis have been conducted to provide surface runoff peak flow estimates (m3/s) and water budget components (i.e. precipitation, evapotranspiration, runoff, infiltration, etc in millimeters).

NOTE: Big Creek was not partitioned into catchments, nor set up for HSPF modeling since the majority of the lands, approximately 330 ha (330.2 ha), are entirely within the Additional Study Area (post 2031). The exception to this is the approximately 12 ha at the corner of Garner Rd East and Fiddlers Green Rd – see Section 5.5 the Council Directed Additional Lands. Development on these Council Directed Additional Lands within the Big Creek subwatershed will be subject to site-specific (lot level) controls and SWM criterion established based on the modeling results obtained from the other watersheds (these SWM criteria can be applied based on dominant soil types). Prior to Development in the remainder of the Big Creek Subwatershed, modeling should be undertaken and this study revisited given the time lapse anticipated between completion of the subwatershed study and Stormwater Master Plan and potential future development (post 2031).

As a first step, the existing conditions hydrologic response of each catchment within the Hamilton Airport Employment Growth District lands was calculated. The baseline data collected from the existing conditions assessment sets the targets for maintaining and enhancing (where possible) the quantity and quality of the study area's surface and groundwater resources. The proposed conditions hydrologic model was then constructed to characterize the hydrologic changes that will occur as the study area undergoes development. Finally, modeling scenarios are developed to determine if various stormwater management strategies are able to mitigate impacts associated with the anticipated development. Typically mitigation of impacts to the study area hydrology are possible provided that sufficient stormwater management measures are implemented.
The following section:

1. Describes the modeling objectives for the AEGD; and

2. Provides guidance on the design and sizing stormwater measures required to mitigate of potential environmental impacts over the range of existing environmental conditions and future development patterns anticipated over the AEGD lands.

Study Data

The following information sources were used in the preparation of this hydrology section:

• 1:10,000 Ontario Base Mapping over the three study areas;

• 1 m contour mapping and aerial photography (2005) of the study area;

• Creek flow observations, photographs and measurement

• Known surface runoff flows at several locations within the study area;

• Watercourse mapping, including field confirmation;

• Surficial Geology Maps produced by the Ontario Geological Survey, Ministry of Northern Development and Mines Queen's Printer for Ontario 2003; and

• Meteorological Data from the John C Munro Hamilton International Airport rainfall Gauge (Environment Canada Gauge # 61543194);

• Urban Hamilton Official Plan: Airport Employment Growth District Secondary Plan

4.1.1 SURFACE RUNOFF PEAK FLOW ESTIMATES

The pattern of the movement of surface runoff (overland flows) within the AEGD is illustrated for each study area on Figure 4.0- Hydrologic Subcatchments. This illustrate distinct parcels of land (catchments) each draining to a watercourse and formed the basis of the hydrologic modeling work undertaken as part of this study.

Surface runoff peak flow estimates have been calculated at the outlet of each catchment at the indicated flow node locations as illustrated on Figure 4.0. Peak flow estimates have been calculated at these flow nodes for the existing and proposed land use conditions using the hydrologic model SWMHYMO (Version 4.02). SWMHYMO is an event-based hydrologic model widely used to determine runoff characteristics for rural and urban watersheds. This model generates storm hydrographs using the Soil Conservation Service Curve Number Method of estimating runoff characteristics.

To develop SWMHYMO models for existing conditions, the following was undertaken:

• Selection of rainfall gauge and associated design rainfall parameters;

• Determination of topographic elevations from 0.5 m contour mapping;

• Determination land use characteristics from aerial photographs;

• Definition of hydrologic soil characteristics (as described below); and

• Estimation of modeling parameters for each subcatchment.

The NASHYD routine in SWMHYMO was used to simulate existing conditions hydrographs and peak runoff flows from catchment areas. The NASHYD routine is commonly used to simulate the runoff from natural and rural areas and requires the drainage area, composite curve number, time to peak, and available storage as inputs. These hydrologic parameters were determined for each drainage area through consideration of the soils, topography and land use conditions found within the AEGD.

For each drainage area, the time to peak was determined using the SCS Upland Method, the SCS CN Method, the Bransby Williams Method and the Airport Method and the results were averaged to provide a single estimate of time to peak. If one or more of these methods of calculating time to peak was not applicable due to the characteristics of a particular drainage area (size, land use etc.), it was removed from the average.

Existing land uses within the watersheds were compiled using (Geographic Information System) and are summarized in Appendix C. All land use categories were analyzed in conjunction with three major hydrologic soil groups; AB, BC and CD summarized also in Appendix C.

The STANDHYD routine in SWMHYMO was used to simulate the proposed conditions hydrology and peak runoff flows from urban catchment areas. The STANDHYD routine requires the following inputs:

1. The drainage area;

2. The pervious area curve number;

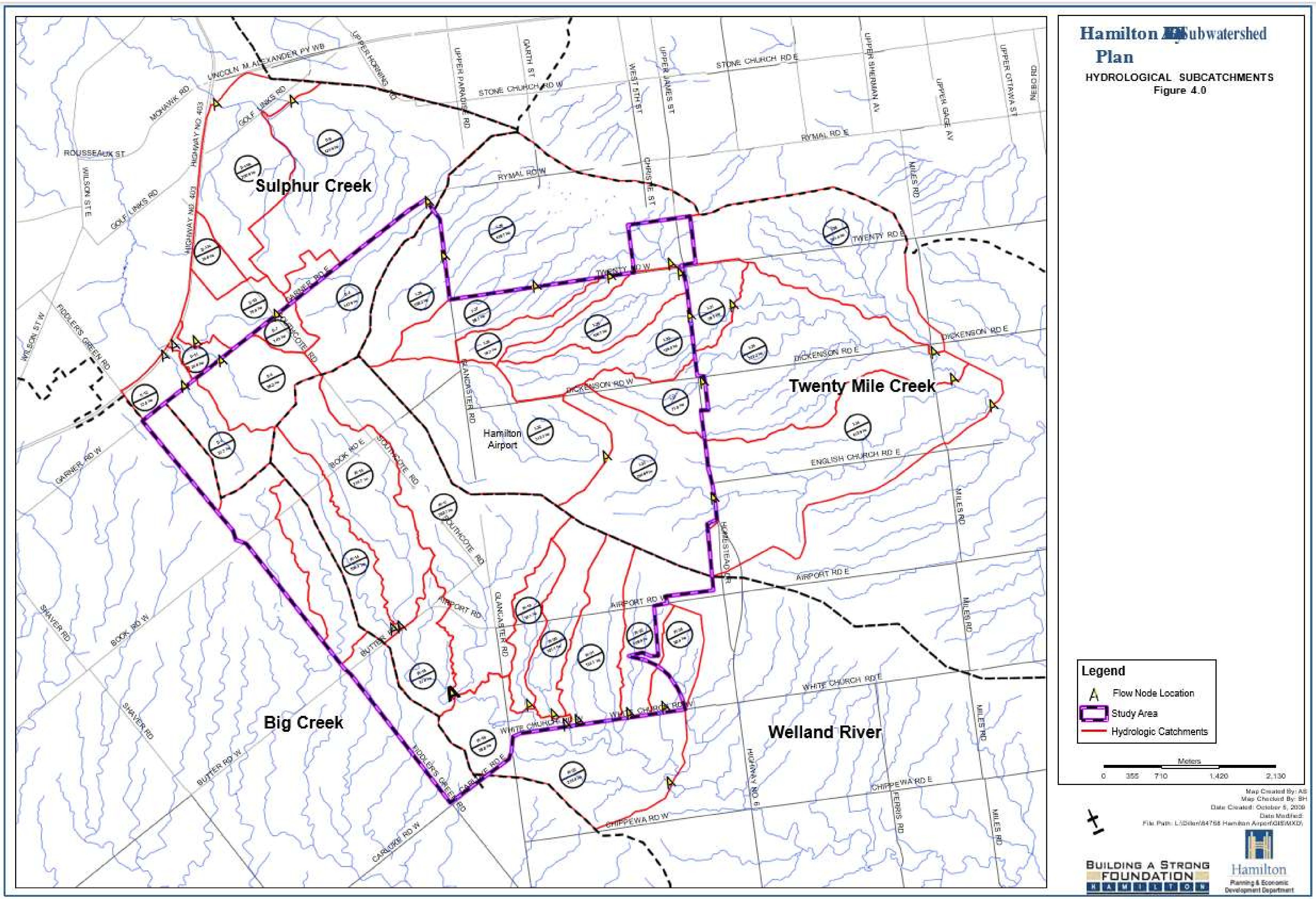
3. The total imperviousness of the drainage area;

4. The percentage of the impervious area that is directly connected;

5. The depression storage for pervious and impervious areas; and

6. The average length, slope and roughness of the flow path for pervious and impervious area

Drawings STM-1 and STM-2 illustrate the existing and proposed drainage areas used in the hydrologic modelling. The drainage areas in these figures have been discretized in more detail for the scoped study area compared to the original AEGD SWS.


Hamilton Subwatershed Plan
HYDROLOGICAL SUBCATCHMENTS
Figure 4.0
Sulphur Creek
Twenty Mile Creek
Big Creek
Welland River
Hamilton Airport
Legend
Flow Node Location
Study Area
Hydrologic Catchments
Meters
0 355 710 1,420 2,130
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HAMILTON
Hamilton
Planning & Economic Development Department

These proposed conditions hydrologic parameters were determined for each drainage area through consideration of the soils, topography and the proposed land uses as illustrated in AEGD Subwatershed Study (Part A) - Figure 5.0.

The John C Munro Hamilton Airport rainfall records were used along with the 24hr SCS Type II Storm distribution to generate the 2yr, 5yr, 25yr, 50yr and 100yr design rainfall events for the SWMHYMO model. For large rural watersheds, the SCS Type II Storm distribution produces higher peak flows than shorter and more intense rainfall distributions such as the Chicago storm distribution.

The hydrologic input parameters to the SWMHYMO model, as well as the SWMHYMO input and summary output files for the existing and proposed conditions are presented in Appendix D. The surface water peak flow estimates for each catchment area (as depicted in the drainage mosaic – hydrologic subcatchments) are presented in Tables 4.2 and 4.3)

Note that Visual OTTHYMO has been used in place of SWMHYMO. Simulations were completed to demonstrate that the peak flows calculated by VO are consistent with the SWMHYMO results.

4.1.2 PREVIOUS HYDROLOGIC ESTIMATES FOR THE STUDY AREA – KNOWN FLOW LOCATIONS

Surface water peak flows have been previously reported for streams within and downstream of the Hamilton Airport Employment Growth District. There flows were reported in the:

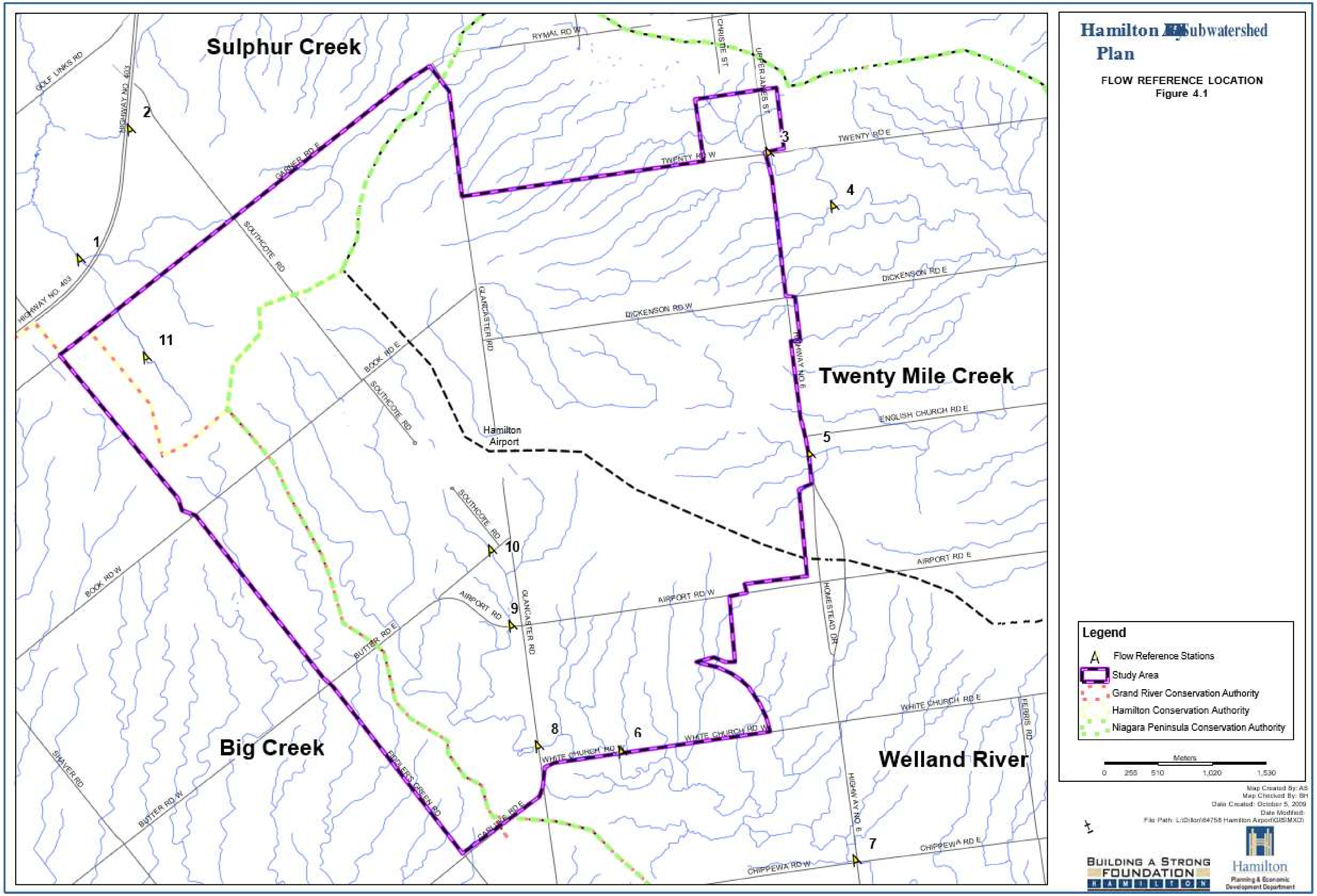
1. Welland River Floodplain Mapping Study, Phillips Planning and Engineering Ltd., 1999;

2. Garner Neighborhood Master Drainage Plan, Phillips Engineering, 2005; and

3. Niagara Peninsula Conservation Authority Twenty Mile Creek Floodplain Mapping , Aug 2005 (revised Aug 2007)

Details on how the flows presented in previous studies were calculated are presented in Appendix E.

There are 6 locations where previously reported flows coincide with points of interests for the current study area. These locations were used to verify model performance. All six locations of known hydrologic data are illustrated on Figure 4.1. Comparison of hydrologic results for the previous and current hydrologic modeling for the large storm events (2yr, 5yr, 10yr, 25yr, 50yr and 100yr) at these six locations was performed to verify that the model is performing well during periods of high flows (Table 4.1)


Hamilton Subwatershed Plan
FLOW REFERENCE LOCATION
Figure 4.1
Sulphur Creek
Twenty Mile Creek
Big Creek
Welland River
Hamilton Airport
RYMAL RD W
CHRISTIE ST
UPPER JAMES ST
TWENTY RD E
TWENTY RD W
DICKENSON RD E
DICKENSON RD W
ENGLISH CHURCH RD E
AIRPORT RD E
AIRPORT RD W
AIRPORT RD
WHITE CHURCH RD E
WHITE CHURCH RD W
CHIPPEWA RD E
CHIPPEWA RD W
GARNER RD E
GOLF LINKS RD
HIGHWAY NO. 403
SOUTHCOTE RD
BOOK RD E
BOOK RD W
GLANCASTER RD
HIGHWAY NO 6
HOMESTEAD DR
BUTTER RD E
BUTTER RD W
FIDDLERS GREEN RD
CARLUKE RD E
SHAVER RD
FERRIS RD
1
2
3
4
5
6
7
8
9
10
11
Legend
Flow Reference Stations
Study Area
Grand River Conservation Authority
Hamilton Conservation Authority
Niagara Peninsula Conservation Authority
Meters
0 255 510 1,020 1,530
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In the Sulphur Creek and Twenty Mile Creek Watersheds, previously reported flows generally correspond well with estimates determined in the current study using SWMHYMO. For the Welland River watershed the initial flow estimates determined using SWMHYMO were significantly lower in comparison to flows reported in the Welland River Floodplain Mapping Study (Phillips Planning and Engineering Ltd., 1999).

There were no previous flow estimates reported within the Welland River portion of the current study area. Previous flow estimates at Node 5 (flow reference station 7 which is approximately 1 kilometer downstream of the outlet of s/c W-23) were used to determine flows at points of interest within the current (Welland River) study area. Flows were calculated within the current study area using an empirical formula to prorate the flows based on the difference in area. The flow estimates determined in the current study were then compared to the prorated flows.

Flows previously reported at Node 5 from the Welland River Floodplain mapping study were derived from a partially calibrated model (see Appendix E for details). To match the previous flow estimates (prorated flows from Node 5) SWMHMO model input parameters were modified from initial estimates. Modifications were performed on two representative subcatchments and then applied to all catchments within the Welland River watershed.

Modifications to the Welland River SWMHYMO model included: 1) reduction in the watershed timing parameter (time to peak) by approximately 50% and 2) modifications to the routing parameters to increase the flow estimates produced using design storms up to the 10yr event, but to decrease flow estimates produced for the 25yr, 50yr and 100yr rainfall events. The ‘modified’ flow estimates are presented in Table 4.1 and match the previously reported flows well.

4.1.3 RESULTS OF HYDROLOGIC MODELING

The surface water runoff flows calculated in previous studies along with the corresponding flows calculated in this study for the Sulphur Creek, Welland River and Twenty Mile Creek Watersheds are presented in Table 4.1.

Table 4.1: Previously Reported Flow estimates in Comparison to Flows Calculated in this Study for Existing Conditions Modeling

Watershed	Flow Reference Station	Corresponding S/C ID	Location	Drainage Area (ha)	2yr Storm		5yr Storm		10yr Storm		20yr Storm		50yr Storm		100yr Storm	
					Previous Estimate	Current Study	Previous Estimate	Current Study	Previous Estimate	Current Study	Previous Estimate	Current Study	Previous Estimate	Current Study	Previous Estimate	Current Study
Sulphur Creek	11	S- 5	101.1	81.7	0.71	0.33	1.33	0.67	1.81	0.93	2.47	1.29	3.01	1.58	3.58	1.88
	1	S-5 + S-12 + S-6 + S-11 + S-7 + S- 10	105.2	343.3	3.04	2.20-4.23	4.88	3.94-6.39	6.38	5.28-7.99	8.63	7.18-10.41	10.42	8.67-12.42	12.37	10.20-14.25
Welland River	9	W-17	Prorated from Node 5[2]	393.7	11.82	8.72	15.12	13.65	17.23	17.05	19.22	21.41	21.77	24.67	23.64	27.93
	6	W-14 to W-20	Prorated from Node 5[2]	1053.3	24.72	18.31-21.45	31.64	26.34-30.62	36.05	31.58-36.68	40.21	38.17-44.55	45.53	43.07-55.04	49.45	47.90-63.87
	na	All Welland River Catchments	Prorated from Node 5[2]	1570.2	33.36	30.76-33.08	42.69	42.95-44.98	48.63	50.44-52.54	54.24	59.62-62.08	61.43	66.27-70.68	66.71	72.82-77.86
	7	na	Node 5 – Hwy6 & Chippewa Rd	2027.2	40.40	na[1]	51.70	na[1]	58.90	na[1]	65.70	na[1]	74.40	na[1]	80.80	na[1]
Twenty Mile Creek	3	T-29	TwCK 57 – Upper James, South of Twenty Mile Rd.	100.7	0.75	0.77	1.31	1.34	-	1.76	-	2.31	-	2.73	3.20	3.16
	4	T-30 + T -31	TwCK-60 – d/s of Upper James	185.1	1.12	1.72	2.16	3.04	-	3.93	-	5.15	-	6.10	5.72	7.05
	5	T-32 + T-33	ThCK 3 – Upper James, South of English Church Rd.	567.3	0.80	4.01	1.36	6.75	-	8.70	-	11.34	-	13.34	3.93	15.42

Notes: 1 Previously reported flows at Node 5 were used to determine flows at points of interest within the current study area using an empirical formula to prorate the flows based on area.
2 Flow reported in ranges (e.g. 5.1-6.3) provide a high flow rate for the assumption of no Stormwater management (attenuation) in existing urban areas, and a lower flow rate for the assumption that all existing urban areas flows are controlled to predevelopment levels. If a portion of the existing area receives stormwater treatment then the expected flow would fall somewhere within the given range.

The verified SYMHYMO models for each watershed were used to calculate design surface runoff flow estimates for large rainfall events at each catchment illustrated on the drainage mosaic (Figure 4.0). The surface water peak flow estimates calculated at the outlet of each catchment area are presented in Tables 4.1 and 4.3.

Some of the flows in Tables 4.2 and 4.3 are reported in ranges (e.g. 5.1-6.3). The ranges are used due to uncertainty regarding the level of stormwater control utilized in existing urban areas. It is beyond the scope of this study to understand the details of each urban drainage system due to the size of the study area. Where ranges are provided the high flow rate represents the condition of no stormwater management (attenuation) in existing urban areas. The lower flow rate represents the condition that in all existing urban areas flows are controlled to predevelopment levels (i.e. full regulatory compliance). If only a portion of the existing urban area receives stormwater treatment then the expected flow would fall somewhere within the given range.

In general the surface flow estimates generated using SWMHYMO correspond well to previously reported estimates for Sulphur Creek and for Twenty Mile Creek. This provides confidence in the modeling results. For the Welland River Watershed, the modified SWMHYMO input parameters produce flows that are higher than the initial SWMHYMO results or estimates. However, the modifications are necessary to provide estimates that correspond with the available information.

Table 4.2: Hydrologic Analysis for Sulphur Creek Watershed and Welland Creek Watershed														
Catchment ID #	Contributing Catchments	Drainage Area (ha)	Surface Runoff Flows (m^3/s) Generated by the Hydrologic Model SWMHYMO											
			2 Year Storm		5 Year Storm		10 Year Storm		25 Year Storm		50 Year Storm		100 Year Storm	
			Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM
Sulphur Creek Watershed														
S-5		81.7	0.33	3.94	0.67	6.03	0.93	7.82	1.29	9.94	1.58	11.61	1.88	14.12
S-6		99.2	0.71	5.72	1.33	8.98	1.79	11.19	2.44	14.12	2.94	17.25	3.45	19.70
S-7		26.2	0.42-1.80	1.98	0.74-2.93	3.23	0.98-3.61	3.98	1.30-4.52	4.96	1.55-5.22	5.71	1.80-6.29	6.86
S-8		147.9	0.96	8.22	1.69	13.01	2.24	16.74	2.97	21.06	3.54	24.39	4.12	29.13
S-9		424.8	2.39-9.91	No Change	4.22-18.68	No Change	5.57-24.16	No Change	7.38-34.72	No Change	8.79-41.73	No Change	10.22-52.82	No Change
S-10		78.1	0.55	No Change	1.05	No Change	1.43	No Change	1.95	No Change	2.36	No Change	2.78	No Change
Sum	S7 + S10	104.3	0.90-1.29	1.83	1.68-1.93	2.91	2.27-2.42	3.65	3.07-3.10	4.62	3.67-3.65	5.34	4.29-4.17	6.25
S-11		20.6	0.21-0.73	No Change	0.52-1.21	No Change	0.69-1.59	No Change	0.91-2.06	No Change	1.08-2.61	No Change	1.26-3.03	No Change
Sum	S6 + S11	119.8	0.90-0.78	5.85	1.57-1.42	9.16	2.09-1.89	11.66	2.81-2.54	14.94	3.39-3.07	18.28	3.98-3.61	20.56
S-12		37.5	1.02-2.84	No Change	1.81-4.12	No Change	2.39-5.07	No Change	3.12-6.66	No Change	3.76-7.81	No Change	4.37-8.82	No Change
Sum	S5 + S12	119.2	1.04-2.85	6.42	1.88-4.13	9.44	2.51-5.12	11.93	3.36-6.75	14.49	4.02-7.94	16.93	4.69-9.0	19.99
S-13A		35.6	0.82-2.58	No Change	1.46-3.74	No Change	1.93-4.96	No Change	2.55-6.11	No Change	3.03-7.20	No Change	3.53-8.14	No Change
S-13B		200.9	1.73-4.72	No Change	3.08-8.47	No Change	4.08-11.92	No Change	5.42-15.75	No Change	6.45-20.58	No Change	7.50-24.22	No Change
Sum	S8 + S9 + S13b	773.6	4.47-12.61	19.13	7.78-22.26	33.90	10.22-29.08	45.01	13.51-39.34	60.78	15.98-47.12	73.11	18.42-58.16	89.67
Welland Creek Watershed														
W-14		106.3	2.15	2.44	3.54	6.06	4.52	8.51	5.80	11.21	6.78	14.54	7.76	16.97
W-15		214.7	1.60-8.74	No Change	2.72-14.56	No Change	3.52-18.45	No Change	3.52-25.64	No Change	5.44-30.08	No Change	6.30-34.65	No Change
W-16		87.0	3.06	4.05	4.79	6.78	5.97	8.62	7.48	11.91	8.60	14.00	9.73	16.13
W-17		393.7	8.72	16.67	13.65	28.16	17.05	35.93	21.41	49.35	24.67	57.84	27.93	66.47
Sum	At outlet of s/c 16	801.7	13.89-18.21	29.01	21.62-28.13	49.12	26.86-34.89	63.77	33.58-43.39	49.35	38.60-49.95	57.84	43.66-56.52	66.47
W-18		60.7	2.20	No Change	3.40	No Change	4.22	No Change	5.26	No Change	6.05	No Change	6.83	No Change
W-19		89.8	2.43	5.83	3.76	9.02	4.66	11.17	5.83	14.00	6.69	17.01	7.56	19.37
W-20		101.1	4.01	No Change	6.07	No Change	7.47	No Change	9.23	No Change	10.55	No Change	11.85	No Change
W-21		132.1	3.64	No Change	5.51	No Change	6.77	No Change	8.36	No Change	9.55	No Change	10.73	No Change
Sum	At outlet of s/c 19	1,185.4	18.31-21.45	30.05	26.34-30.62	49.61	31.58-36.68	63.89	38.17-44.55	86.71	43.07-55.04	102.63	47.90-63.87	119.89
W-22		109.9	3.40	5.75	5.21	9.77	6.45	12.39	8.00	17.25	9.15	20.10	10.31	22.99
W-23		214.0	6.04	No Change	9.43	No Change	11.77	No Change	14.76	No Change	17.06	No Change	19.24	No Change
W-24		60.9	2.21	3.08	3.41	5.47	4.24	7.01	5.28	9.06	6.07	10.63	6.85	11.94
Sum	All Welland River Catchments	1,570.2	30.76-33.08	41.37	42.95-44.98	65.41	50.44-52.54	81.74	59.62-62.08	105.50	66.27-70.68	122.69	72.82-77.86	140.74

Table 4.3: Hydrologic Analysis for Twenty Mile Creek Watershed

Catchment ID #	Contributing Catchments	Drainage Area (ha)	Surface Runoff Flows (m^3/s) Generated by the Hydrologic Model SWMHYMO											
			2 Year Storm		5 Year Storm		10 Year Storm		25 Year Storm		50 Year Storm		100 Year Storm	
			Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM	Existing Land use	Future No SWM
Twenty Mile Creek Watershed														
T-25		108.2	1.10	6.34	1.90	10.13	2.47	13.17	3.24	16.53	3.83	19.10	4.42	22.89
T-26		439.7	3.27-16.76	16.76	5.55-27.37	27.38	7.22-36.77	36.77	9.43-47.31	47.31	11.15-55.55	55.55	12.89-67.50	67.50
T-27		99.1	1.57	6.41	2.57	10.17	3.28	12.60	4.21	15.77	4.90	19.23	5.61	21.81
T-28		59.2	0.42	4.64	0.72	6.95	0.94	8.51	1.24	10.95	1.46	12.60	1.69	15.03
Sum	At outlet of s/c 26	706.2	6.40-17.02	37.34	11.02-28.13	59.93	14.39-37.78	80.68	18.65-48.81	102.90	21.91-57.45	121.02	25.20-69.80	143.67
T-29		100.7	0.77	6.31	1.34	9.66	1.76	12.43	2.31	15.54	2.73	17.96	3.16	21.50
T-30		126.0	1.16	6.99	2.02	11.34	2.65	14.87	3.48	18.73	4.12	21.70	4.78	26.16
T-31		59.1	0.68	No Change	1.21	No Change	1.59	No Change	2.12	No Change	2.52	No Change	2.93	No Change
Sum	At outlet of s/c 31	992.0	7.88-16.38	43.15	13.64-27.33	68.94	17.80-35.99	91.90	23.12-46.80	116.96	27.20-55.23	135.92	31.31-66.51	157.73
T-32		312.3	2.83	18.37	4.74	29.11	6.10	36.00	7.91	47.38	9.28	54.72	10.67	63.46
T-33		255.0	1.35	2.99	2.36	4.73	3.10	5.95	4.09	7.51	4.85	8.69	5.63	9.87
Sum	T32 + T33	567.3	4.01	19.10	6.75	29.47	8.7	36.13	11.34	46.40	13.34	53.03	15.41	60.50
T-34		413.9	1.19	No Change	3.29	No Change	4.30	No Change	5.64	No Change	6.67	No Change	7.73	No Change
Sum	T32 + T33 + T34	981.2	5.24	18.64	8.63	29.14	11.19	35.89	14.49	44.90	17.14	51.20	19.82	56.93
T-35		373.2	1.55	No Change	2.70	No Change	3.55	No Change	4.67	No Change	5.54	No Change	6.43	No Change
T-36		301.4	2.18	No Change	3.64	No Change	4.69	No Change	6.07	No Change	7.12	No Change	8.19	No Change
T-37		71.0	1.17	5.09	1.98	7.71	2.57	10.14	3.34	12.66	3.93	14.57	4.53	16.48
Sum	At outlet of s/c 35	1,737.6	9.57-15.26	43.79	16.30-24.93	68.19	21.33-31.99	87.67	28.12-41.51	112.35	33.39-48.86	131.69	38.78-56.35	154.48
Sum	All Twenty Mile Catchments	2,718.8	14.72-14.82	55.89	24.69-26.94	87.14	32.18-35.17	112.31	42.13-46.35	144.45	49.99-59.03	169.20	58.00-68.89	195.25

Updates have been made to the subwatershed study modelling. The purpose of the existing subwatershed study modelling updates is to address the following objectives:

a) Confirm the existing target flows at key nodes for the range of return period events
b) Determine the impact of the proposed drainage area diversions
c) Determine the impact of the new IDF parameters based on the City of Hamilton Comprehensive Development Guidelines and Financial Policies Manual 2019

Evaluate/ Re-create "Original" AEGD model

Table 1 shows the AEGD SWMHYMO result. The "Original" AEGD model for Twenty Mile Creek in the AEGD study included input / output files from the "existing", "future", and "future with pond" conditions simulations. These models were re-created in SWMHYMO and confirmed to match the AEGD study output files.

The existing SWMHYMO model was converted to VO6 and all catchment parameters were matched, particularly the physical catchment parameters (drainage area, imperviousness, curve number, etc.). All results were generally consistent, with the exception of Catchment T-26. The catchment T-26 pervious area depression storage and flow length of pervious area were calibrated to better match the SWMHYMO model results. The overall differences in total flows is less than 0.5%. Table 2 shows the comparison AEGD's existing SWMHYMO model result to VO6 model results.

Updates to AEGD model

Urbantech used the external drainage areas from the "original" model and made minor updates to the catchments within the study area outside of the Upper West Side Landowners Group (UWS) lands. Several of the larger catchments were further discretized in order to separate lands within the study area from the larger overall catchments. This was necessary to determine the flows and SWM requirements for the subject lands.

With the exception of the proposed conditions imperviousness, drainage area (and corresponding flow lengths), Urbantech has used identical catchment parameters as in the "Original" modeling. Table 3 illustrates the existing model parameters.

The updated / existing drainage areas and outlet locations are illustrated on Drawing STM-2.

Table 4 summarizes the differences between the "original" existing conditions model and the Urbantech updated existing model. In general, the Urbantech model results for existing conditions closely match the existing AEGD model results.

Table 5 summarizes the differences between updated Urbantech VO6 model with AEGD IDF parameters and Urbantech's Updated existing VO6 model with new IDF parameters based on the City of Hamilton Comprehensive Development Guidelines and Financial Policies Manual 2019.

Table 1- Original AEGD SWS SWMHYMO RESULT – Twenty Mile Creek

Catchment ID #	Contributing Catchments	Drainage Area (ha)	SWMHYMO Flows m³/s					
			2 Year Storm	5 Year Storm	10 Year Storm	25 Year Storm	50 Year Storm	100 Year Storm
		AEGD	Existing Condition					
Twenty Mile Creek Watershed								
T-25		108.2	1.10	1.90	2.47	3.24	3.82	4.42
T-26		439.7	16.76	27.38	36.77	47.31	55.55	67.50
T-27		99.1	1.57	2.57	3.28	4.20	4.90	5.60
T-28		59.2	0.42	0.72	0.94	1.23	1.46	1.69
T-29		100.7	0.77	1.34	1.75	2.30	2.73	3.16
Sum	At outlet of 29+26	806.9	17.07	28.13	37.78	48.80	57.44	69.80
T-30		126.0	1.16	2.02	2.64	3.48	4.12	4.77
T-31		59.1	0.68	1.21	1.59	2.11	2.52	2.93
Sum	At outlet of 31	992.0	16.38	27.33	36.00	46.80	55.26	66.51
T-32		312.3	2.83	4.73	6.10	7.90	9.27	10.66
T-33		255.0	1.35	2.36	3.09	4.08	4.84	5.62
Sum	outlet 33	567.3	4.00	6.74	8.69	11.32	13.32	15.39
T-34		413.9	1.91	3.29	4.29	5.62	6.65	7.70
Sum	Outlet33 + T34	981.2	5.23	8.61	11.17	14.49	17.14	19.78
T-35		373.2	1.55	2.70	3.54	4.66	5.53	6.41
T-36		301.4	2.17	3.64	4.68	6.05	7.11	8.17
T-37		71.0	1.17	1.98	2.57	3.34	3.93	4.53
Sum	At outlet of 35	1737.6	10.44	17.12	21.95	28.46	33.46	38.49
Sum	All Twenty Mile Catchments	2718.8	15.24	24.89	31.94	41.44	48.79	56.26

Table 2- Comparison of AEGD existing SWMHYMO model results to VO6 model results

Catchment ID #	Contributing Catchments	Drainage Area (ha)	Flows m3/s																	
			2 Year Storm			5 Year Storm			10 Year Storm			25 Year Storm			50 Year Storm			100 Year Storm		
		AEGD	SWMHYMO	VO6	DIFFERENCE (%)	SWMHYMO	VO6	DIFFERENCE (%)	SWMHYMO	VO6	DIFFERENCE (%)	SWMHYMO	VO6	DIFFERENCE (%)	SWMHYMO	VO6	DIFFERENCE (%)	SWMHYMO	VO6	DIFFERENCE (%)
Twenty Mile Creek Watershed																				
T-25		108.2	1.10	1.10	0.3	1.90	1.90	-0.3	2.47	2.47	0.0	3.24	3.24	0.0	3.82	3.82	0.0	4.42	4.42	0.0
T-26		439.7	16.76	18.68	11.5	27.38	29.95	9.4	36.77	39.71	8.0	47.31	50.54	6.8	55.55	58.95	6.1	67.50	67.56	0.1
T-27		99.1	1.57	1.57	0.0	2.57	2.57	0.0	3.28	3.28	0.0	4.20	4.20	0.0	4.90	4.90	0.0	5.60	5.60	0.0
T-28		59.2	0.42	0.41	-1.4	0.72	0.72	-0.4	0.94	0.94	-0.2	1.23	1.23	0.0	1.46	1.46	0.0	1.69	1.69	-0.1
T-29		100.7	0.77	0.77	0.4	1.34	1.34	-0.1	1.75	1.75	0.0	2.30	2.30	0.0	2.73	2.73	-0.1	3.16	3.16	0.0
Sum	At outlet of 29+26	806.9	17.07	19.04	11.5	28.13	30.76	9.4	37.78	40.70	7.7	48.80	51.99	6.5	57.44	60.80	5.8	69.80	69.80	0.0
T-30		126.0	1.16	1.16	0.1	2.02	2.02	-0.1	2.64	2.64	0.0	3.48	3.48	0.0	4.12	4.12	0.0	4.77	4.77	0.0
T-31		59.1	0.68	0.68	-0.4	1.21	1.20	-0.5	1.59	1.59	0.1	2.11	2.11	0.0	2.52	2.52	0.0	2.93	2.93	0.0
Sum	At outlet of 31	992.0	16.38	18.24	11.3	27.33	29.84	9.2	36.00	38.77	7.7	46.80	49.81	6.4	55.26	58.43	5.7	66.51	67.11	0.9
T-32		312.3	2.83	2.82	-0.2	4.73	4.73	0.0	6.10	6.10	0.0	7.90	7.89	0.0	9.27	9.27	0.0	10.66	10.66	0.0
T-33		255.0	1.35	1.35	-0.1	2.36	2.35	-0.3	3.09	3.09	0.0	4.08	4.08	0.0	4.84	4.84	0.0	5.62	5.62	0.0
Sum	outlet 33	567.3	4.00	4.00	0.0	6.74	6.74	0.0	8.69	8.68	0.0	11.32	11.32	0.0	13.32	13.32	0.0	15.39	15.39	0.0
T-34		413.9	1.91	1.91	-0.2	3.29	3.28	-0.3	4.29	4.29	0.0	5.62	5.62	0.0	6.65	6.65	0.0	7.70	7.70	0.0
Sum	Outlet33 + T34	981.2	5.23	5.23	0.0	8.61	8.61	0.0	11.17	11.17	0.0	14.49	14.45	-0.3	17.14	17.10	-0.3	19.78	19.78	0.0
T-35		373.2	1.55	1.55	0.2	2.70	2.69	-0.2	3.54	3.53	0.0	4.66	4.66	0.0	5.53	5.53	0.0	6.41	6.41	0.0
T-36		301.4	2.17	2.17	0.0	3.64	3.63	-0.3	4.68	4.68	0.0	6.05	6.05	0.0	7.11	7.10	0.0	8.17	8.17	0.0
T-37		71.0	1.17	1.17	0.0	1.98	1.98	0.0	2.57	2.57	-0.2	3.34	3.34	0.0	3.93	3.93	0.0	4.53	4.53	0.0
Sum	At outlet of 35	1737.6	10.44	10.72	2.7	17.12	17.37	1.4	21.95	22.16	1.0	28.46	28.63	0.6	33.46	33.62	0.5	38.49	38.70	0.5
Sum	All Twenty Mile Catchments	2718.8	15.24	15.43	1.3	24.89	25.06	0.7	31.94	32.09	0.5	41.44	41.55	0.3	48.79	48.88	0.2	56.26	56.40	0.2

Table 4 – Comparison of AEGD's existing VO6 model to Urbantech's Updated existing VO6 model (Oct 2023 update with original AEGD IDF data)

Catchment ID #	Contributing Catchments	Drainage Area (ha)			VO6 Flows m³/s																	
			Urbantech	Difference (%)	2 Year Storm			5 Year Storm			10 Year Storm			25 Year Storm			50 Year Storm			100 Year Storm		
		AEGD			AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)
Twenty Mile Creek Watershed																						
T-25		108.2	93.4	-13.7	1.10	0.93	-15.3	1.90	1.61	-15.3	2.47	2.09	-15.3	3.24	2.74	-15.3	3.82	3.24	-15.3	4.42	3.74	-15.3
T-26		439.7	498.9	13.5	18.68	20.88	11.8	29.95	33.46	11.7	39.71	41.99	5.7	50.54	56.37	11.5	58.95	65.76	11.6	67.56	75.38	11.6
T-27-1		99.1	0.5	-26.0	1.57	0.02	-9.6	2.57	0.03	-9.6	3.28	0.04	-9.7	4.20	0.05	-9.7	4.90	0.06	-9.8	5.60	0.06	-9.8
T-27-2			8.5			0.20			0.32			0.41			0.52			0.61			0.69	
T-27-3			11.9			0.25			0.40			0.51			0.65			0.76			0.87	
T-27-4			15.4			0.29			0.47			0.60			0.76			0.89			1.02	
T-27-5			21.3			0.42			0.69			0.88			1.13			1.32			1.51	
T-27-6			15.8			0.25			0.42			0.53			0.68			0.79			0.91	
T-28-1		59.2	58.7	11.4	0.41	0.55	58.2	0.72	0.96	58.7	0.94	1.25	59.0	1.23	1.65	59.0	1.46	1.95	59.1	1.69	2.26	59.3
T-28-2			7.3			0.11			0.18			0.24			0.31			0.37			0.43	
T-29-1		100.7	94.0	-1.5	0.77	0.83	24.1	1.34	1.44	24.1	1.75	1.88	24.3	2.30	2.47	24.3	2.73	2.93	24.4	3.16	3.40	24.4
T-29-2			2.3			0.05			0.09			0.12			0.16			0.19			0.22	
T-29-3			1.8			0.04			0.07			0.10			0.13			0.15			0.17	
T-29-4			1.1			0.04			0.06			0.08			0.10			0.12			0.14	
Sum	At outlet of J29	806.9	830.7	2.9	19.04	21.54	13.1	30.76	34.81	13.2	40.70	43.91	7.9	51.99	58.66	12.8	60.80	68.60	12.8	69.80	78.79	12.9
T-30-1		126.0	82.0	-1.7	1.16	0.72	20.2	2.02	1.25	19.7	2.64	1.64	19.5	3.48	2.16	19.4	4.12	2.56	19.3	4.77	2.97	19.2
T-30-2			23.4			0.34			0.59			0.78			1.02			1.21			1.40	
T-30-3			8.5			0.13			0.22			0.29			0.38			0.45			0.52	
T-30-4			10.0			0.20			0.35			0.45			0.59			0.70			0.81	
T-31		59.1	56.5	-4.4	0.68	0.70	3.8	1.20	1.25	3.7	1.59	1.65	3.7	2.11	2.19	3.6	2.52	2.61	3.6	2.93	3.04	3.6
Sum	At outlet of 31	992.0	1011.1	1.9	18.24	20.90	14.6	29.84	34.20	14.6	38.77	43.41	12.0	49.81	56.90	14.2	58.43	66.60	14.0	67.11	76.04	13.3
T-32-1		312.3	22.2	-18.6	2.82	0.31	7.3	4.73	0.52	7.5	6.10	0.67	7.5	7.89	0.87	7.6	9.27	1.02	7.6	10.66	1.17	7.6
T-32-2			10.0			0.14			0.23			0.29			0.38			0.45			0.51	
T-32-3			185.2			2.02			3.40			4.38			5.68			6.67			7.67	
T-32-4			22.6			0.31			0.51			0.66			0.86			1.00			1.15	

Catchment ID #	Contributing Catchments	Drainage Area (ha)	Urbantech	Difference (%)	VO6 Flows m³/s																	
					2 Year Storm			5 Year Storm			10 Year Storm			25 Year Storm			50 Year Storm			100 Year Storm		
		AEGD			AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)	AEGD	Urbantech	Difference (%)
T-32-5		255.0	9.2	-19.0	1.35	0.16	26.0	2.35	0.27	26.8	3.09	0.35	27.0	4.08	0.45	27.2	4.84	0.53	27.3	5.62	0.61	27.3
T-32-6			5.1			0.09			0.16			0.20			0.26			0.31			0.35	
T-33-1			203.2			1.64			2.87			3.78			4.99			5.93			6.89	
T-33-2			3.3			0.06			0.11			0.15			0.19			0.23			0.27	
Sum	outlet 33A	567.3	460.8	-18.8	4.00	4.33	8.4	6.74	7.25	7.6	8.68	9.33	7.5	11.32	12.18	7.6	13.32	14.32	7.5	15.39	16.57	7.7
T-34		413.9	413.9	0.0	1.91	1.91	0.0	3.28	3.28	0.0	4.29	4.29	0.0	5.62	5.62	0.0	6.65	6.65	0.0	7.70	7.70	0.0
Sum	Outlet33 + T34 (J34)	981.2	874.7	-10.9	5.23	5.12	-2.0	8.61	8.47	-1.6	11.17	10.91	-2.3	14.45	14.10	-2.4	17.10	16.62	-2.8	19.78	19.22	-2.8
T-35		373.2	381.3	2.2	1.55	1.58	2.0	2.69	2.75	2.2	3.53	3.61	2.2	4.66	4.76	2.2	5.53	5.65	2.2	6.41	6.55	2.2
T-36		301.4	270.0	-10.4	2.17	1.94	-10.4	3.63	3.25	-10.4	4.68	4.19	-10.4	6.05	5.42	-10.4	7.10	6.36	-10.4	8.17	7.32	-10.4
T-37-1		71.0	11.1	-9.0	1.17	0.15	-25.3	1.98	0.26	-25.4	2.57	0.33	-25.4	3.34	0.43	-25.5	3.93	0.51	-25.5	4.53	0.58	-25.5
T-37-2			50.4			0.55			0.94			1.21			1.58			1.86			2.15	
T-37-3			0.9			0.06			0.10			0.13			0.17			0.20			0.23	
T-37-4			2.2			0.11			0.18			0.24			0.31			0.36			0.41	
Sum	At outlet of 35	1737.6	1726.1	-0.7	10.72	11.20	4.5	17.37	17.93	3.2	22.16	22.94	3.5	28.63	29.43	2.8	33.62	34.62	3.0	38.70	39.83	2.9
Sum	All Twenty Mile Catchments	2718.8	2600.8	-4.3	15.43	16.01	3.8	25.06	25.79	2.9	32.09	33.06	3.0	41.55	42.54	2.4	48.88	50.07	2.4	56.40	57.70	2.3

Table 5- Comparison updated Urbantech VO6 model with AEGD IDF parameters to Urbantech's Updated existing VO6 model with new IDF parameters based on the City of Hamilton Manual 2019

Catchment ID #	Contributing Catchments	Drainage Area (ha)	VO6 Flows m^3/s																	
			2 Year Storm			5 Year Storm			10 Year Storm			25 Year Storm			50 Year Storm			100 Year Storm		
			UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)
Twenty Mile Creek Watershed																				
T-25		93.4	**0.95**	0.93	-1.5	**1.69**	1.61	-4.9	**2.22**	2.09	-5.7	**2.94**	2.74	-6.9	**3.45**	3.24	-6.2	**3.97**	3.74	-5.8
T-26		498.9	**21.29**	20.88	-1.9	**35.51**	33.46	-5.8	**47.64**	41.99	-11.9	**61.55**	56.37	-8.4	**71.48**	65.76	-8.0	**81.79**	75.38	-7.8
T-27-1		0.5	**0.02**	0.02	1.4	**0.03**	0.03	-3.5	**0.04**	0.04	-4.4	**0.05**	0.05	-5.6	**0.06**	0.06	-5.0	**0.07**	0.06	-4.8
T-27-2		8.5	**0.20**	0.20		**0.33**	0.32		**0.43**	0.41		**0.55**	0.52		**0.64**	0.61		**0.73**	0.69	
T-27-3		11.9	**0.25**	0.25		**0.42**	0.40		**0.53**	0.51		**0.69**	0.65		**0.80**	0.76		**0.92**	0.87	
T-27-4		15.4	**0.29**	0.29		**0.48**	0.47		**0.62**	0.60		**0.81**	0.76		**0.93**	0.89		**1.07**	1.02	
T-27-5		21.3	**0.42**	0.42		**0.72**	0.69		**0.92**	0.88		**1.20**	1.13		**1.39**	1.32		**1.58**	1.51	
T-27-6		15.8	**0.25**	0.25		**0.43**	0.42		**0.55**	0.53		**0.72**	0.68		**0.83**	0.79		**0.95**	0.91	
T-28-1		58.7	**0.56**	0.55	-1.1	**1.01**	0.96	-4.8	**1.33**	1.25	-5.6	**1.77**	1.65	-6.9	**2.09**	1.95	-6.2	**2.41**	2.26	-5.8
T-28-2		7.3	**0.10**	0.11		**0.19**	0.18		**0.25**	0.24		**0.33**	0.31		**0.39**	0.37		**0.45**	0.43	
T-29-1		94.0	**0.84**	0.83	0.0	**1.51**	1.44	-5.0	**2.00**	1.88	-5.9	**2.66**	2.47	-7.2	**3.13**	2.93	-6.5	**3.62**	3.40	-6.1
T-29-2		2.3	**0.06**	0.05		**0.10**	0.09		**0.13**	0.12		**0.17**	0.16		**0.20**	0.19		**0.24**	0.22	
T-29-3		1.8	**0.04**	0.04		**0.08**	0.07		**0.10**	0.10		**0.14**	0.13		**0.16**	0.15		**0.18**	0.17	
T-29-4		1.1	**0.04**	0.04		**0.06**	0.06		**0.08**	0.08		**0.11**	0.10		**0.13**	0.12		**0.15**	0.14	
Sum	At outlet of J29	830.7	**21.90**	21.54	-1.7	**36.83**	34.81	-5.5	**49.22**	43.91	-10.8	**63.87**	58.66	-8.2	**74.33**	68.60	-7.7	**85.20**	78.79	-7.5
T-30-1		82.0	**0.73**	0.72	-0.6	**1.32**	1.25	-4.4	**1.75**	1.64	-5.4	**2.33**	2.16	-6.7	**2.74**	2.56	-6.0	**3.16**	2.97	-5.7
T-30-2		23.4	**0.34**	0.34		**0.62**	0.59		**0.81**	0.78		**1.08**	1.02		**1.27**	1.21		**1.47**	1.40	
T-30-3		8.5	**0.13**	0.13		**0.23**	0.22		**0.30**	0.29		**0.40**	0.38		**0.48**	0.45		**0.55**	0.52	
T-30-4		10.0	**0.20**	0.20		**0.36**	0.35		**0.48**	0.45		**0.63**	0.59		**0.74**	0.70		**0.86**	0.81	
T-31		56.5	**0.70**	0.70	0.3	**1.30**	1.25	-3.7	**1.73**	1.65	-4.7	**2.33**	2.19	-6.0	**2.76**	2.61	-5.4	**3.20**	3.04	-5.0
Sum	At outlet of 31	1011.1	**21.18**	20.90	-1.3	**36.06**	34.20	-5.2	**47.37**	43.41	-8.4	**61.85**	56.90	-8.0	**71.70**	66.60	-7.1	**80.87**	76.04	-6.0

Catchment ID #	Contributing Catchments	Drainage Area (ha)	VO6 Flows m³/s																	
			2 Year Storm			5 Year Storm			10 Year Storm			25 Year Storm			50 Year Storm			100 Year Storm		
			UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)	UT Updated new IDF	UT updated old IDF	Diff (%)
T-32-1		22.2	**0.31**	0.31		**0.54**	0.52		**0.70**	0.67		**0.92**	0.87		**1.07**	1.02		**1.23**	1.17	
T-32-2		10.0	**0.14**	0.14		**0.24**	0.23		**0.31**	0.29		**0.40**	0.38		**0.47**	0.45		**0.54**	0.51	
T-32-3		185.2	**2.05**	2.02	-0.9	**3.57**	3.40	-4.4	**4.64**	4.38	-5.2	**6.09**	5.68	-6.4	**7.10**	6.67	-5.8	**8.14**	7.67	-5.4
T-32-4		22.6	**0.31**	0.31		**0.53**	0.51		**0.69**	0.66		**0.91**	0.86		**1.06**	1.00		**1.21**	1.15	
T-32-5		9.2	**0.16**	0.16		**0.28**	0.27		**0.37**	0.35		**0.48**	0.45		**0.56**	0.53		**0.64**	0.61	
T-32-6		5.1	**0.09**	0.09		**0.16**	0.16		**0.21**	0.20		**0.28**	0.26		**0.32**	0.31		**0.37**	0.35	
T-33-1		203.2	**1.66**	1.64	1.7	**3.02**	2.87	-5.0	**4.01**	3.78	-5.9	**5.38**	4.99	-7.1	**6.34**	5.93	-6.5	**7.34**	6.89	-6.1
T-33-2		3.3	**0.06**	0.06		**0.12**	0.11		**0.16**	0.15		**0.21**	0.19		**0.25**	0.23		**0.29**	0.27	
Sum	outlet 33A	460.8	**4.37**	4.33	-0.9	**7.57**	7.25	-4.3	**9.88**	9.33	-5.5	**13.04**	12.18	-6.6	**15.25**	14.32	-6.1	**17.59**	16.57	-5.8
T-34		413.9	**1.90**	1.91	0.4	**3.40**	3.28	-3.4	**4.48**	4.29	-4.3	**5.96**	5.62	-5.7	**7.00**	6.65	-5.0	**8.08**	7.70	-4.7
Sum	Outlet33 + T34 (J34)	874.7	**5.12**	5.12	0.0	**8.77**	8.47	-3.4	**11.41**	10.91	-4.4	**14.95**	14.10	-5.7	**17.54**	16.62	-5.2	**20.21**	19.22	-4.9
T-35		381.3	**1.58**	1.58	0.4	**2.85**	2.75	-3.4	**3.78**	3.61	-4.4	**5.05**	4.76	-5.7	**5.95**	5.65	-5.1	**6.88**	6.55	-4.7
T-36		270.0	**1.95**	1.94	-0.1	**3.37**	3.25	-3.7	**4.39**	4.19	-4.6	**5.76**	5.42	-5.9	**6.72**	6.36	-5.3	**7.70**	7.32	-4.9
T-37-1		11.1	**0.15**	0.15		**0.27**	0.26		**0.35**	0.33		**0.46**	0.43		**0.53**	0.51		**0.61**	0.58	
T-37-2		50.4	**0.56**	0.55	-0.5	**0.98**	0.94	-4.2	**1.28**	1.21	-5.1	**1.69**	1.58	-5.4	**1.98**	1.86	-5.2	**2.28**	2.15	-4.9
T-37-3		0.9	**0.06**	0.06		**0.11**	0.10		**0.14**	0.13		**0.18**	0.17		**0.21**	0.20		**0.24**	0.23	
T-37-4		2.2	**0.04**	0.04		**0.06**	0.06		**0.08**	0.08		**0.08**	0.10		**0.11**	0.12		**0.13**	0.14	
Sum	At outlet of 35	1726.1	**11.20**	11.20	-0.1	**18.56**	17.93	-3.4	**23.81**	22.94	-3.7	**31.16**	29.43	-5.6	**36.40**	34.62	-4.9	**41.72**	39.83	-4.5
Sum	All Twenty Mile Catchments	2600.8	**16.02**	16.01	0.0	**26.70**	25.79	-3.4	**34.42**	33.06	-4.0	**45.09**	42.54	-5.7	**52.75**	50.07	-5.1	**60.60**	57.70	-4.8

4.1.4 SIZING OF SWM PONDS FOR FLOOD AND EROSION CONTROL

As illustrated in Tables 4.2 and 4.3, the proposed development will have a large impact on the surface water hydrology. It is not uncommon to find surface runoff flows (m3/s) increasing up to 6 times that of existing conditions due to the increase in impervious area associated with development. The increase in surface water runoff volume and rate will dramatically increase flood risk and erosion of downstream watercourse if left untreated.

To mitigate impacts to surface water resources, centralized stormwater management facilities (stormwater management dry ponds) have been proposed at the locations illustrated on Figure 3.3. As part of the analysis of the performance of LID measures in addressing erosion, an erosion component for ponds was modeled without increasing pond size. Preliminary design for three of these stormwater management facilities (stormwater dry ponds) has been provided to illustrate that proposed development will not increase flood risk or in-stream erosion potential in downstream watercourses (Tables 4.4, 4.5 and 4.6). Details of the design characteristic of these facilities are presented in Appendix F.

To mitigate the effects of flooding each facility was designed to control flood flows to predevelopment levels (Qpost to Qpre) for large storm events (i.e. the 2yr, through to the 100yr storms). The three facilities were selected as examples to provide anticipated extremes in the range of volumes (m3/ha) to control flood levels to predevelopment conditions. In general the analysis indicates that the flood control portion of facilities in the AEGD lands will be required to provide between 300m3/ha and 400m3/ha depending on the existing and post development conditions (soils, change in land use etc.) of lands draining to the facility.

A major component of the Stormwater Master Plan is to maintain the pre development water balance through the use of on-site infiltration facilities (source controls). Infiltration facilities will also provide benefits of water quality treatment and lessen the impact of development on downstream erosion. For this reason the stormwater management dry ponds do not incorporate a water quality component. However, some erosion control (15 mm runoff volume to be released over a 24 hour detention time) was included into the facility design as it was anticipated that infiltration facilities alone may not meet the desired erosion control target.
Detailed studies of in-stream erosion potential may need to be conducted through an analysis as part of a stormwater management study.

Table 4.4 Storm Water Management Facility S5 - Preliminary Design Characteristics	
Total Tributary Area (hectares)	81.7
Impervious (%)	55
Composite Runoff Coefficient	0.55
Pre Development Peak Flow (m^3/s)	1.88
Post Development Peak Flow (m^3/s)	14.12
Level of Water Quality Protection (1)	n/a
Type	Dry Pond
Permanent Pool Requirement (m^3/ha)	n/a

Extended Detention Requirement (m^3/ha) for Erosion Control (15mm released over 24hrs)			83
Flood Attenuation Requirement (m^3/ha)			331
Depth (m)		Permanent Pool	na
		Extended Detention	0.77
		Attenuation	2.23
		Total (excl. freeboard)	3.0
Storage Volume (m^3)	Permanent Pool	Required	n/a
		Provided	n/a
	Extended Detention (2)	Required	6,740
		Provided	6,740
	Attenuation	Required	27,060
		Provided	27,060
	Total Provided		33,800

Table 4.5
Storm Water Management Facility W17 - Preliminary Design Characteristics

Total Tributary Area (hectares)		393.7
Impervious (%)		44
Composite Runoff Coefficient		0.53
Pre Development Peak Flow (m^3/s)		27.91
Post Development Peak Flow (m^3/s)		66.47
Level of Water Quality Protection (1)		n/a
Type		Dry Pond
Permanent Pool Requirement (m^3/ha)		n/a
Extended Detention Requirement (m^3/ha) for Erosion Control (15mm released over 24hrs)		80
Flood Attenuation Requirement (m^3/ha)		303
	Permanent Pool	0

Depth (m)		Extended Detention	0.7
		Attenuation	2.3
		Total (excl. freeboard)	3.0
Storage Volume (m^3)	Permanent Pool	Required	n/a
		Provided	n/a
	Extended Detention (2)	Required	31,299
		Provided	31,299
	Attenuation	Required	119,301
		Provided	119,301
	Total Provided		150,600

Table 4.6 Storm Water Management Facility T29 - Preliminary Design Characteristics		
Total Tributary Area (hectares)		100.7
Impervious (%)		56
Composite Runoff Coefficient		0.61
Pre Development Peak Flow (m^3/s)		3.16
Post Development Peak Flow (m^3/s)		21.50
Level of Water Quality Protection (1)		n/a
Type		Dry Pond
Permanent Pool Requirement (m^3/ha)		0
Extended Detention Requirement (m^3/ha) for Erosion Control (15mm released over 24hrs)		92
Flood Attenuation Requirement (m^3/ha)		438
Depth (m)	Permanent Pool	0
	Extended Detention	0.64
	Attenuation	2.36

		Total (excl. freeboard)	3.0
Storage Volume (m^3)	Permanent Pool	Required	n/a
		Provided	n/a
	Extended Detention (2)	Required	9,214
		Provided	9,214
	Attenuation	Required	44,106
		Provided	44,106
	Total Provided		53,320

Establishing SWM Facility Targets

Due to the proposed drainage diversions, the allowable release rates at the various post-development outlet locations were based on the matching existing release rates from the catchments at the property boundary at the key nodes / overall scoped study area outlets.

Under proposed conditions, there are two major outlets from the Upper West Side Landowners Group lands. The first drainage area flows to Outlet J26+ J29, and the second area flows to Outlet J30. Any future SWM strategies must ensure that the existing flows for all events are not exceeded at these key outlet nodes as shown on Table 5 on the preceding pages..

Preliminary Pond Design

As shown on Drawing STM-2, fifteen (15) SWM facilities (6 SWM ponds and 8 Storage Tanks) are currently proposed within the study area. To control the uncontrolled post-development flow to the existing targets, a weighted approach may be necessary to ensure each facility manages it's "share" of the exceedance. Due to the potential drainage diversions to the north (to maintain drainage to the existing features and SWM facilities north of Twenty Road West), establishing the SWM facility release rates will require coordination with the City regarding acceptable flows / volumes for diversion. Furthermore, some portions of the study area may have more LID features than others, which may affect the target rates for the end-of-pipe facilities. These factors will impact the rating curves of the facilities and iteration will be required to ensure all targets are met (not just the quantity control targets upstream).

As such, the facilities storage requirements have not been established, but the general locations of the facilities have been identified on Drawing STM-2.

As required by the AEGD criteria, all facilities will be dry ponds, hence, permanent pool storage is not required. Furthermore, based on the LID / recharge requirements (29mm of infiltration / retention), the ponds do not require extended detention drawdown, assuming the retention targets can be met (subject to hydrogeological conditions).

4.1.5 CONTINUOUS HYDROLOGIC SIMULATION

Continuous hydrologic characteristics (i.e. time series flows and annual water balance quantities) have been calculated for the existing land use conditions using the Computer Model Hydrological Simulation Program - FORTRAN (HSP-F). HSP-F has been selected for its ability to:

1. Simulate the entire hydrologic cycle (precipitation, snowpack accumulation and melt, surface runoff, soil water movement, evapotranspiration, groundwater recharge and groundwater discharge to local watercourses).

2. Simulate the hydrologic regime and surface water quality regime over multi-year continuous periods.

3. Simulate the movement of water accounting for specific quantities of water moving separately through e.g. rooftops, lawns, driveways, storm sewers, streams and through different stormwater management measures e.g. rooftop disconnection, bioretention cells, permeable pavement etc.

<u>Modeling Input Parameters</u>

Data requirements to an HSPF model are extensive. The model input parameters must account for the effect of snow and ice on the study area hydrology. Such parameters determine when and how snow accumulates and melts. Parameters must be included to guide how infiltration of precipitation will occur, how and when evapotranspiration will occur and the amount of precipitation that will be intercepted. Parameters must also be included to determine how water will flow over the land surface, in pipes and streams and through different layers of soil. Description of the total number of input parameters used in the setup of the existing conditions model can be found in the HSPF reference manual. Descriptions of some of the most important input parameters are provided below.

<u>Meteorological Input Data</u>

Continuous meteorological data was obtained from Environment Canada Gauge at the John C Munro Airport. The meteorological data obtained included hourly data for precipitation, dew point temperature, air temperature, cloud cover and wind speed from 1953 to the present. The hourly meteorological data is required for the continuous hydrologic modeling simulations (time series inputs). Time series data for hourly Solar Radiation and Potential evapotranspiration were calculated by Aquafor Beech Limited for the same timeframe (1953-present).

<u>Soil Type and Land Use</u>

Land use largely determines hydrologic response within each catchment. Representation of land-use within each catchment was therefore fundamental to model development. Within any catchment, a number of different land uses can be present. Each land use category is characterized by its imperviousness in addition to representative surface slopes and surface roughness as dictated by local topography and local surface characteristics.

Within HSP-F, each land-use type has been represented using a combination of impervious land (IMPLND) segments and pervious land (PERLND) segments. The IMPLND segments represent surfaces such as paved roadways, parking areas, driveways, walkways, and building roofs. The PERLND segments represent the various vegetated areas including lawns, parkland, undeveloped land, wooded areas and farm fields. The existing and proposed land use conditions of the three watersheds within the study area are presented in Tables 4.7 and 4.8. Detailed breakdown of the percent of land use types within each catchment is presented in Appendix C

Beyond land use, some of the most critical modeling input parameters are related to surficial soil types within each catchment. The surficial soils of catchments in all three study watersheds are illustrated in Table 4.9. Detailed breakdown of the percent of soil types within each catchment is presented in Appendix C. The soils and land use breakdown were determined using GIS software and AutoCAD.

Table 4.7: Existing Conditions Land Use Distribution Reported as Percent of Total Area

Watershed	Area (ha)	Existing Conditions Land Use Distribution (%)									
		Woodlot	Row Crop / Pasture	Utilities / Open Space	Airport Lands	Residential	Commercial	Highways	Institutional	Total Pervious	Total Impervious
*For the catchments located with the study area (**Figure 4.0**)*											
Sulphur Creek	*355.0*	*8*	*64*	*8*	*-*	*7*	*6*	*3*	*4*	*85*	*15*
Welland River	*1,295.3*	*16*	*54*	*-*	*25*	*4*	*1*	*4*	*-*	*84*	*16*
Twenty Mile Creek	*1,131.5*	*13*	*49*	*-*	*24*	*8*	*2*	*2*	*-*	*86*	*14*

Table 4.8: Proposed Conditions Land Use Distribution Reported as Percent of Total Area

Watershed	Area (ha)	Proposed Conditions Land Use Distribution (%)									
		Woodlot	Row Crop / Pasture	Utilities / Open Space	Airport Lands	Prestige Industrial	Eco Prestige Industrial	Highways	Residential	Total Pervious	Total Impervious
*For the catchments located with the study area (**Figure 4.0**)*											
Sulphur Creek	*355.0*	*8*	*4*	*8*	*-*	*14*	*60*	*5*	*2*	*42*	*58*
Welland River	*1,295.3*	*16*	*22*	*-*	*25*	*11*	*21*	*6*	*-*	*63*	*37*
Twenty Mile Creek	*1,131.5*	*13*	*7*	*-*	*24*	*26*	*29*	*2*	*-*	*47*	*53*

Table 4.9: Existing Conditions Land Use Distribution Reported as Percent of Total Area

Watershed	Area (ha)	Hydrologic Soil Distribution (%)			
		Type A Soils	Type B Soils	Type C Soils	Type D Soils
*For the catchments located within the study area (**Figure 4.0**)*					
Sulphur Creek	*355*	*53*	*12*	*30*	*0*
Welland River	*1,356*	*12*	*21*	*57*	*9*
Twenty Mile Creek	*1,571*	*10*	*16*	*53*	*18*
Total Area of Hydrologic Modeling (Study Area and downstream area included in assessment)					
Sulphur Creek	*1,152*	*50*	*30*	*20*	*0*
Welland River	*1,571*	*13*	*20*	*59*	*9*
Twenty Mile Creek	*2,718*	*10*	*13*	*66*	*11*

Stream Channel Data

Stream channel data (tributary and main stream channel) is required for the overland flow and channel routing procedures in HSPF. For this study the distance-elevation relationship of the overbank (floodplain) areas was determined using topographic mapping.

Each watercourse reach is modeled within HSPF as a RCHRES segment. The hydraulics of the reach are characterized in the model by supplying a table of values of flow depths and corresponding water surface areas, water storage volumes and volume-dependent outflows. These data are then used by HSPF to provide hydrologic routing of flows through each reach in the network.

Representative stream and valley cross-sections for each reach were used to develop the necessary depth-area-volume-flow tables for each reach. Using the cross-section data determined through examination of topographic mapping, 39 distinct F-tables were constructed using spreadsheets to determine the surface area of water in the stream reach and the volume of water in the stream reach. The volume dependent outflows were then determined (at each flow depth) through application of Manning's equation. Channel bottom width and Manning's "n" values were based on field information and best professional judgment of the consultant team.

HSPF Unit Response Functions

During model set-up, it was recognized that proper representation of urban processes would need to account for the fact that any given land-use could exist in combination with various native soil types. For example, on agricultural lands tilled areas could have clay soils whereas in a different part of the study area a fallow pasture may be comprised of sandy loam soils.

Therefore, within any given land-use category there could be a number of different combinations of soil and/or internal drainage connectivity conditions that need to be represented in the model. To meet this need, it was decided to build a number of "unit response functions" (URFs), each of which would represent a unique combination of land-use type, soil type and internal drainage connectivity.

Each URF has been constructed using the necessary number and combination of impervious land uses (IMPLND) and pervious land uses (PERLND), with connectivity between them as appropriate to represent conditions such as roof drainage discharging onto lawn areas, driveway areas draining onto roadways, etc. To represent all of the existing conditions within the three study areas, it was necessary to construct a total of 26 URFs. Three additional URFs were constructed to represent the proposed conditions land uses.

The URF approach is particularly useful in analyzing future uncontrolled and future mitigation scenarios where variations in internal drainage may significantly affect the local hydrologic response. For example, with medium-density residential (located in small pockets throughout the study area), there are lots where the roof drains discharge onto grassed yards areas versus lots on which roof drains are connected directly to storm sewers.

Model Structure

The basic HSPF model structure is as follows:

1. The watershed is represented as a set of catchments as illustrated on the drainage mosaic;
2. Each catchment is characterized by the land-use, surficial soil types and topography found within the catchment. These characteristics are reflected in specific HSPF model input parameters;
3. Surface runoff, interflow and groundwater discharge from each catchment is routed through various pathways (pipes, soils etc.) into the upstream end of a watercourse (stream, river);

4. The watercourses are characterized using representative stream and valley cross- sections, as well as hydraulic roughness values, channel slopes and depth surface area, storage-outflow relationships.

The URF approach to modeling alters the basic model set up in the following manner:

A number of HSPF input files (.UCI files - "User Control Input files") for simulating the unit response functions (URFs) were generated and then the URFs were applied to develop the subcatchment responses. Each URF has been constructed as a representative 10-hectare area. First model file is used to generate generic flows in cubic metres per 10 ha per time interval for each 10-hectare URF.

To simulate watershed response the total area of each URF within each catchment was determined. A second model input file is then run to produce a flow rate in m3/time interval (15 minutes) resulting from all of the URFs within each catchment. The second model file provides the hydrologic response of the catchments and accounts for the timing (routing of flows) through the watercourse network.

When the model is executed, URF time-series outputs and subcatchment outputs are stored in WDM files, to facilitate analysis. The URF outputs are then used as inputs to the watercourse reach network files to develop the simulated stream flow and water-quality response within each catchment.

4.1.6 WATER BUDGET

The hydrologic cycle is a complex process and its natural components are dependent on many factors: soils, topography, vegetation, geology, climate, etc. Any change to these natural factors will result in a change to the hydrologic cycle; these changes occur with urbanization. A tool often used in water resources management is a “water budget”, which sums the various components of the hydrologic cycle for a watershed by balancing precipitation input, evaporation and evapotranspiration output, groundwater flow input and output, and surface runoff input and output.

Modification of the hydrologic cycle has impacts on water quantity, water quality, and stream morphology. Specifically, urbanization reduces evaporation, evapotranspiration, and infiltration, thereby, increasing surface runoff. Increased and more rapid surface runoff results in more frequent and higher peak flows in the rivers and streams causing increased flooding and erosion. Reduction of infiltration decreases groundwater recharge, potentially affecting cool baseflow to streams and wetlands.

4.1.6.1 WATER BALANCE ASSESSMENT WITH HSP-F

HSP-F was used to provide annual water balance estimates for each subcatchment as illustrated on the drainage mosaic (Figure 4.0). One of the primary advantages of using HSP-F for water balance estimates is that it incorporates the alternating effects of dry and wet hydrologic processes and the specific land use characteristics (impervious/pervious areas) in the estimation of groundwater recharge and overall water balance components.

The existing conditions water budget provides baseline environmental hydrologic conditions. The post development hydrologic model is run under future development scenarios and the resulting post-development water budget is compared to determine potential alteration to the study area hydrology for each catchment. Finally, the hydrologic model is run under a post development scenario incorporating mitigation measures to determine if proposed stormwater management measures are capable of restoring the water budget to predevelopment levels.

The water balance components employed in the HSP-F concept are presented in Figures 4.2 and 4.3, as per the HSP-F Design Manual (provided below for reference). The primary components are defined and summarized as follows:

SUPY The total amount of moisture provided to the land surface (i.e., rain+ snowmelt);
SURLI Surface Lateral Inflow from adjacent areas;
TAET The total actual evapotranspiration (composed of five separate terms: CEPE (interception evaporation), UZET (upper zone E-T), LZET (lower zone E-T), BASET (riparian E-T) and AGWET (deep-rooted E-T).
SURO Surface overland runoff to a surface stream;
IFWO Interflow runoff (from the unsaturated soil zone) to a surface stream; AGWO Groundwater runoff to a surface stream;
IGWI Groundwater lost to a deep aquifer.

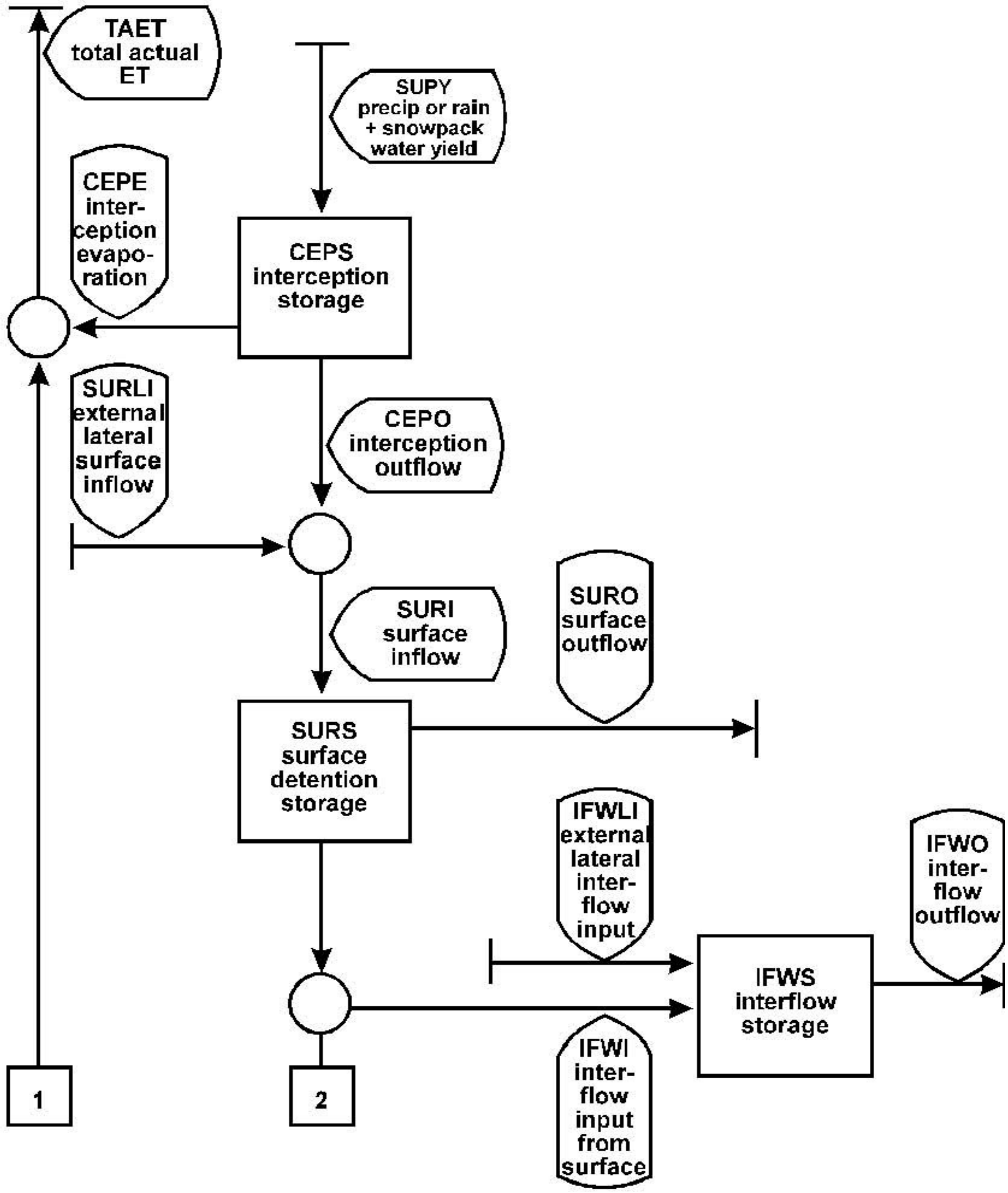


Figure 4.2 Flow Diagrams of Water Movement and Storage Modeled in the PWATER section of the PERLND Application Module (Part 1)

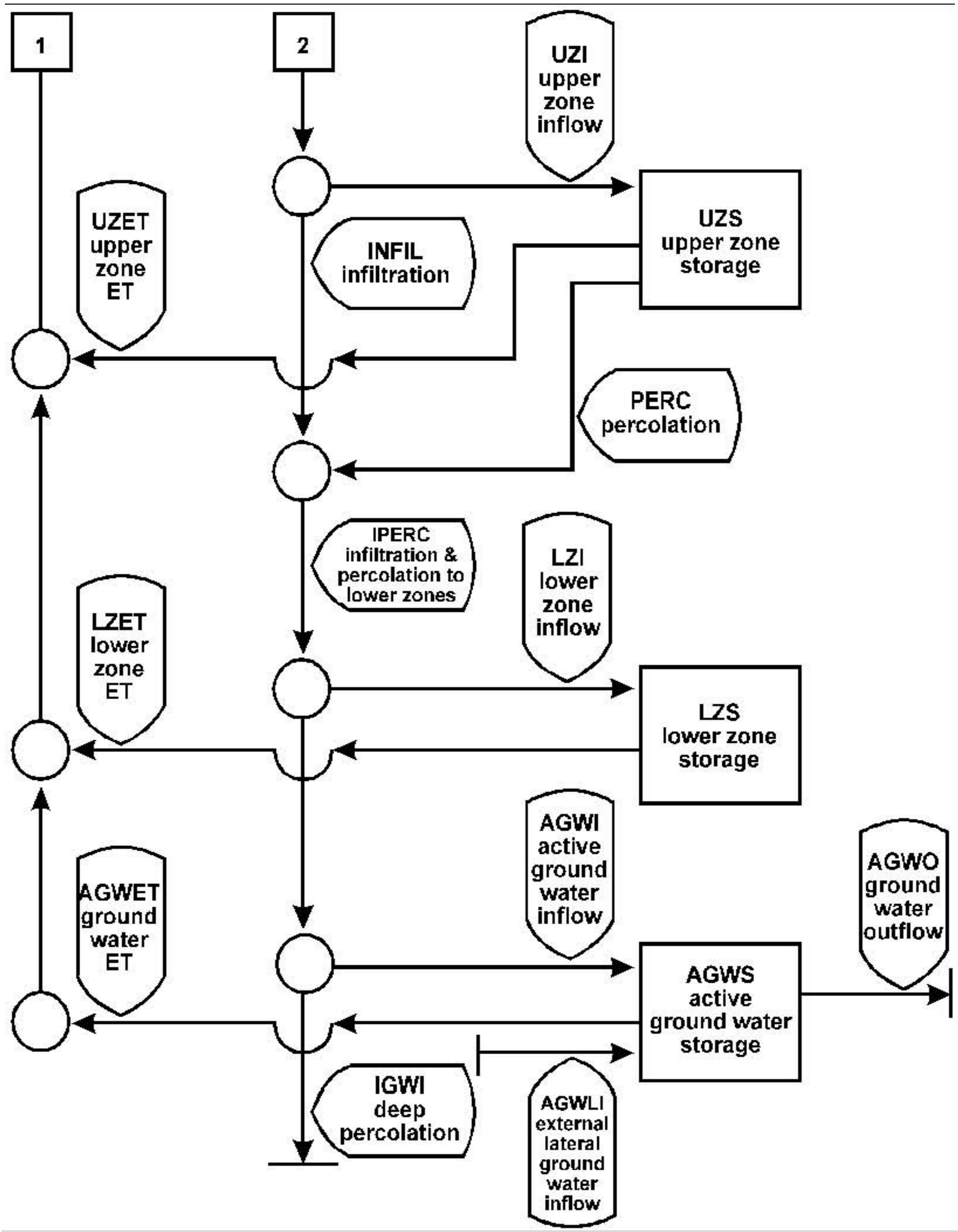


Figure 4.3 Flow Diagrams of Water Movement and Storage Modeled in the PWATER section of the PERLND Application Module (Part 2)

The input portions of the water balance equation are comprised of SUPY (precipitation and snowfall) and SURLI (surface runoff lateral inflow). The total moisture supply (precipitation input) to the land surface (SUPY) is applied to all land use units (roads, rooftops, lawns, sidewalks etc) found within the 10 ha parcels of land. Certain land use units (e.g. lawn and roadway) may also receive lateral inflow due to for example, stormwater moving from the rooftop to the lawn or from the lawn onto the roadway. This lateral inflow is termed SURLI.

Adjustment must be made to prevent double counting of terms in the overall water balance. For example, the same runoff from the rooftop which is directed to the lawn should not be added twice in the calculation of runoff for the 10ha area. To make the adjustments, the proportion of SURLI / (SURLI +SUPY) is determined and the resulting fraction is used as an adjustment factor to reduce all of the water budget output components for land uses that receive SURLI. Using this approach SURLI does not have to be included within the water balance equation. This allows the precipitation to be the only input required in the water balance equation which is favourable since this input is constant for all land uses.

The output portions of the water balance equation are comprised of SURO, IFWO, AGWO, TAET, IMPEV and IGWI. Surface Runoff is comprised of SURO + IFWO while groundwater flows are termed AGWO. The resulting outflow to the stream (SURO+IFWO+AGWO), losses due to total actual evapotranspiration from pervious surfaces (TAET) and impervious surfaces (IMPEV), and groundwater lost to deep aquifer (IGWI) are unique to each catchment based on combination of % imperviousness, soil types and connectivity.

For the purpose of this study the water budget components derived from HSP-F output files were summarized for six years of data (1991 to 1996), averaged and compiled on a monthly and annual basis, and expressed in depth (mm) and/or volume (cu.m/month, cu.m/year) units. This data set was considered to be most representation of average or typical precipitation years.

On a monthly basis the highest values are observed during spring rain-snowmelt events (April), major summer storms and higher precipitation in the fall. With respect to land use type, commercial and industrial areas result in the lowest evapotranspiration rates and direct groundwater flows to streams (due to small pervious areas available for groundwater inflow). At the same time they generate high surface runoff to stream. In residential areas where roof and foundation drains are connected to storm sewers relatively high volumes of surface runoff are also observed.

The water budget analysis was preformed for five years in order to reduce the error associated variation in meteorological conditions that could occur in any one year. The years 1991 to 1996 were selected since these years are known to provide relatively stable meteorological conditions that have not been seen in recent years.

The resulting water balance fluxes reflect differences in land use configuration, routing paths and specific soil properties, as well as seasonal variation in moisture supply and meteorological conditions.

URF Water Balance Assessments

Since the URF modelling approach has been used, as a first step a water balance must be performed separately for each URF (each land use type found within the study area). HSP-F outputs a pervious water budget assessment and an impervious water budget assessment for each of the different land use units (roads, rooftops, lawns, sidewalks etc) which comprise each URF. To determine water balance components for each URF (10 hectare area), the total amount of infiltration, runoff etc. is summed from each land unit. A summary of the calculated water balances for each of the characteristic land uses (URFs found within Sulphur, Welland and Twenty Mile Creeks) are presented in Appendix G. Spreadsheets and model files used in development of the URF water balance assessment are also presented in Appendix G.

The URF water budget analysis compares the impact of land conversion from agriculture to each of the three dominant proposed land uses for three distinct soil types. To compare the existing, future and mitigated scenarios the following URF's have been used:

1. Three URFs to simulate existing conditions water budgets for agricultural lands on sandy, loamy and clay soils;

2. Nine URFs to simulate proposed conditions water budgets for two types of industrial/commercial areas and for highway areas on three soil types; and

3. Nine URFs to simulate proposed conditions water budgets for proposed land uses incorporating LID measures to treat impervious areas within the URF.

The mitigated post development water budget analysis determines the volume targets (m3 / impervious ha) required (by LID infiltration measures) to restore predevelopment infiltration levels under the proposed land use conditions. The required storage targets are driven by the magnitude of the infiltration deficit (i.e. existing conditions infiltration less the post development infiltration). When the infiltration deficit is large, a larger volume of water must be directed to LID measures. The main factors responsible for a large infiltration deficit include:

1. A high infiltration rate of the existing soils; sandy soils will infiltrate more water than clayey soils and much more water than impervious areas;

2. A low level of total impervious area in the existing conditions relative to the total impervious area of the future conditions; and

3. The percent imperviousness of areas draining to LID treatment areas.

These conditions which cause high levels of infiltration in the existing conditions and low levels of infiltration in the future conditions result in larger infiltration requirements (capture volumes) to restore predevelopment infiltration levels.

The modeling methodology to determine the required capture volumes for three different proposed conditions land uses (Highways (URF – THC), Prestige Business Park / Airport Related Business (URF - IPE) and Airside Industrial / Light Industrial (URF - IPR) was as follows:

1. Calculate the volumes of water for capture from all impervious surfaces within each URF for depths between 5mm and 15mm at 1mm increments. The appropriate depth/volume will be used for the facility design;

2. Run HSP-F for 6 years (1991 to 1996) to determine the average annual LID capture volume for each treatment depth. Partition this volume into two components:

(a) the portion that will infiltrate from the LID measure to the ground water; and

(b) the portion that will evapotranspirate from the LID measure;

3. Create a new water balance for each LID scenario through modification of the post development water balance (i.e. reduce runoff and increase of evapotranspiration and infiltration); and

4. The design runoff depth which results in a water balance that matches predevelopment infiltration is selected for each URF.

The results of the URF analysis are illustrated graphically in Figures 4.4, 4.5 and 4.6. The anticipated range of LID storage requirements (to restore predevelopment infiltration levels on AEGD lands) are presented in Table 4.10.

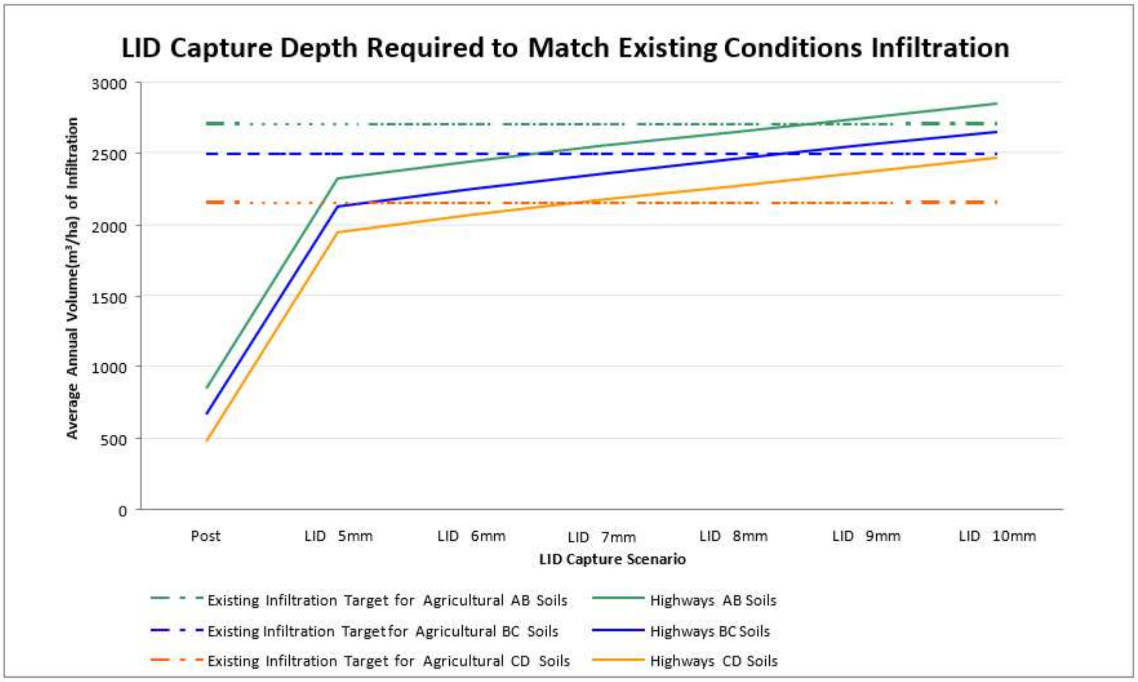


Figure 4.4: Required LID Capture Depths for Highways

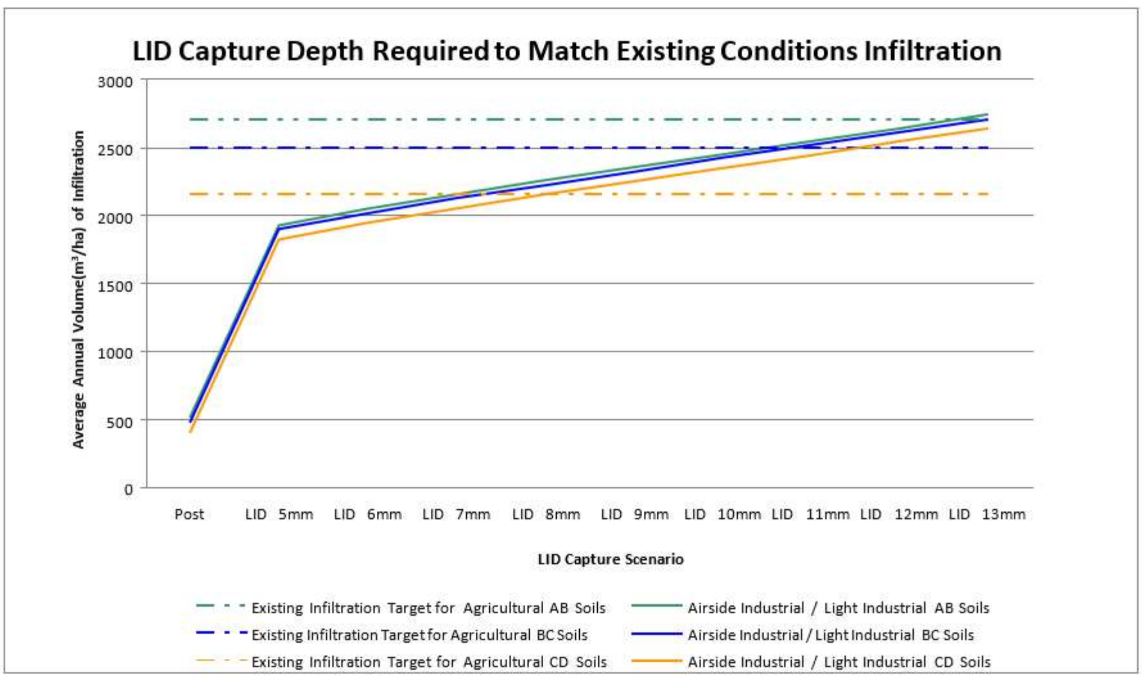


Figure 4.5: Required LID Capture Depths for Airside Industrial / Light Industrial

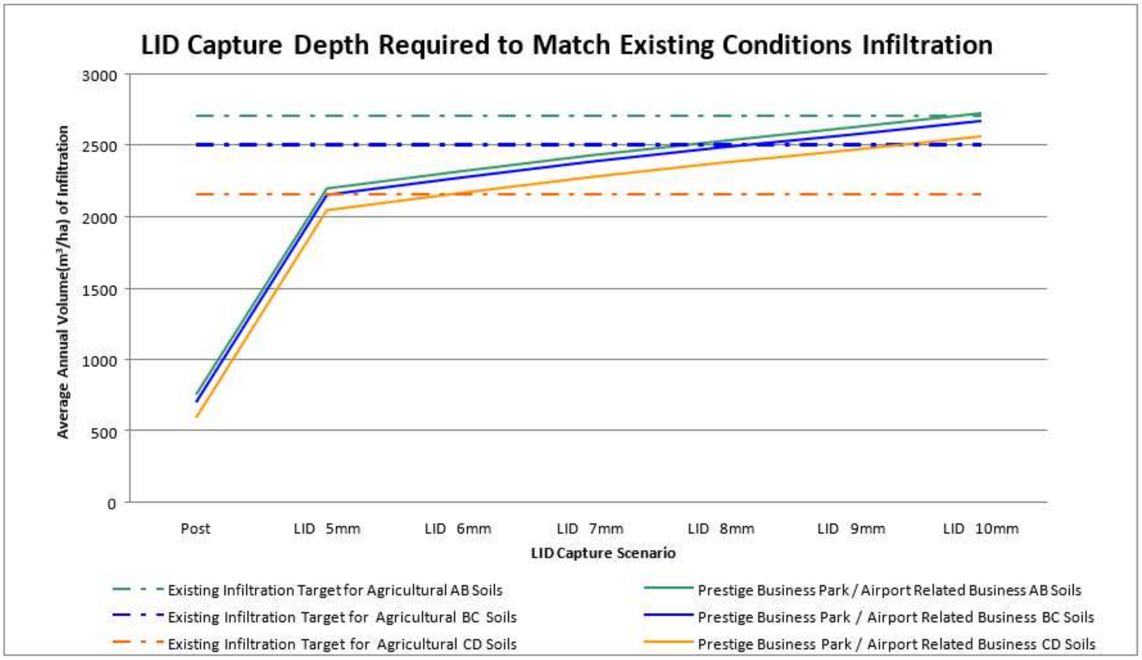


Figure 4.6: Required LID Capture Depths for Prestige Business Park / Airport Related Business

Table 4.10: LID Capture Target (m³/impervious ha served) for Proposed Conditions Land uses

Scenario	LID Facility Design Capture Target		% Imperviousness of future conditions land use
	(mm)	(m³ / imp ha)	
Roads AB Soils	9	90	70
Roads BC Soils	8	80	70
Roads CD Soils	7	70	70
Prestige Business Park / Airport Related Business AB Soils	10	100	70
Prestige Business Park / Airport Related Business BC Soils	8	80	70
Prestige Business Park / Airport Related Business CD Soils	6	60	70
Airside Industrial / Light Industrial AB Soils	13	130	80
Airside Industrial / Light Industrial BC Soils	11	110	80
Airside Industrial / Light Industrial CD Soils	8	80	80

Note: Targets for residential land use should be established in the functional servicing study, but will like be in the range of values listed above.

The results from the URF water balance analysis (Table 4.10) provide capture estimates for facility design purposes given the proposed land use and dominant soils types, and assuming conversion from solely agricultural areas.

Watershed Scale Water Balance Assessments

The watershed scale water budget assessment is completed though HSP-F modelling and spreadsheet analysis using:

1. The total number of URFs required to represent the existing land uses and existing soil types found within each of the three watersheds;

2. The total number URFs required to represent the proposed land uses (on existing soil types) within each of the three watersheds; and

3. The total number of URFs required to estimate the appropriate level of mitigation required for the proposed land uses within each of the three watersheds.

The anticipated range of storage required to mitigate the proposed development within each of the three watersheds is presented in Table 4.11. Spreadsheets and model files used in development of the watershed scale water balance assessment are presented in Appendix G.
Results of the watershed scale water budget analysis (average annual water balance partitioning) for each catchment and watershed are presented in Figures 4.7 – 4.9. Average annual water balances for the three watersheds within the AEGD study area are presented below:

4.1.6.2 EXISTING CONDITIONS ANNUAL WATER BUDGET

Presented below are the existing conditions (pre-development) water budget for the Welland River, Sulphur Creek and Twenty Mile Creek Watersheds.

Welland River Watershed

- Rainfall (Supply) = 645mm
- Runoff (RO) = 69mm (11%)
- Evapotranspiration (ET) =342mm (55%)
- Infiltration (Infil) = 213 (34%)

Sulphur Creek Watershed

- Rainfall (Supply) = 645mm
- Runoff (RO) = 103mm (17%)
- Evapotranspiration (ET) =308mm (48%)
- Infiltration (Infil) = 209 (33%)

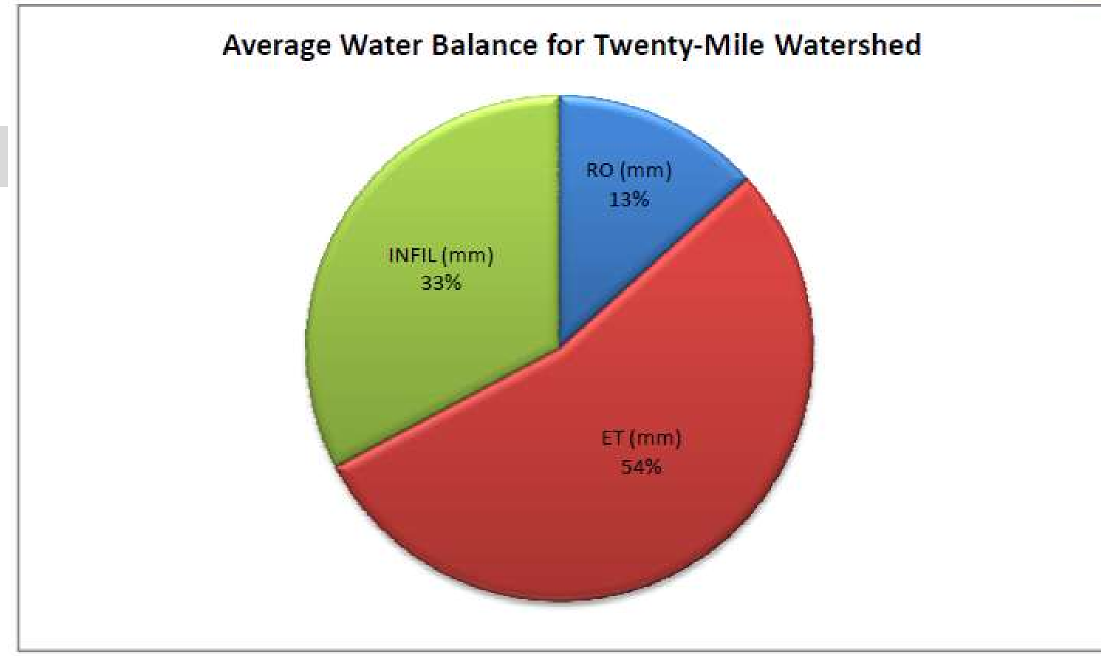
Twenty Mile Creek Watershed

- Rainfall (Supply) = 645mm
- Runoff (RO) = 83mm (13%)
- Evapotranspiration (ET) =338mm (54%)
- Infiltration (Infil) = 205 (33%)

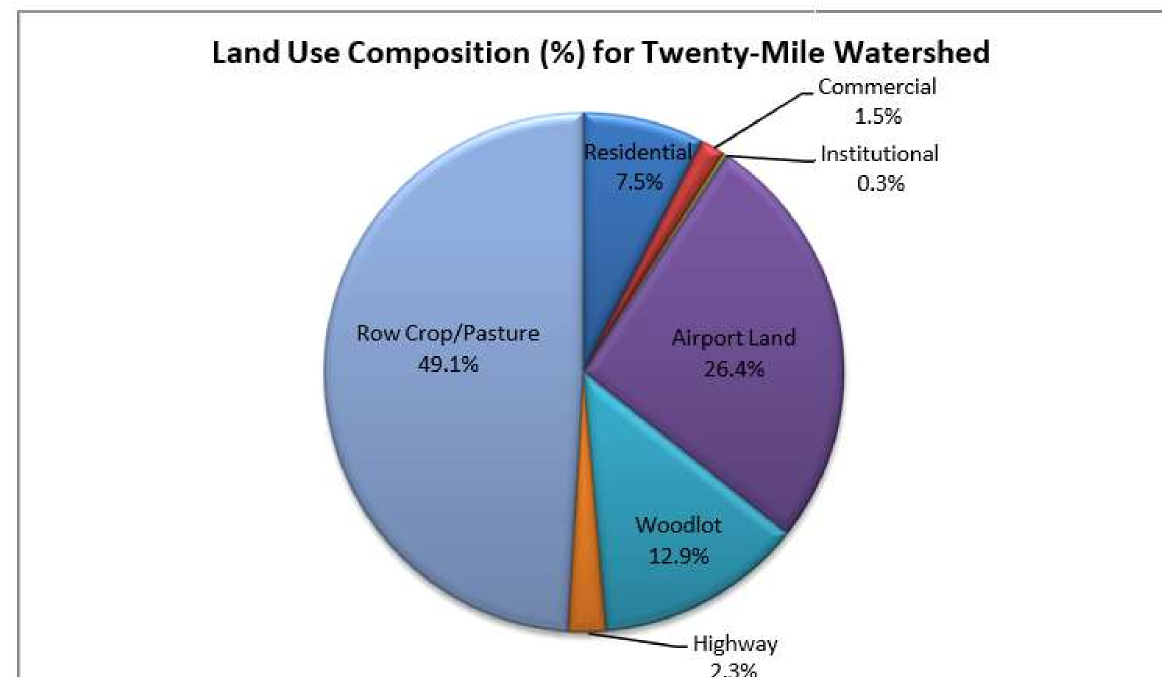
For the existing land use conditions water budget, in all three watersheds evapotranspiration comprises the largest component of the outputs (runoff, evapotranspiration and infiltration). In general infiltration is approximately double the proportion of runoff. The mean annual water balance quantities determined using HSP-F compare well to Phase 1 calculated estimates. Existing conditions water budget was not completed for the Big Creek watershed (See Section 1.1 General Information).

Figure 4.9 - Water Balance and Land Use Composition (Twenty Mile Creek Watershed)
Predevelopment Conditions

Twenty Mile Creek Watershed – Water Balance									
Sub-Catchment	**T-25**	**T-27**	**T-28**	**T-29**	**T-30**	**T-32**	**T-33**	**T-37**	**AVERAGE**
Area (ha)	108	99	59	101	126	312	255	71	
SUPPLY (mm)	645	644	646	645	645	644	645	645	645
RO (mm)	71	96	54	75	93	87	82	108	83
ET (mm)	338	331	352	342	334	338	346	325	338
INFIL (mm)	215	202	219	209	200	203	201	195	205



Land Use	Land Use Composition (ha) Twenty Mile Creek Watershed
Residential	85.4
Commercial	17.1
Institutional	3.0
Airport Land	298.1
Woodlot	146.4
Highway	26.4
Row Crop/Pasture	555.0



4.1.6.3 PROPOSED CONDITIONS UNCONTROLLED ANNUAL WATER BUDGET

Presented below are the uncontrolled (post-development with no stormwater management) water budget for the Welland River, Sulphur Creek and Twenty Mile Creek Watersheds.

Welland River Watershed

- Rainfall (Supply) = 642mm
- Runoff (RO) = 202mm (32%)
- Evapotranspiration (ET) =282mm (45%)
- Infiltration (Infil) = 150 (23%)

Sulphur Creek Watershed

- Rainfall (Supply) = 641mm
- Runoff (RO) = 306mm (48%)
- Evapotranspiration (ET) =239mm (37%)
- Infiltration (Infil) = 95 (15%)

Twenty Mile Creek Watershed

- Rainfall (Supply) = 641mm
- Runoff (RO) = 291mm (45%)
- Evapotranspiration (ET) =251mm (40%)
- Infiltration (Infil) = 99 (15%)

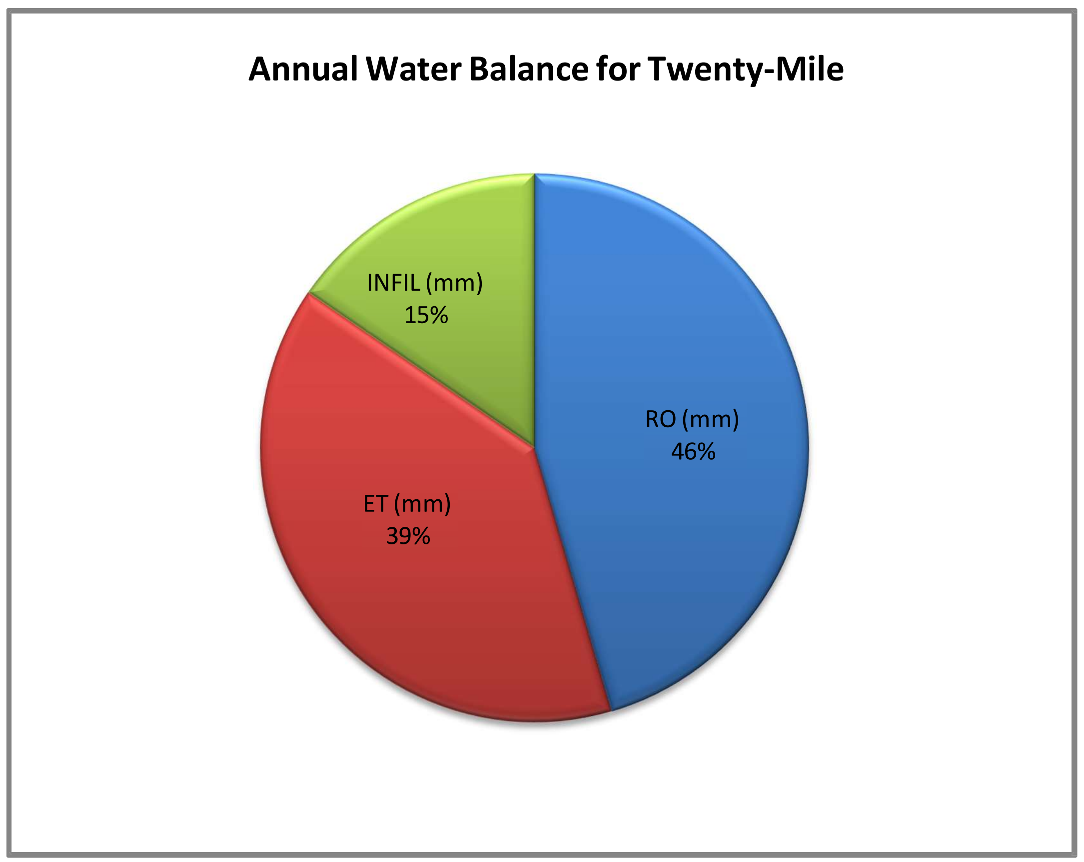
For the proposed land use conditions water budget, runoff is the largest of the water budget output components for Sulphur Creek Watershed and for Twenty Mile Creek Watershed.
Evapotranspiration continues to be the largest water budget component in Welland River Watershed (due to less urbanization in this watershed). This illustrates the hydrologic trend that occurs with urbanization; as imperviousness increases so does the amount of runoff thereby leaving less water available to infiltrate or evapotranspirate.

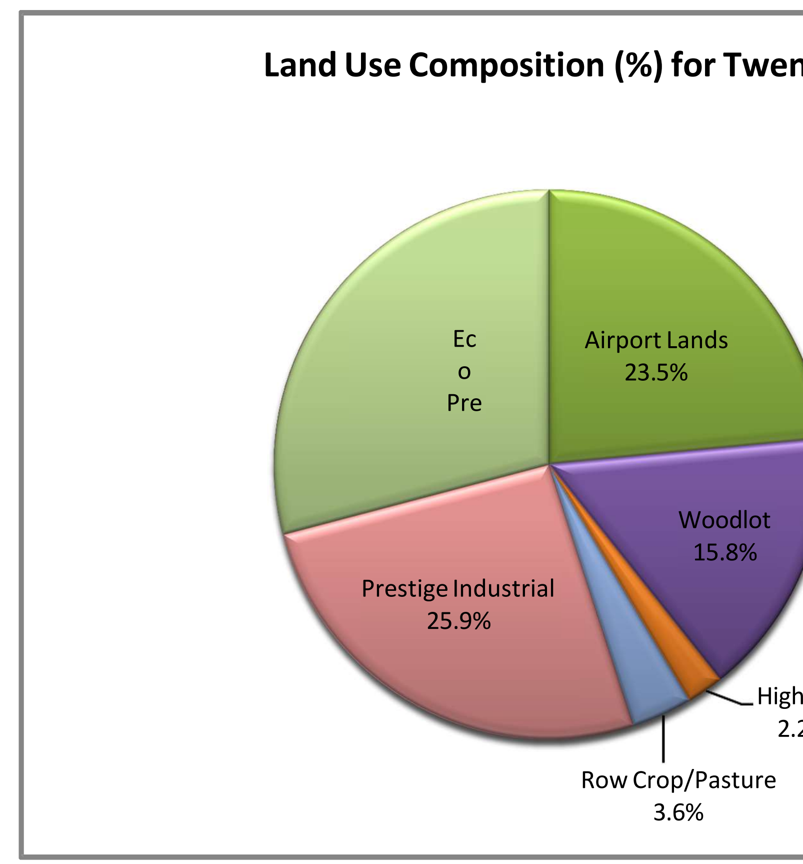
Due to reduced moisture retention there is less evaporation/evapotranspiration from impervious areas than from pervious areas. For all three watersheds the evapotranspiration drops from the existing to the proposed conditions generally from approximately 50% of the rainfall to 40% of the rainfall. Due to the hard surfacing of the ground, in general the runoff volume is three times that occurring in the existing conditions and the level of infiltration is about half of what occurs in the existing conditions. Results of the post development uncontrolled water budget analysis for each watershed are presented on an annual basis (1991-1996) in the following Figures 4.10– 4.12

**Figure 4.12 - Water Balance and Land Use Composition (Twenty Mile Creek Watershed)
Post Development Conditions (uncontrolled)**

Twenty Mile Creek Watershed – Water Balance									
Sub-Catchment	**T-25**	**T-27**	**T-28**	**T-29**	**T-30**	**T-32**	**T-33**	**T-37**	**AVERAGE**
Area (ha)	108	99	59	101	126	312	255	71	
SUPPLY (mm)	642	642	642	642	642	640	638	639	641
RO (mm)	285	288	330	293	284	323	204	321	291
ET (mm)	250	253	236	251	252	237	291	236	251
INFIL (mm)	103	98	76	96	103	82	145	86	99

Land Use	Land Use Composition (ha) Twenty Mile Creek Watershed
Residential	0.0
Commercial	0.0
Airport Lands	266.0
Woodlot	178.4
Highway	24.4
Row Crop/Pasture	40.3
Prestige Industrial	293.10
Eco Prestige Industrial	329.20





4.1.6.4 PROPOSED CONDITIONS WITH LID CAPTURE ANNUAL WATER BUDGET

Applying the infiltration targets identified in Table 4.10: LID Capture Target (m3/impervious ha served) for Proposed Conditions Land uses, a watershed analysis was performed. Targets from Table 4.10 account for the various AEGD future land use types and the various soils types.
After applying the respective targets, Table 4.11 presents a comparison of the watershed water balances: pre-development versus post-development with LID practices, the overall watershed capture volumes resulting from the application of the appropriate targets from Table 4.10 and a general summary of the corresponding catchment characteristics including:

• Hydrologic soil groups

• Future, existing and relative change in watershed imperviousness; and

• Average imperviousness of proposed land uses

The modeling results reported in Table 4.11 illustrate the effects of applying the LID Capture Target (Table 4.10) on the respective watersheds as a whole. These results demonstrate the effects of applying site level targets to the overall watershed for the combinations of soil types and proposed land uses found within the AEGD study area over each watershed. The water budget for the proposed land use conditions that incorporate LID measures, infiltration has been restored to predevelopment levels. Provided that the capture target (m3/ impervious area) is infiltrated, the water balance can be restored under the proposed land uses. Current research indicates that the surface area for infiltration measures becomes very large where the hydraulic conductivity of soils is low. For the majority of soil conditions found in the AEGD study area infiltration of the required target volumes is feasible.

The results of the water budget assessment for proposed land use conditions incorporating the implementation of LID measures are reported below, and presented graphically in Figure 4.13.

Table 4.11: Watershed Capture Results

Welland River Watershed	
Post with LID capture	Pre Development
Rainfall (Supply) = 642mm Runoff (RO) = 110mm (18%) Evapotranspiration (ET) =320mm (50%) Infiltration (Infil) = 204 (32%)	Rainfall (Supply) = 645mm Runoff (RO) = 69mm (11%) Evapotranspiration (ET) =342mm (55%) Infiltration (Infil) = 213 (34%)
Sulphur Creek Watershed	
Rainfall (Supply) = 641mm Runoff (RO) = 114mm (18%) Evapotranspiration (ET) =320mm (50%) Infiltration (Infil) = 206 (32%)	Rainfall (Supply) = 645mm Runoff (RO) = 103mm (17%) Evapotranspiration (ET) =308mm (48%) Infiltration (Infil) = 209 (33%)
Twenty Mile Creek Watershed	
Rainfall (Supply) = 641mm Runoff (RO) = 114mm (18%) Evapotranspiration (ET) =324mm (51%) Infiltration (Infil) = 202 (31%)	Rainfall (Supply) = 645mm Runoff (RO) = 83mm (13%) Evapotranspiration (ET) =338mm (54%) Infiltration (Infil) = 205 (33%)

Watershed	Area (ha)	Overall Watershed Capture Volume	Imp Area	Hydrologic Soil Class				Watershed Imperviousness			Average Imperviousness of proposed land uses
		mm	m^3 / ha	A	B	C	D	Ex (%)	Fut (%)	%	
*For the catchments located within the study area (as illustrated in **Figure 4.0**)*											
Sulphur Creek	*355*	*8*	*80*	*53*	*12*	*30*	*0*	15	*58*	*43*	*72*
Welland River	*1,356*	*8*	*80*	*12*	*21*	*57*	*9*	*12*	*38*	*26*	*73*
Twenty Mile	*1,571*	*7*	*70*	*10*	*16*	*53*	*18*	*8*	*52*	*44*	*75*

4.1.6.5 SUMMARY OF STORMWATER MANAGEMENT OBJECTIVES DETERMINED THROUGH HYDROLOGIC MODELING

Hydrologic modeling has been completed to demonstrate the infiltration capture targets (m3/imp ha) for the proposed land uses in the AEGD study area. It has been shown that these capture targets are sufficient to restore the predevelopment water budget for the built out proposed land use scenario (Figures 4.4 to 4.6) given the watershed characteristics.

The established infiltration targets will be met through the use of LID measures dispersed throughout the proposed development area. Guidance on the types and design characteristics of LID measures are provided to assist developers and regulatory agencies in implementing those features at the detailed design stage. Additional information regarding each LID practice is provided in Appendix A and can also be found in the Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC - 2010).

It is anticipated that in addition to matching the predevelopment water balance levels, the LID infiltration facilities will also provide water quality treatment and runoff reduction for erosion control.

Stormwater management dry ponds (end-of-pipe controls) provide post to pre-development controls for all design flows from the 2-year to the 100-year event. As part of the erosion sensitivity analysis performed as an integrated component of the modeling, it is anticipated that the combination of runoff reduction from LID controls and post to pre-development design flow controls using dry ponds will be sufficient to meet erosion control targets. However it must be acknowledged that the targets provided in this document are minimum targets only, and as such it is anticipated that practitioners applying and implementing the proposed Stormwater Master Plan will do so in full recognition of the Eco-Industrial design approaches which form the foundation of the treatment train approach (LID source and conveyance controls) proposed for the AEGD. With greater adoption and implementation of LID techniques, that transcend stormwater management into areas of energy efficiency, water conservation and re-use, green space maximization, tree conservation and better site design, the additional environmental and economic benefits of LID as part of an Eco-Industrial Park can be fully realized.

4.1.7 QUALHYMO SITE PLAN EVALUATION

With the greater adoption of LID throughout North America and the Europe, a new generation of hydrologic models are being developed which better represent the ultimate function and capabilities of LID techniques, both singularly and when used in combination. Qualhymo Build 62, is one such model (as is MIKE Urban, the LIFE model and variants of SWMM) which has been developed / upgraded to include functions such as:

1. The evaluation of distributed storage options;

2. Incorporating a volume enabling routing of runoff from impervious areas to an LID element; and

3. Balances long term volume inflow and recovery.

Within Qualhymo Build 62, commands such as Pervious with storage (Soakaway pits, Special Bioretention, Bioretention and Bioswale facilities, Grassed swales), Pervious surface (Infiltration trench and galleries, Green roofs, Permeable pavement) and Cistern (Rain Water Harvesting) can be used to represent the various LID techniques by allowing for temporary storage of water for eventual infiltration and varying soil and media compositions within individual sites.

In an effort to demonstrate the effectiveness of LID in the AEGD and to introduce newer models better capable of representing LD techniques, the following site plan evaluation has been provided.

Note that Visual OTTHYMO can be a surrogate for QUALHYMO modelling.

4.1.7.1 PURPOSE

The ultimate purpose/ goal of the section is provide planners, practitioners and stormwater professionals with a demonstration of:

• The treatment train approach for stormwater management using LID;

• The effectiveness of multiple LID techniques applied in within a site;

• The capability to utilize site specific features and opportunities;

• The flexibility inherent in the 13 LID technique; and

• The methodology of integrating LID into the site/ urban fabric.

To complete the assessment of the preferred SWM alternative for the AEGD, a site plan test case of a typical 20ha Prestige Business Park (PBP) development was developed which compares:

• Pre-development conditions,

• Site development with no stormwater management controls,

• Site development with conventional stormwater management controls (end of pipe controls)

• Site development with LID Source (lot level bio-swales, rainwater harvesting, downspout disconnection and amended soils) and Conveyance Controls (Roadway conveyance- bio-swales)

The site plan assessment was performed with the aid of the QualHymo model using both a 25mm event and continuous historical meteorological records from 1991-1996 for John C Munro Hamilton International Airport (Station # 61543194). The function and application of event based models versus continuous based models is discussed in subsequent sections. The purpose of the analysis is to assess the effectiveness of LID Source and Conveyance controls function in the soils and climate of the AEGD and in the context of the intended employment land uses as part of an Eco-Industrial approach, with respect to the appropriate management targets.

For this analysis, QUALHYMO (Build 62, December 2007) has been used. Build 62 combines many of the original QualHymo commands, but also includes modeling elements designed to represent various LID measures, including:

• The ability to simulate impervious and pervious surfaces as separate but linked elements;

• The ability of impervious surfaces to receive lateral inflows from other impervious or pervious surfaces, representing the treatment train approach to stormwater management;

• The ability to simulate impervious and pervious surfaces that include surface storage volumes. This allows the model to represent infiltration devices with storage and storage only techniques such as cisterns for rainwater harvesting;

• The ability to simulate stormwater filtration /removal devices

4.1.7.2 MODEL STRUCTURE

Pre-Development

Pre-development, the site plan test case is represented in the QualHymo model as an agricultural land use (100% pervious). The various site attributes are presented in Table 4.12, and a schematic is provided in Figure 4.14.

Table 4.12: Pre-development Site Characteristics

Site Feature	Characteristic	Surface Area
Impervious Area (Agricultural field)	Pervious	20 ha
Total Site Area	**100% Per**	**20 ha**

Post -Development - No SWM Control and Conventional SWM

Post-development, the site plan test case is represented in the QualHymo model as a typical 20ha Business Park, comprised of 70% impervious area and a corresponding 30% pervious area. The site is drained via a conventional storm sewer system. The post-development no- control scenario represents the site outflows when no end-of-pipe controls are used, i.e. the site discharges via the storm sewer system only. The post development, conventional SWM control scenario represents the site outflows when a conventionally sized end-of-pipe stormwater management pond is used.

The various site attributes are presented in **Table 4.13**, and a schematic is provided in **Figure 4.15.**

Table 4.13: Post-development No SWM Control and Conventional SWM Site Characteristics

Site Feature	Characteristic	Surface Area
Main Building Roof	Impervious	2.0 ha
Building Lobby Roof	Impervious	2.0 ha
Loading and Service Area	Impervious	2.5 ha
Main and Access Roads	Impervious	1.5 ha
Main Parking Area	Impervious	6.0 ha
Turf Area	Pervious	6.0 ha
Total Site Area	**70% Imp, 30% Per**	**20 ha**

Post -Development – LID Source and Conveyance Controls

Post-development, the site plan test case is represented in the QualHymo model as a typical 20ha Prestige Business Park (PBP), comprised of 62% impervious area and a corresponding 38% pervious area. The site drainage utilizes the following LID Source and Conveyance controls in a treatment train approach to on site stormwater management:

- The main building roof is drained to a cistern for rainwater harvesting. The contents of the cistern are used for outdoor irrigation of the site landscaping and turf areas. The daily withdrawal rate used in the modeling is intended to represent average irrigation water demands, which fluctuate with seasonal use. Overflow from the rainwater harvesting system is directed to the dry-pond facility, as overflows will typically occur during larger infrequent storm events.

- The building lobby roof is drained to the pervious turf area via a series of downspout disconnections. The pervious area soils have also been modified with soils amendments to increase infiltration and water holding capacity prior to sod and seed.

- The main road, local access road and loading and service areas are drained to the 3m wide bio-swales within each road boulevard/cross-section (see Figure 3.0-3.2: Standard road cross-sections). The bio-swales are assumed to be trapezoidal grass swales with a 0.4m bottom width, 3:1 (h:v) side slopes and a bed slope of 1%.

- The main parking area is drained to a series of distributed bio-filters (bio-swales) placed in the medians of the parking area (total area = 1.4 ha).

The various site attributes are presented in **Table 4.14**, and a schematic is provided in **Figure 4.16**.

Table 4.14: Post-LID Source and Conveyance Controls Site Characteristics

Site Feature	Characteristic	Surface Area
Main Building Roof	Impervious	2.0 ha
Building Lobby Roof	Impervious	2.0 ha
Loading and Service Area	Impervious	2.5 ha
Main and Access Roads	Impervious	1.5 ha
Main Parking Area	Impervious	4.4 ha
Turf Area	Pervious	5.6 ha
Road ROW Bio-swales	Pervious	0.6 ha
Parking lot Bio-Filters	Pervious	1.4 ha
Total Site Area	**62% Imp, 38% Per**	**20 ha**

Figure 4.13: Site Plan Test Case - Pre-Development

Figure 4.14: Site Plan Test Case - Post Development Conventional SWM

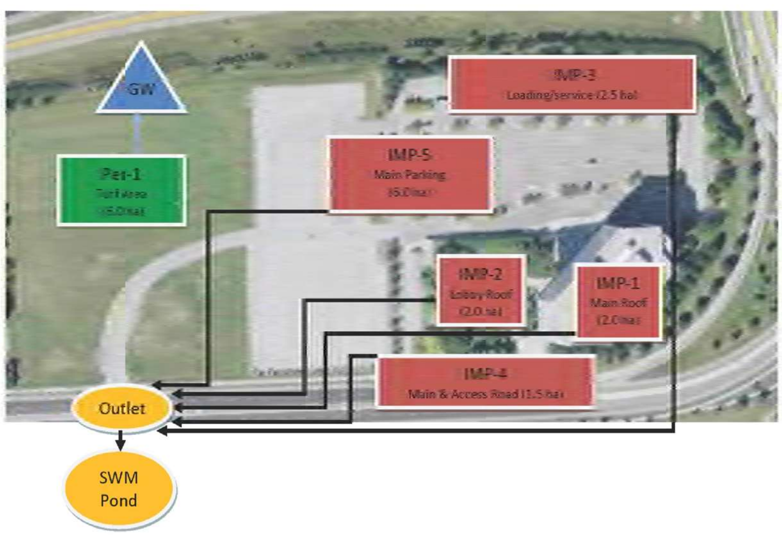
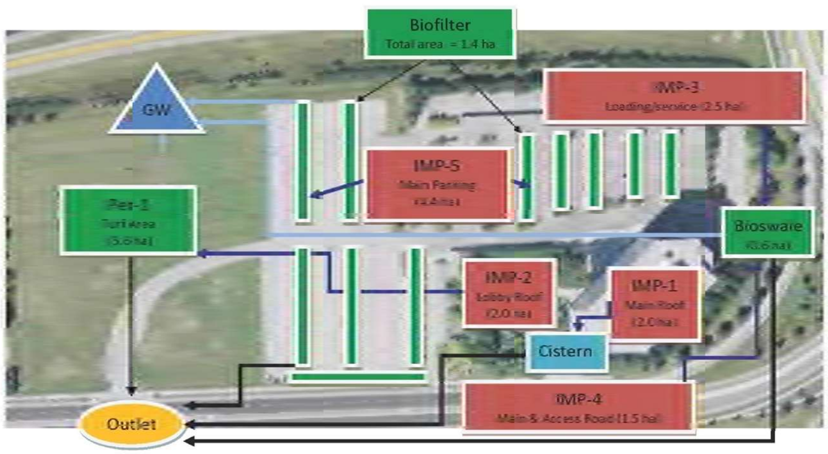


Figure 4.15: Site Plan Test Case - Post Development with LID



4.1.7.3 SITE PLAN TEST CASE RESULTS: WATER BALANCE

The following table provides water budget volumes and corresponding depths (mm) for the site plan test case based on 5 year continuous simulation (January 1, 1991 to Dec 31, 1995).
The continuous model spans several seasons, and simulates more hydrologic processes than single event models and therefore requires long term time series of historical meteorological data for precipitation, temperature, cloud cover, dew point, wind speed, solar radiation* and evapotranspiration* (Note:* denotes data calculated from long-term observed data). In addition to estimating surface runoff rates and volumes, continuous models are best used to simulate processes such as snow melt and accumulation, evapotranspiration, and groundwater recharge. When the continuous model outputs are combined an annual water balance can be generated. An average yearly water balance for the site plan test case for each of the three scenarios (pre-development, conventional control and LID design) are summarized in Table 4.15 and Figure 4.16.

Table 4.15: 5 year (1991-1995) Continuous Simulation Water Balance

Water Budget Analysis, January 1, 1991 - Dec 31, 1995						
Precipitation (Hamilton A- 1991-1996)	**Pre-Development (TIMP= 0%)**		**Conventional Design (TIMP = 70%)**		**LID Design (TIMP = 62%)**	
	m^3	**(mm)**	**m^3**	**(mm)**	**m^3**	**(mm)**
Precipitation	675,379	3377	675,379	3377	674,576	3373
Surface Runoff	76,552	383	360,035	1800	93,703	469
Evapotranspiration	138,133	691	176,818	884	187,551	938
Infiltration	437,705	2,189	115,221	576	354,008	1770
Storage	22,989	115	23,304	117	32,574	163

In regards to the effectiveness of LID Source and Conveyance controls function in the soils and climate of the AEGD and in the context of the intended employment land uses as part of an Eco-Industrial approach and with respect to the appropriate management targets, the following conclusions can be drawn from the QualHymo analysis:

1. LID source and conveyance controls better match pre-development infiltration targets. From this simulation, LID techniques provided 81% of the pre-development infiltration, while only utilizing 10% of the total site area, as compared to the conventional design which provided only 26% of pre-development infiltration.
2. LID source and conveyance controls better match pre-development evapotranspiration (ET) targets. The results of this simulation demonstrate the ability of LID techniques to match pre-development ET, providing greater than 100%. Note this is largely a result of the use of the collected rainwater for outdoor irrigation where it is subject to high rates of ET.
3. LID source and conveyance controls reduce runoff volumes, more closely matching pre-development levels.

The results as presented above represent only one singular site plan example whereby specific LID techniques have been applied in an attempt to match the pre-development water balance. The implications of the results in are presented below:

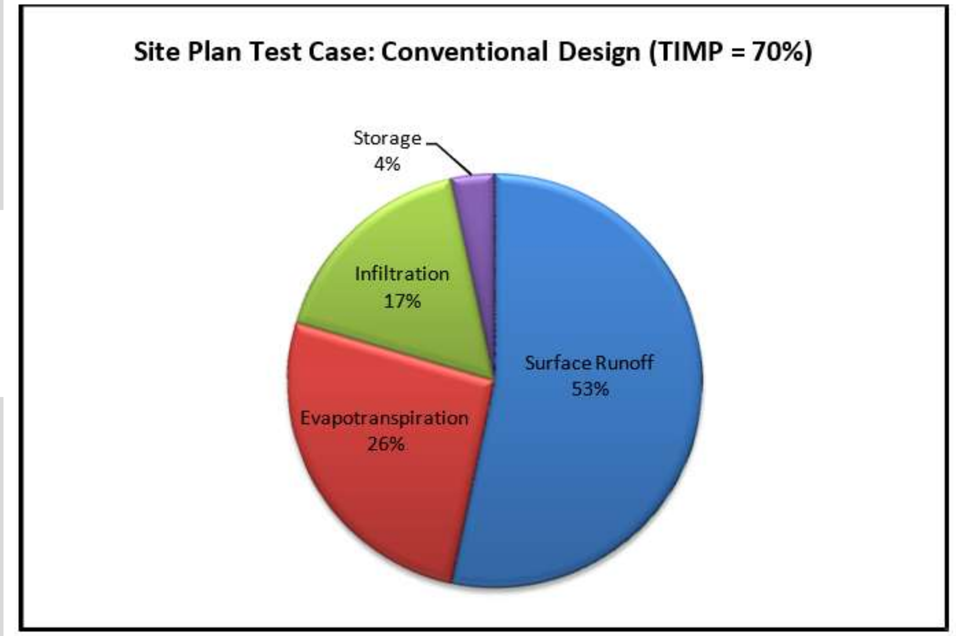
- A small increase in the percentage of total site area dedicated to LID techniques could be implemented to restore the pre-development infiltration on this site or alternatively the individual selection of the LID techniques could be modified to include techniques that more directly influence infiltration. The freedom with which designers can select and implement the thirteen (13) LID techniques in various configurations (flow pathways) provides greater flexibility with which to achieve the design objectives.

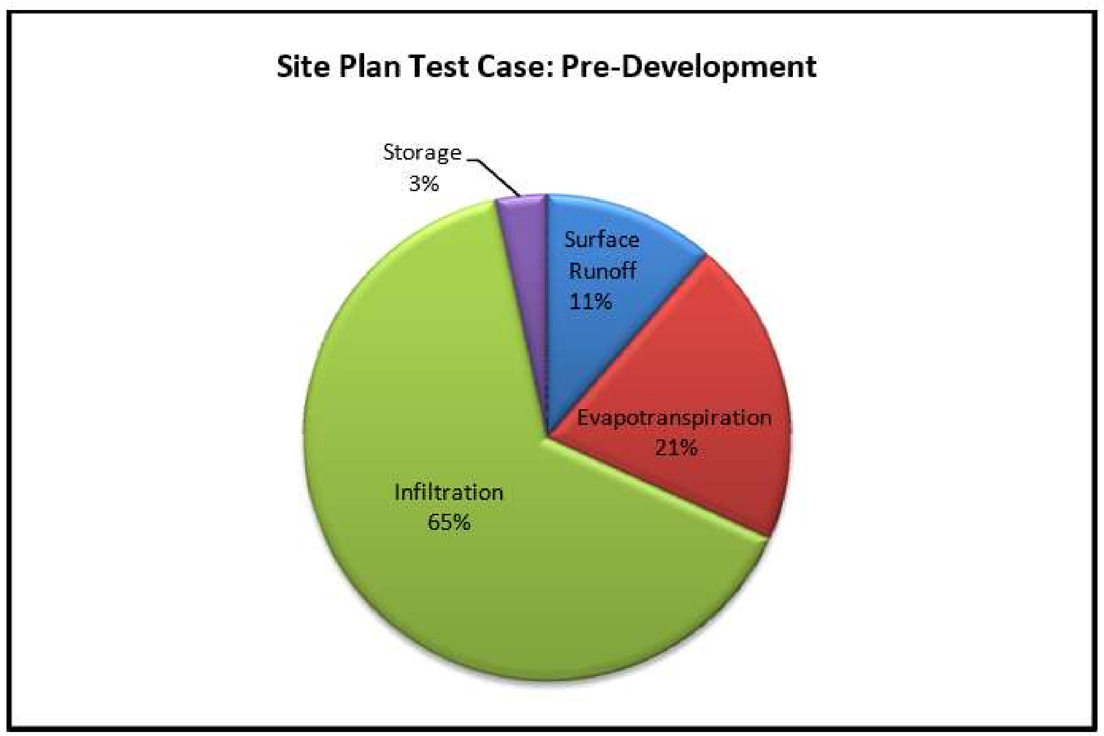
- This site plan was intentionally designed to incorporate rainwater harvesting as it is expected that many designers will adopt this practice in recognition of the Eco-Industrial design approaches which form the foundation of the treatment train approach (LID source and conveyance controls) proposed for the AEGD. By implementing RWH on this site, the design provided greater than 100% of the pre-development ET and greatly reduced post-development runoff volumes thereby providing greater erosion control. The relative benefit of these two effects are inseparable in regards to the post-development water balance and demonstrate the achievable benefits from greater adoption and implementation of LID techniques (beyond minimum targets).

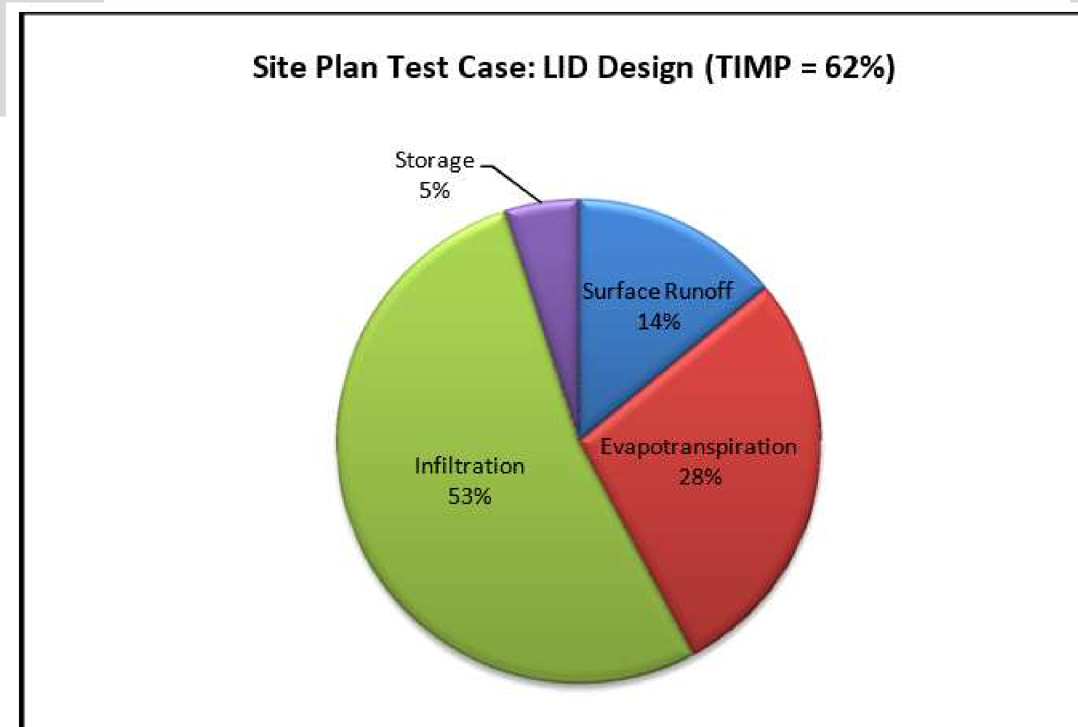
- Figure 4.16 – Site Plan Test Case: Water Balances

Site Plan Test Case: Water Balances

Pre-Development	Conventional Design (TIMP = 70%)	LID Design (TIMP = 62%)
675	675	675
77	360	94
138	177	188
438	115	354
23	23	33
0	0	7







4.1.7.4 SITE PLAN RESULTS: EVENTS BASED RESULTS (25 MM EVENT)

As part of the assessment of the effectiveness of LID Source and Conveyance controls for lands within the AEGD study area, an event based analysis was performed. An event based model simulates the runoff response of the catchment (20ha test site) to a short duration rainfall event, in this case a synthetic design storm of 25mm event over a 6 hour period. A 25mm event was selected for the event based analysis due to the following:

i. Based on rainfall frequency analyses for Southern Ontario, the ability to control a 25mm event represents control of approximately 90% of the total annual precipitation events and therefore 90% of the events that would release contaminants into the environment if allowed to become runoff. The remaining 10% represent infrequent, large magnitude events.

ii. In accordance with current MOE Stormwater guidelines as they pertain to watercourse erosion, a generalized control target of the capture of a runoff volume equal to that generated by a 25mm rain event and its release over 24 hours.

Five scenarios were modeled using the event based approach; they include:

1. Pre-development conditions;

2. Post development with no SWM controls;

3. Post development with conventional SWM controls (storm sewer and wet-pond);

4. Post development source controls (Bio-filter, Rainwater Harvesting, Soil Amendments); and

5. Post development with a treatment train approach – LID Source and Conveyance controls (Bio-filter, Rainwater Harvesting, Soil Amendments and Bio-swales along each side of the road ROW within the 3m road cross-section dedication).

6. Hydrograph results from the 25mm event analysis (Figure 4.17) demonstrate the effect of the treatment train approach, whereby source and conveyance controls are applied in series along the stormwater flow path. The results indicate:

• the effectiveness of LID development techniques at reducing runoff; and

• the relative benefit (increased runoff reduction) of an LID Treatment Train approach to SWM (LID Source and Conveyance controls in combination), over LID source controls alone.

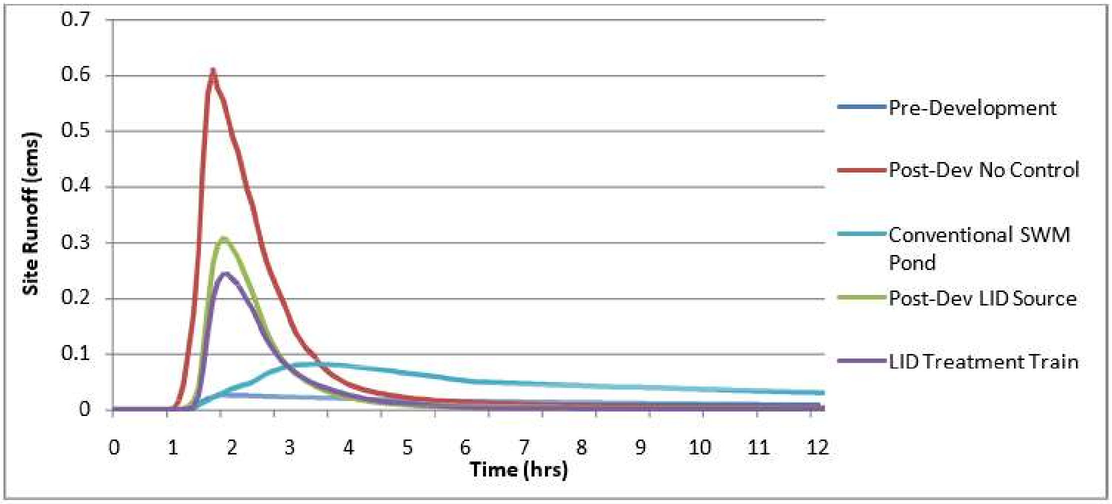


Figure 4.17: Runoff Characteristics of a 25 mm 6hr Event for a 20ha Site Plan Test Case

4.1.7.5 SITE PLAN RESULTS: CONTINUOUS MODELING

As a continuation of the assessment of the effectiveness of LID Source and Conveyance controls for lands within the AEGD study area, a continuous based analysis was performed for the years 1991-1996. Continuous models differ from single event models in that they use a long term time series of historical meteorological data instead of a single synthetic design storm. Continuous-runoff models estimate the entire runoff hydrograph from the rainfall excess remaining after initial abstraction, infiltration, depression storage and antecedent moisture conditions have been taken into account. This provides a measure of continuous runoff reduction in response to observed climatic conditions and better represents LID performance.

Three scenarios were modeled using the continuous modeling approach; they include

1. Pre-development conditions;

2. Post development with no SWM controls; and

3. Post development LID Controls (Bio-filter, Rainwater Harvesting, Soil Amendments)

Figures 4.18-4.20 illustrate the results of the continuous modeling for the year 1992 at various temporal resolutions of 1-year, October 8- Oct 21 demonstrating successive events during key months of the evaluated year. Continuous modelling results (Figures 4.18- 4.20) clearly demonstrate the same runoff reduction potential using LID as that demonstrated through the event based model (Figure 4.17).

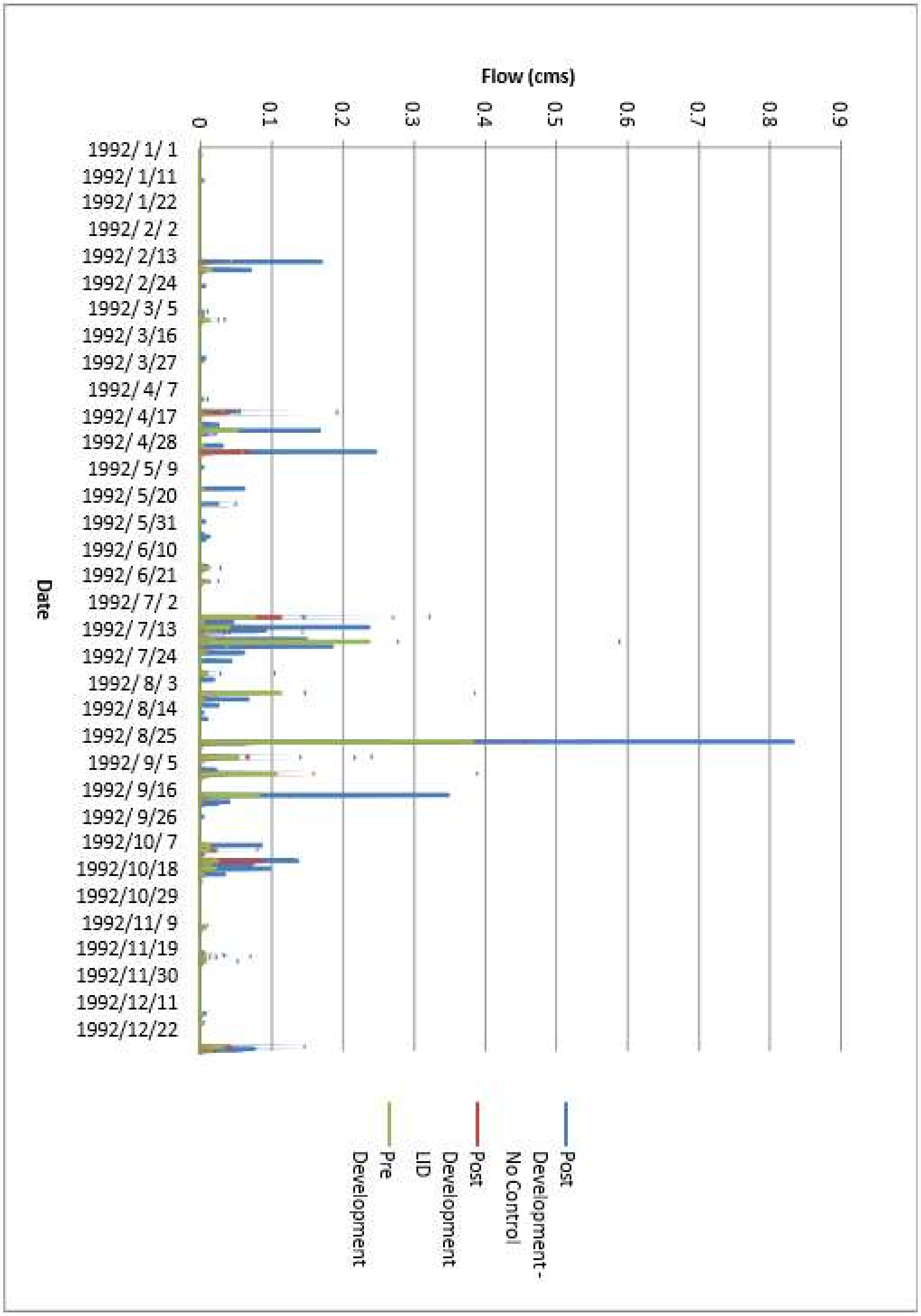


Figure 4.18: Site Plan Test Case – Continuous Modeling results for 1992

4.1.8 LID CONVEYANCE/ ROW ANALYSIS

As part of the Transportation Master Plan for the AEGD, a 3m allowance within the standard local, collector and arterial road cross-sections have been reserved for the inclusion of LID conveyance systems. It is also intended that LID conveyance systems be implemented on all roads with the AEGD. These systems intend to provide a conveyance function while encouraging infiltration of water into the ground, improving water quality and reducing runoff.

According to the "City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design" (Philips Engineering, 2007), minor systems (ditches, sewer, etc.) shall be designed according to the approved Master Drainage Plan (MDP). Approved MDP's may have established sizing criteria other than 1 in 5 year standard which would govern the sizing of the stormwater infrastructure, however the proposed LID conveyance systems shall be designed to a minimum 1 in 5 year event.

As part of the 'Dual Drainage Concept', whereby stormwater drainage is managed using a combination of a:

• minor system, removing surface runoff from more frequent storms and deliver it to receiving waters ;and

• major system, consisting of overland flow routes (roads, drainage swales etc) and end-of-pipe stormwater management facilities;

LID conveyance controls are intended to function as the minor system for the AEGD where feasible. As such the LID conveyance controls should be designed as a minor system in compliance with the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips- 2007). Other design considerations during site planning may include the following:

• LID conveyance systems (see Section 3.3.2) should convey flow from the ROW and adjacent development areas from the upstream end to the centralized dry pond (SWM facility;

- Conventional storm sewers may be required to service portions of the subject lands.

• LID conveyance systems (see Section 3.3.2) should be designed to accommodate/ convey flows underneath driveways (using culverts/ perforated pipes etc.)

• LID conveyance systems are to have the capacity to accommodate flows from the outlets from adjacent development (pipes, open channels, Other LID conveyance controls)

• LID conveyance techniques should be combined or stacked (perforated pipes, gravel storage areas, infiltration/filtration media, enhanced landscaping) to provide additional water quantity/quality benefits where soil / groundwater conditions permit.

The AEGD, as with all developments, will require a major system - the overland route the excess runoff will follow when the minor system capacity is surpassed or is inoperable. The major system exists whether it is deliberately designed or not, therefore it is vital in the initial planning stages, to recognize the need for a continuous grade to convey runoff in excess of the minor system capacity to a free outlet. The major system includes such features as natural and constructed open channels, streets and roadways, drainage easements and stormwater management facilities. The major system should be designed in compliance with the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips- 2007).

Although the Transportation Master Plan for the AEGD has provided a 3 m allowance for the inclusion of LID conveyance systems, the performance of these systems in relation to the various road configurations is unclear. It is anticipated that the capabilities of the LID conveyance systems may be exceeded as they are implemented along larger roadways which produce greater amounts of runoff. As such, it was concluded that a performance assessment of the proposed LID conveyance systems be conducted for each road type. This aimed to ensure that conveyance systems implemented along each road type would not exceed its capacity during the 1 in 5 year event, as per City of Hamilton design criteria, for runoff received from the road surface only. This assessment is specific and limited to the conveyance capacity of the surface portion of the LID Conveyance systems (grass channel or bio-swale) and adopts a conservative approach by not including the effects of incorporating subsurface storage (gravel storage area), underdrains (perforated pipes) or infiltration capabilities. As such the conveyance assessment is intended to be used as a planning tool to assist in road network layout and LID conveyance selection and design. Uncertainty with respect to the exact configuration, building footprint, and extent of LID techniques which will ultimately be utilized within each individual site did not allow for flow estimates from each site to be determined. As noted above, conventional storm sewers may be a more feasible solution subject to the ultimate ROW configuration, land use, and proximity to the outlet.

The objective of the analysis was, for each road type, to determine the maximum unit length of roadway that may be constructed before runoff volumes from adjacent road surfaces exceed the surface capacity of the LID conveyance systems.

4.1.8.1 ANALYSIS

To complete the evaluation of the LID conveyance systems capabilities, a variety of modeling scenarios were completed using each of the five standard road configurations and modeling them against a range of road lengths. Each of the following five (5) standard road types was evaluated using various road lengths ranging from 1 km to 5.5 km:

- Local Roads;
- 2 Lane Collectors;
- 4 Lane Collectors;
- 4 Lane Arterial; and
- 6 Lane Arterial

For this analysis, SWMMHYMO and HEC RAS Version 4.0 models were used. For the purposes of the following exercise, SWMMHYMO modeling was utilized to determine runoff flows from road surfaces during a 1 in 5 year event. A typical 1 in 5 year event for Mount Hope was deemed applicable for the purpose of this assessment due to its close proximately to the study area.

HEC RAS hydraulic model was used to represent the runoff flows, determined by SWMMHYMO, as surface water elevations within the LID conveyance system configurations. This preliminary stage of modeling was used to determine which unit length of roadway would produce runoff flows which would exceed the capacity of the conveyance systems. It should be noted, that each LID conveyance swale receives runoff volumes from one half of the drivable road surface (3m ROW have been provided on each side of the road cross section per the AEGD Transportation Master Plan). The hydraulic modeling of the LID conveyance systems were conducted accordingly.

Configurations of the LID conveyance systems were generally assumed. However, provided that the entire 3 m allowances would be utilized, the systems were modeled using a 3 m top width and a typical side slope value (2:1). General system configurations and assumptions are demonstrates in Table 4.15.

Table 4.15 – General Assumptions – LID Conveyance System Configurations

Parameter	Assumption
Top Width	3 m
Side Slope	2:1
Depth	0.5 m
Bottom Width	1 m
Channel Slope	0.5%
Roughness (Manning's "n")	0.35 grass swales (Chin, 2006)

4.1.8.2 RESULTS: LOCAL ROADS

According to the City of Hamilton and the Standard Road Drawings Index, the typical road cross section for local urban residential roads indicated that the drivable surface occupies 8.0 m of the 20.0 m or 18.0 m Right-of-Way (ROW). Refer to Appendix H for the standard road crossing for local urban residential roadway (18m & 20m R.O.W) as per the City of Hamilton. For the purposes of this analysis, the local road has assumed to be 8m.

Using the standards local road configurations, SWMMHYMO models were conducted to determine the runoff flow rates from various lengths of local road. HEC RAS modeling results indicated that the LID conveyance systems may convey a maximum runoff flow rate of approximately 0.95m3/s assuming a channel slope of 0.5% - a slope that coincides with the existing topographic characteristics of the AEGD study area. An assumed roughness coefficient of 0.035 was used provided the LID conveyance swales are to be vegetated. Figure 4.20 demonstrates the surface water elevation of the runoff flow accumulation from 5km (0.86 m3/s) and 5.5km (0.95 m3/s) of 2 lane local road.

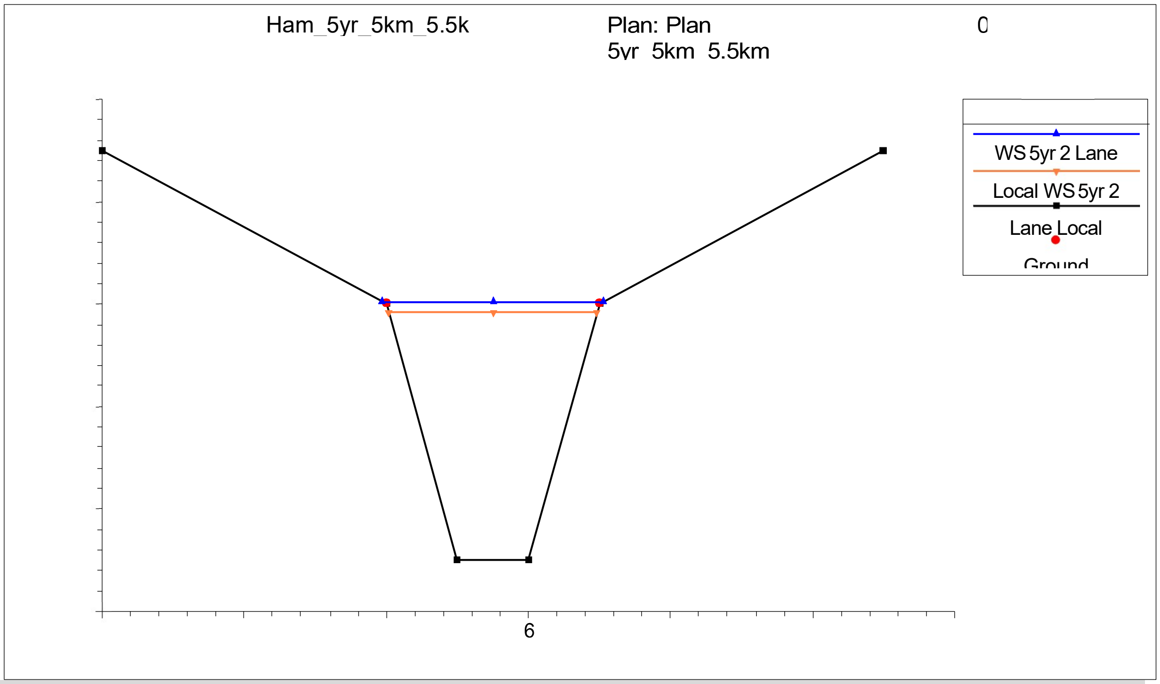


Figure 4.20 – Surface water elevation of the various runoff flow accumulation from 5km and 5.5km of 2 lane local road.

Upon evaluation, the proposed LID conveyance systems would be able to accept runoff volumes from 5km local roads without exceeding the capacity of the LID conveyance system (not including drainage from contributing sites).

4.1.8.3 RESULTS: STANDARD COLLECTOR AND ARTERIAL ROADWAYS

The remaining four standard road crossings will be constructed as per the AEGD Transportation Master Plan. The typical road cross-sections for the proposed collector and arterial roadways indicated that the drivable surface are comprised of the automobile traffic lanes, but also incorporate an additional 3.0 m for cyclist traffic. A combination of these impermeable surfaces was used within the SWMMHYMO and HEC RAS models to represent the surfaces contributing runoff to the LID conveyance systems. Refer to Appendix H for the configurations of the proposed collector and arterial roadway. Table 4.16 summaries the modeling results for the remaining arterial and collector roadways.

Table 4.16 – Summary of Allowable Road Lengths for each Road Type

Roadway Type	**Half Total Impermeable Surface (m) (Roadway + Bike Lane)**	**Maximum Allowable Contributing Road Length based on Conveyance Capacity (km)** (does not including drainage from contributing sites)
2 Lane Collectors	5	4

4 Lane Collectors	8.5	2.5
4 Lane Arterial	10.5	2
6 Lane Arterial	14	<2

Full details, figures and modeling results for the roadway types listed in Table 4.16 are presented in Appendix H.

In summary, hydrologic and hydraulic modeling results indicated that the construction length of the various roadways proposed for the AEGD are limited by the available capacity of the adjacent LID surface conveyance systems. As such, a maximum allowable contributing length for each roadway has been determined to ensure the capacity of the LID surface conveyance systems is not exceeded. The varying lengths are as follows:

- Local Roads contributing to a surface conveyance system are not to exceed 5km;
- 2 Lane Collectors contributing to a surface conveyance system are not to exceed 4.5km;
- 4 Lane Collectors contributing to a surface conveyance system are not to exceed 2.5km;
- 4 Lane Arterial contributing to a surface conveyance system are not to exceed 2km; and
- 6 Lane Arterial contributing to a surface conveyance system must be less than 2km

In order to appropriately convey the required flows from unit road length greater than those listed above using the 3m allowance within the standard local, collector and arterial road cross- sections which have been reserved for LID conveyance systems as part of the AEGD Transportation Master Plan, the inclusion/combination of sub-surface storage and underdrained/perforated pipe infiltration systems will be necessary.

This assessment is specific and limited to the conveyance capacity of the surface portion of the LID Conveyance systems (grass channel or bio-swale) by design, and conservatively does include the effects of incorporating subsurface storage (gravel storage area), underdrains (perforated pipes) or infiltration capabilities. As such the conveyance assessment is intended to be used as a planning tool to assist in road network layout and LID conveyance selection and design.

More detailed, site specific modeling is required at subsequent stage of development to confirm specific design performance in relation to surface conveyance systems.

5.0 CATCHMENT-BASED ENVIRONMENTAL CRITERIA AND TARGETS

The following section is intended to outline the environmental criteria for the suite of LID stormwater management techniques including source and conveyances systems, end-of-pipe dry ponds and stream restoration (corridor protection and riparian plantings) in the context of the AEGD study area and the four land-uses. Following the discussion of the environmental criteria are the specific targets for the AEGD in relation to the individual environmental criteria. It must be acknowledged that the targets provided in this document are minimum targets only and as such it is anticipated that practitioners applying and implementing the proposed Stormwater Master Plan will do so in full recognition of the Eco-Industrial design approaches which form the foundation of the treatment train approach (LID source and conveyance controls) proposed for the AEGD and will strive for a "best achievable" implementation strategy on a lot level basis based on local soils and other relevant site characteristics. With greater adoption and implementation of LID techniques, that transcend stormwater management into areas of energy efficiency, water conservation and re-use, green space maximization, tree conservation and better site design, the additional environmental and economic benefits of LID as part of an Eco- Industrial Park can be fully realized.

5.1 GENERAL

The 2003 Hamilton Airport Servicing study (Lewellyn Associates) recommended that a rural road cross section be maintained for a majority of the proposed development within the study area. The study further recommended utilizing "source" or "lot level" stormwater management facilities over centralized facilities to address stormwater management requirements (for water quality, erosion and infiltration), in part because of the limitation of existing drainage features to provide an outlet for such facilities.

'Traditional' end-of-pipe stormwater management facilities are resulting in longer periods of elevated flow, thermal enrichment of surface water bodies and increased pollutant loadings. As such, there is a growing body of evidence that suggests that a greater emphasis on, and implementation of, Low Impact Development (LID), that employ infiltration at the lot level and during conveyance will be required to meet environmental targets for stormwater management controls.

In a general sense, LID techniques can be applied on all four of the primary land-uses of the AEGD, however in terms of the five (5) design criteria:

1. Flood protection;
2. Water quality;
3. Erosion;
4. Infiltration (Water Balance); and
5. Natural features

As part of water balance approach to stormwater management, it is important to acknowledge early in the selection process, as to which of the five (5) design criteria LID techniques are effective and ineffective. Figure 5.0 illustrates the general effectiveness of LID in relation to each of the five design criteria.

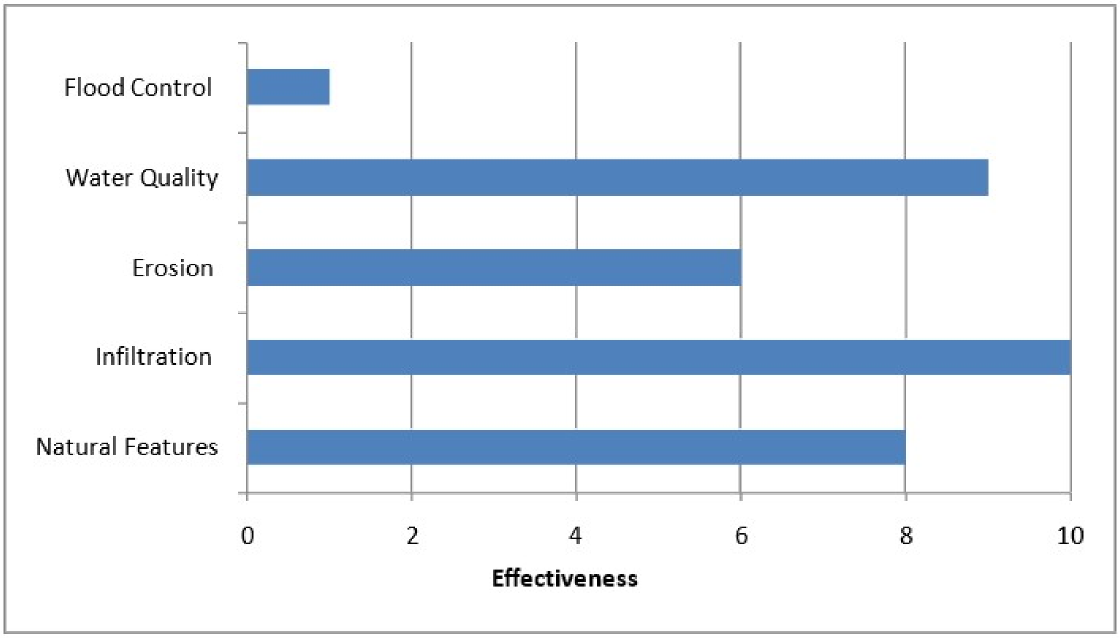


Figure 5.0: General Effectiveness of LID Techniques in Relation to Water Balance Design Criteria

5.1.1 FLOOD PROTECTION

LIDs are highly effective in terms of meeting water quality, erosion, infiltration and natural feature design criteria; however they are largely ineffective in addressing flood control criteria (Figure 5.0). LID techniques are intended to manage the smaller, more frequent events and as such are largely ineffective when dealing with larger infrequent events.

To address this LID source and conveyance controls are often partnered with more traditional end-of-pipe measures such as dry-ponds (per Section 3.0). To that end, the preferred Stormwater Master Plan for the AEGD utilizes a suite of LID source and conveyance controls in combination with end-of-pipe Dry-ponds. As it relates to flood control within the AEGD, the implementation of a treatment train approach to SWM management that includes Dry-pond end- of-pipe controls is essential given the existing airport constraints (Section 1.3.1) and drainage feature constraints (Section 1.3.2).

The dry ponds will form part of the AEGD's major system, consisting of overland flow routes (roads, drainage swales etc) and end-of-pipe stormwater management facilities (Section 3.3.1). LID conveyance controls are intended to function as the minor system only. The Major System exists whether it is deliberately designed or not, therefore it is vital in the initial planning stages, to recognize the need for a continuous grade to convey runoff in excess of the minor system capacity to a free outlet in order to avoid flooding and the associated property damage and potential loss of life. The major system includes such features as natural and constructed open channels, streets and roadways, drainage easements such as floodplains and stormwater management facilities. The major system should be designed in compliance with the City of Hamilton Criteria and Guidelines for Stormwater Infrastructure Design (Phillips- 2007).

Although the majority of the proposed suite of LID techniques have some capacity to partially meet water quantity targets, this approach is generally not supported by regulatory agencies and has been found historically to be extremely costly and as such is not proposed as part of the preferred Stormwater Master Plan for the AEGD.

Based on the hydrologic modeling work for Phase 2, as well as the regulatory requirements of the 3 conservation authorities, post to pre peak flow controls for a time series flows from the 2 through 100 year event is required for all dry ponds. Floodplain mapping for AEGD study area

has been completed (See Figure 3.3) and no additional floodplain mapping has been identified as part of the AEGD Stormwater Master Plan. The AEGD Flood control targets are presented in Table 5.0: AEGD Environmental Criteria and Targets.

To appropriately manage drainage from future development within the AEGD study area which flow into existing private stormwater facilities in communities adjacent to the study area on the north side along Garner Road and Twenty Road, legal access for the purposes of inspection, maintenance or facility upgrade by the City will be required. As such, it is recommended that development draining into existing private facilities be precluded until such time as the City retains easements to access these facilities.

5.1.2 WATER QUALITY

The AEGD Transportation Water/Wastewater Stormwater Master Plans - Phase 1 Draft (May 2008) identified the following as it relates to water quality:

• Due to the sensitivity of downstream areas to water quality impacts (fisheries, erosion susceptibility, ESA/wetland features, and Great Lakes Areas of Concern), all proposed development will require level 1 or enhanced stormwater treatment.

• In general, results show that both the Welland and Twenty Mile Creeks in the study area and immediately downstream are nutrient rich (as indicated by total phosphorus), moderately contaminated by bacteria (E.coli) and have elevated chloride levels. In general, levels of trace metals, such as copper, lead and zinc, are below provincial guidelines. In comparing the levels in the Welland tributaries, located just downstream of the Airport and the Welland River station at Tyneside Road, it would appear that the airport contributes to the elevated nutrient, bacteria and chloride levels. However, agricultural land uses and the existing road network are also contributors.

• All of the tributaries are upstream of either the Niagara or Hamilton Harbour Areas of Concern, and as a result require enhanced or level 1 stormwater treatment from a water quality/fish habitat perspective.

The Ministry of the Environment's 2003 Stormwater Management Planning and Design (SWMPD) manual (Table 3.2), although not expressly stated in the manual, predominately deals with end-of-pipe controls. However, the SWMPD manual also contains guidance for stormwater

management facilities that employ infiltration including lot level and conveyance controls. More specifically and in relation to the soils within the AEGD, the 2003 SWMPD manual under Section 4.2 and Table 4.1 provides guidance that relates to "physical constraints which could limit the use of lot level, conveyance and end-of-pipe controls", but does not in any way indicate that area soil with lower relative infiltration rates be excluded from infiltration practices. The infiltration rate of soils will have an obvious effect on the drawdown-time of the facility between events and therefore should be sized accordingly based on design guidance from sources such as the Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC - 2010) or others. As such, soil infiltration capacity guidance in the SWMPD manual should not be interpreted as a prohibition but as a caution that controls relying primarily on infiltration may not be as effective as they could be on soils with higher relative rate of infiltration.

Furthermore, LID stormwater management practices in soils with lower infiltration capacities can utilize multiple mechanisms (beyond simply infiltration) such as, but not limited to; Filtration, Retention, Evaporation and/or Transpiration. If sized such that they empty between events and will not be perceived as a nuisance, should not exclude the implementation of such measures to realize water quality, as well as water balance objectives regardless of the native soils. Provided that the proposed LID techniques incorporate the appropriate runoff storage volumes, empty within inter-event periods and are otherwise appropriately sited, designed, monitored and maintained (similar to all other stormwater management facilities), there should be no impediment to the application of infiltration technologies, in all soils type, for the realization of water quality. The AEGD Water Quality Control targets are presented in Table 5.0: AEGD Environmental Criteria and Targets.

5.1.3 EROSION

The approach used to define erosion control targets in the AEGD study area includes:

- City of Hamilton - Municipal Erosion Control Guidelines; and
- The 2003 MOE Stormwater Management Planning and Design Manual
- Implementation of LID measures to achieve water balance and water quality criteria

Integrated into the definition of erosion control targets for the AEGD and its respective watersheds is the understanding of how hydromodification affects those elements of natural channel form that can lead to watercourse destabilization and destruction of aquatic habitat. Watercourse erosion is cause by Hydromodification, which contains three key concepts:

1. Magnitude – Peak flow rate
2. Duration – Runoff Volume
3. Frequency- Number of Runoff Events

Magnitude

Excessive erosion occurs post-development, even with the inclusion of 'traditional' erosion controls because peak flow management often results in flows that are in excess of the watercourse erosion thresholds for prolonged periods of time when compared to pre- development.

Duration

To mitigate the geomorphic impacts that result from current practices, LID practices utilize multiple mechanisms such as infiltration, filtration, retention, evaporation and/or transpiration to reduce runoff volumes and to more closely return the post-development water balance to pre- development levels. It is however, the water balance that ultimately determines watercourse flow and the flow which dictates the channel form.

Frequency

When dealing with watercourse erosion, the frequency of runoff events is important. It is during these frequent runoff events and corresponding watercourse flows (effective discharge) that the majority of the annual sediment load is conveyed. LID stormwater techniques are inherently designed to manage the smaller, more frequent rainfall events and as such are highly effective at reducing runoff frequency, thereby reducing watercourse erosion.
Therefore, by better matching the pre-development water balance the effects of Hydromodification (magnitude, duration and frequency) can be diminished. The Stormwater Master Plan for the AEGD focuses on the implementation of LID source and conveyance controls in order to maintain the pre-development water balance. In addition, the Stormwater Master Plan identifies the protection of stream corridors and extensive woody riparian planting to improve bank stability and increase out of bank roughness to reduce erosive flows. The AEGD Erosion Control targets are presented in Table 5.0: AEGD Environmental Criteria and Targets.

5.1.4 INFILTRATION (WATER BALANCE)

The AEGD Transportation Water/Wastewater Stormwater Master Plans - Phase 1 Draft (May 2008) identified the following as it relates to the soil types within the AEGD study area and therefore infiltration objectives and targets:

• Infiltration potential in near-surface soils is limited due to extensive veneer of glaciolacustrine silt and clay across the AEGD. However, the SNC Lavalin study (2004) reported considerable thicknesses of sand and gravel along Glancaster Road, locally reaching thicknesses of 15 metres between Dickenson and 20th Road West.

• It should be noted that the “sand and gravel” represents a grouping of consecutive sand and gravel layers with an interlayer aquitard of less than 1 metre to form the “parent” unit. The SNC Lavalin study considered that a “parent unit” of sand and gravel was significant if its aggregate thickness was greater than 2 metres. The depth at which these sand and gravel deposits occur is not readily apparent from the SNC Lavalin study; further investigation is warranted to determine if these deposits are suitable for infiltration-based stormwater management facilities.

• At the northwest corner of the AEGD (near Southcote), the sand deposit may be up to six metres thick, forming a scarp along the south margin.

There is a growing body of evidence which suggests that ‘traditional’ end-of-pipe stormwater management techniques are not achieving the level of watershed management we now realize in necessary to protect hydrologic function. Therefore, considerable effort has been placed on the characterization of the pre and post development water balances as part of the hydrologic analysis performed as part of the AEGD Stormwater Master Plan (see Sections 4.1.5 and 4.1.6). The intent is to provide planners, designers and other practitioners with catchment based pre-development water balances from which to plan and design LID source and conveyance controls with the goal of re-establishing/matching pre-development infiltration after development has occurred. Detailed hydrologic modeling has produced pre-development water balances for all sub-catchments with the AEGD study area (Sections 4.1.5.2 – 4.1.5.4; with the exception of the Big Creek watershed) as well as infiltration targets for LID techniques for Proposed Conditions Land uses based on the dominant soil types (Table 4.10).

Table 4.10: LID Capture Target (m^3/impervious ha served) for Proposed Conditions Land uses

Scenario	LID Facility Design Capture Target		% Imperviousness of future conditions land use
	(mm)	(m^3 / imp ha)	
Roads AB Soils	9	90	70
Roads BC Soils	8	80	70
Roads CD Soils	7	70	70
Prestige Business Park / Airport Related Business AB Soils	10	100	70
Prestige Business Park / Airport Related Business BC Soils	8	80	70
Prestige Business Park / Airport Related Business CD Soils	6	60	70
Airside Industrial / Light Industrial AB Soils	13	130	80
Airside Industrial / Light Industrial BC Soils	11	110	80
Airside Industrial / Light Industrial CD Soils	8	80	80

Note: Infiltration targets are based on the dominant soil types and post development land use. Targets for residential land use areas should be established at the functional servicing level of detail. The targets for these areas will likely be within the range of values shown above.

The AEGD Stormwater Master Plan requires that pre-development infiltration volumes be maintained post development through the use of the LID capture targets presented in **Table 4.10**. Post development infiltration volumes should be checked against pre-development water balances (for the appropriate area) provided as part of this study.

5.1.5 NATURAL FEATURES

Natural features, such as existing wetlands, woodlands, and streams are integral components of the natural landscape of the AEGD that can be impacted following urban development. Impacts are typically linked to changes in hydrology, including changes in water quantity, quality, volume, duration, frequency, and spatial distribution of flow. The AEGD Transportation Water/Wastewater Stormwater Master Plans - Phase 1 Draft (May 2008) recommended a water budget approach to maintain the existing hydrologic cycle in new developed areas. A water balance approach is required in order to demonstrate that flow regimes will be maintained in the post-development scenario.

The four step procedure used to ensure natural features are protected has been undertaken, with steps 1 and 2 integrated into the AEGD Phase 1 Report and Phase 2 methodologies. This includes:

• Needs Establishment (Step 1),

• Baseline Conditions Establishment (Step 2),

• Pre-development Site Characterization (Step 3) and

• Pre-development vs. Post-development Comparison (Step 4).

In addition, stream restoration measures in the form of protecting a stream corridor and revegetating the corridor with woody riparian vegetation achieves a number of environmental benefits including water quality/quantity attenuation, stream bank erosion control, reduction of overland sediment delivery, stream shading and microclimate modification.

5.1.6 ENVIRONMENTAL CRITERIA AND TARGETS

Based on the foregoing, the Table 5.0 provides the recommended environmental targets to be met on a catchment and individual site basis (where development is proposed within the Big Creek subwatershed, See Part A- Section 5.5 the Council Directed Additional Lands; and Section 6.1- Recommended Subwatershed Plan and Part B – Section 4.1 – Hydrologic and Hydraulic Modeling. It is anticipated that practitioners applying and implementing the proposed Stormwater Master Plan will do so in full recognition of the Eco-Industrial design approaches which form the foundation of the treatment train approach (LID source and conveyance controls) proposed for the AEGD and will strive for a “best achievable” results in relation to each of the targets listed in Table 5.0.

Table 5.0: AEGD Environmental Criteria and Minimum Targets

Category	**Generalized Control Target**	**AEGD Minimum Targets**
Flood Control	Control peak outflows to pre- development rates, for design storms with return periods up to 100 years using End-of-pipe dry ponds. **Or** Upon approval from the City (with all necessary easements – Part A- Section 3.0 and Part B - Section 5.1.1) and if site and development conditions allow, on- site flood control may be feasible and should be assessed at the site plan stage. On site flood controls must adhere to AEGD minimum targets.	Post to Pre, 2 through 100 yr event controlled using Dry-ponds as per the AEGD Stormwater Master Plan Flood control target for the AEGD = 303-438 m^3/ha (See **Section 4.1.3**) Additional floodplain mapping for the AEGD study area is not required.
Watercourse Erosion Control	1. In accordance with current MOE guidelines: capture the Runoff volume generated by a 25mm event, and release it to the outlet over 24 hrs **Or** 2. Control the frequency and duration of site outflows such that in-stream index of erosion potential (e.g. multi-year erosive impulse) is not increased.	Match pre-development water balance (See **Sections 4.1.5.2 – 4.1.5.4)** Where matching pre-development water balance is not possible, integrate erosion control within end-of-pipe facility.

Infiltration (Water Balance)	Maintain groundwater recharge per the pre-development water balance	At a minimum, maintain groundwater recharge (infiltration) volume as per **Table 4.10** LID Capture Target (m^3/impervious ha served) for Proposed Conditions Land uses and Verify agreement with catchment based pre-development water balances for the AEGD Sub Watersheds where applicable. (See **Sections 4.1.5.2 – 4.1.5.4)**
Surface Water Quality	Control pollutant loadings in accordance with current MOE guidelines. Enhanced level 1 protection as defined in the 2003 Stormwater Management Planning & Design manual – reduce the average long term annual load of suspended sediment by 80% or better	Current MOE requirement for end-of pipe infiltration@ 70% TIMP =3.5mm Minimum water quality target for the AEGD is the infiltration of 10mm for water quality. It is expected the practitioners will strive for a "best achievable" results which include LID practices that utilize filtration, evaporation, transpiration and retention in order to control greater than 10mm target

For details as to the implementation of the AEGD Stormwater Master Plan, see Section 6.0 and the AEGD Stormwater Implementation Document (under separate cover). The Implementation document is intended to provide guidance with respect to selection, planning and design as well as the relevant stormwater targets for flooding, erosion, water quality, infiltration and natural features.

5.2 CONSTRUCTION AND OPERATION & MAINTENANCE (O&M)

5.2.1 CONSTRUCTION COSTS

5.2.1.1 DC COST ESTIMATE SUMMARY

5.2.1.2 LID SOURCE AND CONVEYANCE CONTROL ESTIMATES

5.2.2 OPERATION AND MAINTENANCE COSTS

5.2.2.1 OPERATION AND MAINTENANCE COSTS FOR LID TECHNIQUES

5.2.2.2 OPERATION AND MAINTENANCE COSTS FOR DRY POND END-OF-PIPE FACILITIES

6.0 AEGD IMPLEMENTATION DOCUMENT

7.0 ADDITIONAL STUDIES AND RECOMMENDATIONS

8.0 REFERENCES