PART B - Stormwater Master Plan

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1.0 Introduction

This Stormwater Master Plan is part of the City of Hamilton's coordinated Class Environmental Assessment and land-use planning process for the Airport Employment Growth District (AEGD).

1.1 General Information

As described in the Subwatershed Study (Part A), the Stormwater Master Plan is part of the Surface Water Management component of the recommended Subwatershed Plan. The development of the Stormwater Master Plan was completed following the Municipal Class EA process for Master Plans as noted in the introduction to this report.

The Stormwater Master Plan complements the proposed eco-industrial land use concept and is consistent with the key principles of: water and energy conservation, open space and greenway systems, and the multiple use of open spaces. As noted in the AEGD Subwatershed Planning Study (Part A) the stormwater management system developed for the AEGD requires an innovative state of the art approach to managing stormwater by first and foremost treating runoff (precipitation) at its source, as a resource to be managed and protected rather than a waste. In this regard, the emphasis in managing runoff is to retain/maintain the existing infiltration of water into the ground by managing runoff through source (lot level) and conveyance (street level) measures using what is referred to as a "treatment train" approach to stormwater management. Measures such as green roofs, rain gardens, and rainwater harvesting implemented on individual lots, and combined with additional measures such as biofilters, grassed swales, perforated storm sewers within road right of ways, encourage infiltration and reduce the quantity of runoff reaching local drainage features. These measures are part of a suite of stormwater management techniques collectively known as Low Impact Development (LID) and are consistent with the forms of development that are fundamental to the Eco-Industrial land Use Concept. This approach is also consistent with recommendation from Source Water Protection Plans which are under development.

The Stormwater Master Plan provides direction/guidance on the water resources and environmental criteria to be met within the headwaters of four different Watersheds (which are governed by three different Conservation Authorities), each of the drainage features/land use designations in the study area:

- Big Creek – Grand River Conservation Authority
- Sulphur Creek – Hamilton Region Conservation Authority
- Twenty Mile Creek – Niagara Peninsula Conservation Authority
- Welland River - Niagara Peninsula Conservation Authority

These criteria address the following:

- Protection and maintenance of stream corridors to address flood control and fish habitat regulatory requirements
- Flow requirements designed to prevent increases in flooding and erosion within and downstream of the study area
- Water balance criteria to protect groundwater infiltration requirements and local groundwater supplies
- Runoff reduction requirements to address water quality requirements necessary to meet provincial water quality objectives for receiving waters consistent with level one treatment

In addition, the Stormwater Master Plan outlines a suite of source and conveyance control measures that can be used to meet these stormwater criteria, including providing the necessary design flows and volumes needed for flood storage 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).

1.2 Background

The Vision and Objectives for the AEGD is:

> *The employment area is vibrant and visually appealing and the natural and cultural heritage resources in the area have been preserved and used to establish a distinct character for the area. It is a working community that attracts a range of airport related and other businesses providing both conventional and knowledge-based services. The environmental footprint of the area has been managed through a range of sustainable design techniques and the character of the surrounding land uses have been protected through appropriate land use transitions and transportation planning.*

As part of the overall Eco-Industrial design approach adopted within the AEGD, a Technical Memo by Eco-Industrial Solutions Ltd (April 23, 2009) provided high level guidance regarding the eco-industrial aspects of the City of Hamilton AEGD secondary plan process, with the goal of "providing eco-industrial solutions" for both the public and private site infrastructure complete with "eco-industrial design guidelines." These guidelines have been prepared as part of the Phase 2 project submissions. The principles of ecological design are fundamental to eco-industrial parks (EIPs), and influence the entire development cycle, from subdivision planning, to infrastructure design (including stormwater management), to zoning, and ultimately, to individual businesses' lot plans, building designs, and operations.

Beyond planning and infrastructure development, an eco-industrial approach aims to transform the nature of business by building collaborative relationships between businesses, as well as with the community and government, in order to use resources more effectively and efficiently. Stakeholders can then take advantage of this networked environment by working together to strategically manage all the resources necessary to develop and operate businesses and their related environment – resources like materials (raw materials, waste materials, etc), water, energy, land, infrastructure and knowledge.

The eco-industrial approach includes numerous design provisions, including guidance with respect to stormwater management. The generalized Eco-industrial stormwater management principles include:

- Vegetated swales to collect, pre-treat and convey stormwater instead of conventional curb and gutter and the inclusion of vegetated swales as acceptable drainage feature in municipal standards
- Maximization of permeable surfaces to reduce stormwater runoff and ensure groundwater recharge
- Reduction of runoff via landscaping design and where appropriate reduce impervious cover
- To the extent feasible, integration of ecological features into stormwater management design
- Working collaboratively with the development sector to create a practical municipal policy to encourage progressive policies i.e. mandate green roofs on large facilities
- Use of zoning to establish maximum permitted impervious cover, both at the surface level, and on the roof
- Allowance for deviation from minimum standards where proposed changes are supported by proof of performance/rationale. i.e. road ROWs to reduce impervious cover and allow for natural stormwater facilities
- Consideration of rainwater harvesting for irrigation of landscaped areas and/or on site centralized stormwater storage for firefighting water requirements (underground storage)
- Integration of stormwater systems with landscape areas
- Minimum of 10% landscaped area for industrial zones
- Encourage the use of landscaped parking strips, vegetated swales and/or other design strategies to minimize runoff impacts from parking areas
- Ensure zoning to establish higher landscaping and screening requirements in industrial areas
- Ensure zoning bylaws require integration of landscaped/natural features

These principles form the core of the Eco-Industrial approach to stormwater management and the central theme used in the development of the Stormwater Master Plan for the AEGD.

1.3 AEGD Constraints

The lands surrounding the Hamilton International Airport (HIA) constitute the study area of the AEGD and are the subject of this Stormwater Management Master Plan (**Figure 3.3**). In the context of developing stormwater management alternatives, these lands have a high degree of constraints that include the proximity to the HIA and the regulations imposed by Transport Canada on land uses adjacent to airports; the nature of the existing drainage features and the application of Eco–Industrial design principles.

1.3.1 Airport Constraints

Open water bodies in close proximity to airports pose a serious safety concern to air travel as such features attract water fowl and increase the likelihood of bird strikes during aircraft takeoff and landing activities. Federal regulations under Transport Canada require that such features be prescriptively managed to reduce the presence and attraction of water fowl species and other birds that may pose a threat to air travel safety. Therefore, the proximity of the AEGD lands to the HIA, inherently limits the use of traditional end-of-pipe stormwater facilities, such as wet-pond and wetlands, due to safety concerns.

1.3.2 Existing Drainage Feature Constraints

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. These relatively low gradient features provide little to no opportunity to outlet a conventional stormwater management systems (subsurface pipes at depth) to the existing drainage features without significant watercourse alteration or great expense.

Currently, 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 (internal stormwater system), and the Highway 6/403 interchange.

1.4 Problem Identification

During the past three decades, there has been an evolution in stormwater management in an effort to address downstream conditions resulting from urbanization **(Figure 1.0).** In the early 1980s, stormwater management focused solely on controlling the quantity of runoff and providing flood protection through rapid conveyance measures. By the early 1990s, water quality and downstream erosion control were given additional focus. Today, with improvements in watershed management and our understanding of the watersheds themselves, stormwater management now addresses a broad suite of issues including stream morphology, the protection of groundwater resources, fish habitat, and terrestrial habitat (primarily wetlands).

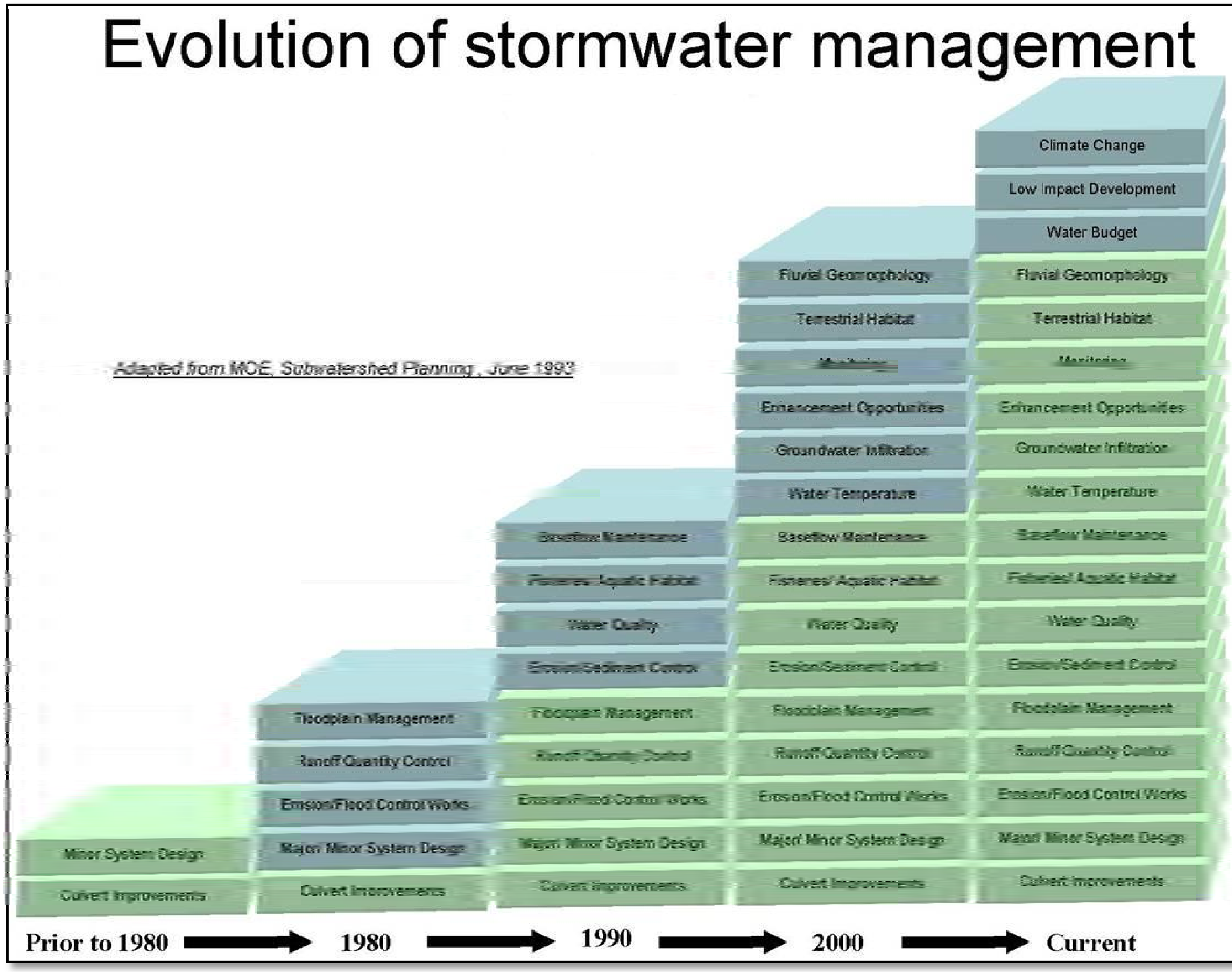


Figure 1.0: Evolution of Stormwater Management

Stormwater runoff from urban areas may degrade the environment both during construction activities and post-development. Post construction pollutant loadings from urbanized areas are significant. Common sources of pollutants include heavy metals from automobiles and air emissions, nutrients, fertilizers, bacterial contamination from humans (combined sewer overflows) and animals (stormwater runoff) wastes, and toxic contamination from a variety of residential, commercial and industrial sources.

These pollutants, when conveyed to the receiving water bodies, impact the environment in many ways. The particulate (those that can be settled) and dissolved contaminants stress aquatic ecosystems by depleting oxygen, covering habitat or through the bioaccumulation or bio-concentration of contaminants in the tissues of various aquatic species. In addition, receiving waters can also be effected by thermal impacts resulting from an increase in ambient water temperatures.

1.4.1 Problem Definition

The City of Hamilton has undertaken a coordinated Class Environmental Assessment and land-use planning process for the Airport Employment Growth District (AEGD) using an eco-industrial design approach.

As noted in the AEGD Subwatershed Study (Part A), the AEGD as part of an Eco-Industrial design approach requires an innovative, state of the art approach to stormwater management by first and foremost treating runoff (precipitation) at its source, as a resource to be managed and protected rather than a waste. In this regard, the emphasis in managing runoff is to retain/maintain the existing infiltration of water into the ground by managing runoff through source (lot level) and conveyance (street level) measures using what is referred to as a “treatment train” approach to stormwater management

This Study and Environmental Assessment Process has been initiated in order to assess, evaluate, prioritize, and select the preferred stormwater management alternatives for the AEGD as part of an Eco-Industrial employment district.

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.

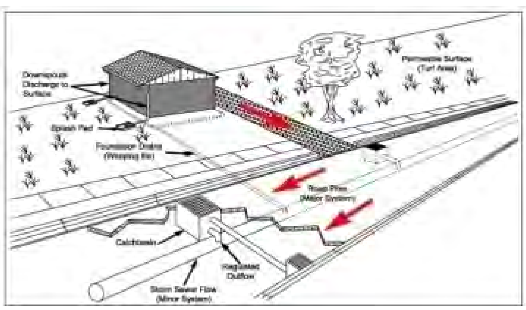
LID practices, together with traditional BMP's can be applied to achieve an overall stormwater management system which provides better performance, is more cost effective, has lower maintenance burdens, and is more protective during extreme storms than conventional stormwater practices alone. The basic 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 Controls

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:

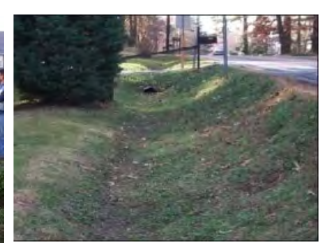
1) Rapid Conveyance Systems – primary function is conveyance. Traditional curb and gutter piped systems or concrete lined channels are typical of these types of systems.



(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.

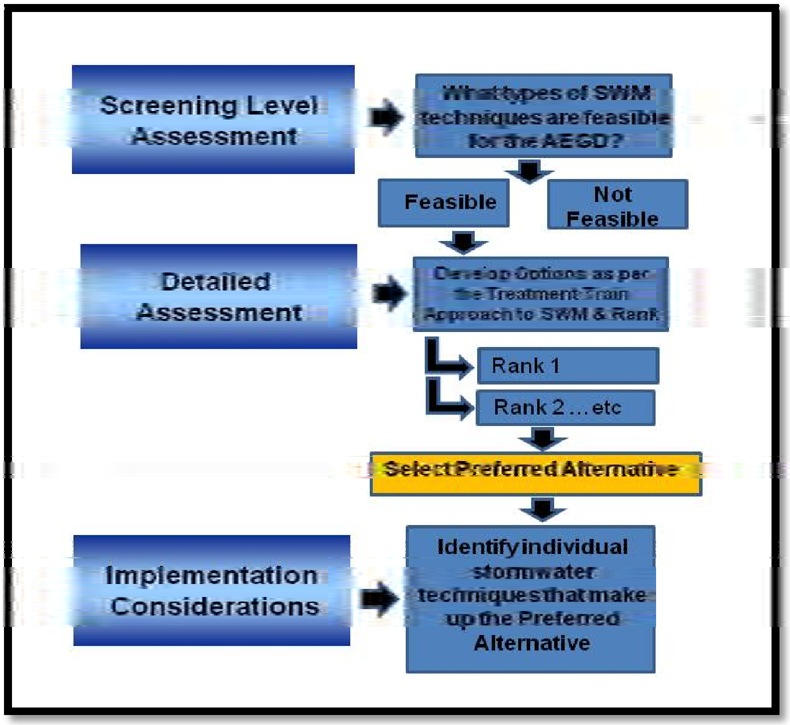


Figure 2.1: Environmental Assessment (EA) Evaluation Process Flow Chart

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 not 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									

<u>**Phase 1 – Screening Level Assessment Recommendations**</u>

- 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:

Physical and Natural Environment Criteria

- 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 Detailed Assessment

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).

	site potential are areas within a 300m catchment area from existing watercourses and as such policies In the Secondary Plan will require completion of archaeological assessments (Phase 2 Assessment) or other appropriate studies during the site plan/plan of subdivision approval process to address the management of such archaeological sites.	

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: o 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	Regulatory agency acceptance	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	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	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	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	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	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**	**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	2	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	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

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.

3.1 Background

The AEGD Transportation Water/Wastewater, Stormwater Master Plans - Phase 1 (May 2008) identified the following as it relates to stormwater management within the AEGD:

- 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.
- 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 at the low end of the range of suitability for infiltration facilities, 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 applied to these lands. 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

- o perforated storm sewers
- o grassed swales/ditches
- o "end-of-pipe" controls for water quality control, erosion control, flood control and/or to promote infiltration:
  - § constructed wetlands
  - § centralized infiltration facilities

3.2 Overview of Low Impact Development (LID) Source Controls

The Stormwater Master Plan for the AEGD calls for the implementation of combination of LID source control techniques at the site level of each phase of development.

The following section(s) provide an overview of the suite of LID source control techniques including general function, performance and water balance benefits. The LID techniques to follow include:

1. **Rainwater Harvesting**
2. **Green Rooftops**
3. **Downspout Disconnection**
4. **Soakaway Pits**
5. **Bioretention**
6. **Special Bioretention**
7. **Soil Compost Amendments**
8. **Tree Clusters**
9. **Filter Strips**
10. **Permeable Pavement**

3.2.1 Rainwater Harvesting

Rainwater harvesting is an ancient practice of intercepting, diverting and storing rainfall for future use that is enjoying a recent revival due to the inherent value of rainwater as a resource and the many beneficial uses that it can provide (TWDB, 2005). The rain that falls upon a catchment surface, such as a rooftop, is collected and conveyed into an above or below-ground storage tank. The captured rainwater is then pumped into the building where it can be used for non-potable water uses such as to serve toilets, to be used in industrial cooling processes or for irrigation applications such as underground sprinkler systems for landscaped elements. This capture and re-use of rainwater can, in turn, significantly reduce stormwater runoff volumes and pollutant loads.

Rainwater Harvesting systems, Guelph, Ontario.

Harvested rainwater that is used for watering landscaping meets the objectives of the water balance requirement, as these flows are infiltrated or evapotranspired after storage. On a larger scale, the reduced demand on the water resources (such as groundwater aquifers and reservoirs) from which municipal water supplies are drawn will add to the water balance benefits of rainwater harvesting. It is estimated that these applications alone can reduce the municipal water consumption by up to 55% (Reid Homes, 2007).

Rainwater harvesting systems can be applied on any, commercial, industrial or institutional site where rainwater can be captured, stored, and used. They are particularly useful on infill and redevelopment sites that have little room for other stormwater BMPs. Except in retrofit situations, rainwater harvesting should not be a stand-alone BMP. It is part of a treatment train that will likely include practices such as filter strips and grass channels in addition to detention for geomorphic requirements. See **Appendix A- LID 1**.

3.2.2 Green Rooftops

Green rooftops, also known as "living roofs" or "eco-roofs," consist of a thin layer of vegetation and growing medium installed on top of conventional flat (large commercial roofs) or sloped roofs. Green roofs are touted for their multiple benefits to cities, as they improve energy efficiency, reduce heat island effects, and create urban green space for passive recreation, aesthetics and habitat. To a water resources manager, they are attractive for their water quality, water balance, and geomorphic benefits. Hydrologically speaking, the green rooftop acts like a lawn or meadow by storing rainwater in the growing medium and ponding areas. Excess rainfall enters underdrain and overflow points and is conveyed in a typical building drainage system and onto the next BMP in the treatment train. After the storm, stored water is evapotranspired by the plants or evaporates.

Green rooftops are physically feasible in most development situations and are particularly useful in ultra urban sites where space for ground level BMPs is limited. Green rooftops are a feasible BMP for cold climates. Snow can protect the vegetation layer and once it thaws, it percolates through the growing medium and is either absorbed or drained away just as it would during a rain event.

Extensive Green Roof at York University (Source: TRCA)

Green roofs help achieve stormwater management goals by reducing total annual runoff volumes, decreasing the impervious cover area by providing a surface that hydrologically responds like a pervious area and can be used to meet peak flow geomorphic requirements when flow restrictors are used. Considerable research has been conducted in recent years to define the runoff reduction capability of extensive green roofs. Reported rates for runoff reduction have been shown to be a function of media depth, roof slope, annual rainfall and cold season effects. Based on the prevailing climate for the region, a conservative runoff reduction rate for green roofs of 45 to 55% is recommended for initial design. Note: Runoff reductions correspond to rain events up to a 25 mm rainfall. See **Appendix A- LID 2**.

3.2.3 Downspout Disconnection

Simple downspout disconnection involves directing flow from downspouts to a pervious area. This prevents stormwater from directly entering the drainage system or flowing across a “connected” impervious surface such as a parking lot. Downspout disconnections are typically used in combination with other LID source controls, but can be used as stand alone techniques if appropriate quantities of pervious area are present.

Rooftop disconnection with treatment is possible on lots with any size and configuration; however functional downspout disconnection requires a minimum length of pervious flow path and appropriate soil conditions.

Downspout disconnection is primarily a practice used to achieve water balance, although it can contribute to water quality improvement. Downspout disconnection alone is not capable of meeting geomorphic criteria, although it can help reduce the size of total runoff storage needed. See **Appendix A- LID 3**.

3.2.4 Soakaway Pits

Soakaway pits are typically stone-filled trenches that temporarily store water to be infiltrated. Manufactured underground infiltration galleries (or stone-less trenches) can also be included in the general category of soakaway pits.

Runoff is directed to the trench via a downspout or swale or other conveyance feature. French drains and dry wells are variations on the soakaway pit, with slightly different geometries. A French drain is a shallow underground trench with a perforated pipe running along the bottom whereas a dry well is deeper and shorter. The sizing calulations and materials for these practices are the same.

The amount of the water balance requirement met will depend on the amount of runoff stored and percolated into the native soils. Runoff reduction capability of soakaway pits, is presumed to be high, given that infiltration is the designed intent of the practice, however some surface overflows do occur when the infiltration storage capacity is exceeded. Assuming the practice is designed with adequate pretreatment and soil infiltration testing, a conservative runoff reduction rate of 90% is assigned to soakaway pits. While soakaway pits are not specifically designed to store the channel protection volume, their ability to reduce runoff volumes should help protect downstream channels from erosion. Note: Runoff reductions correspond to rain events up to a 25 mm rainfall.

Each practice serves a small drainage area, such as a single rooftop or roof leader. Because the application is limited by building setbacks, soakaway pits are not a best management practice that can be used in very high density settings. See **Appendix A- LID 4**.

3.2.5 Bioretention

Bioretention, also known as 'rain gardens' captures, temporarily stores, and treats stormwater runoff by passing it through an engineered filter media. The primary component of a bioretention practice is the filter bed, composed of a mixture of sand, soil, and organic material as filtering medium.

Established Bioretention Cell, Milton, Ontario.

During storms, runoff temporarily ponds above the filter bed surface and then filters through the media. Bioretention can be applied in most soils or topography, since underdrains which collect and return filtered water to the surface system may be used when full infiltration into native soils is not feasible. If infiltration rates in native soils permit, filtration practices can be designed without an underdrain for full infiltration and water balance benefits. A combination of these methods can be used to infiltrate a portion of the filtered runoff. Pre-treatment, such as a settling forebay or grass filter strip, precedes the filter bed to remove particles that would otherwise clog the filter bed. Conveyance of excessive flows can be directed out or away from the bioretention facility by using a flow-splitter to capture a limited discharge or an overflow structure with its invert set at the maximum ponding depth. Snow storage can be provided by bioretention, especially those located adjacent to parking lots and roadways. To function as snow storage, bioretention must include an overflow for snow melt in excess of the designed ponding depth. Additionally, the plant material must be salt-tolerant, perennial, and tolerant of periodic inundation. Bioretention is often popular in developments with a higher urban design standard as it can meet local landscaping requirements and provide improved site aesthetics.

Bioretention is best suited to meet water quality objectives but can also be used to meet water balance objectives by reducing runoff volume through evapotranspiration and infiltration of runoff. A conservative runoff reduction rate of 80% is assigned to designs that rely upon full infiltration (Note: Runoff reductions correspond to rain events up to a 25 mm rainfall). Bioretention may also be used in a treatment train with traditional detention practices that meet the geomorphic peak discharge requirements. The most recent studies indicate that bioretention provides effective pollutant removal for many pollutants as a result of sedimentation, filtering, plant uptake, soil adsorption, and microbial processes and can do so with and without an underdrain.

The feasibility of storing the channel protection volume within bioretention areas will be dependent on the size of the drainage area and available space. It may prove infeasible due to the large footprint needed to maintain the maximum recommended ponding depth. Meeting the geomorphic requirement through bioretention will be dependant on the hydraulic capacity of the native soils however in permeable soils the reduction in runoff volume through infiltration and evapotranspiration may be sufficient. Bioretention and other filtration and infiltration practices benefit aquatic life by reducing the heat effect from urban runoff. In contrast to ponds, bioretention facilities do not raise water temperature. See **Appendix A- LID 5**.

3.2.6 Special Bioretention

Special bioretention designs treat stormwater in the same way as regular bioretention (see Bioretention) however they are adapted to fit into the “containers” of urban landscapes. Typically, these practices are placed into the roadway right-of-way (or boulevard) and are sometimes called ‘curb extensions’, landscaping beds in ultra-urban settings, tree-pits, and plazas. Special bioretention facilities feature a hard edge, often with vertical concrete side (while regular bioretention facilities have gentle earthen slopes). Special bioretention refers to the practices of extended tree pits, stormwater planters, and curb extensions. In general, special bioretention has the same suitability and constraints as given for regular bioretention however the beauty of special bioretention applications is their ability to fit into the ultra-urban landscape.

Special bioretention design variations
(Source: Portland BES)

Like bioretention, special bioretention is best suited to meet water quality objectives but can be used to meet water balance (infiltration) objectives when underlying soils permit. Special bioretention may also be used in a treatment train with traditional detention practices that meet the geomorphic peak discharge requirements. These practices are assigned a conservative runoff reduction capability of 15%-30% (Note: Runoff reductions correspond to rain events up to a 25 mm rainfall). See **Appendix A- LID 6**.

3.2.7 Soil Compost Amendments

Compost amendments are tilled into existing soils thereby enhancing or restoring soil properties by reversing the loss of organic matter and compaction. They also are used to make Hydrologic Group C and D soils suitable for on-site stormwater BMPs such as downspout disconnection, filter strips, and grass channels. Soil amendments benefits include increased infiltration, stormwater storage in the soil matrix, survival rate of new plantings, root growth and stabilization against erosion, improved overall plant health and decreased need for irrigation and fertilization of landscaping. Amended soils are suitable for any pervious area where soils have been or will be compacted by the grading and construction process. The area or strip of amended soils should be hydraulically connected to the stormwater conveyance system.

While soil amendments will never be used solely to meet stormwater management objectives they are effective in reducing the overall runoff volume, will contribute to a lower peak discharge, and can help reduce the size of total runoff storage needed. Soil amendments can increase infiltration rates from 2 to 10 times over un-amended soil rates (Pitt et. al., 2005) and an additional 50% runoff reduction rate is given when amended soils receive runoff from an appropriately design rooftop disconnection or grass channel (Note: Runoff reductions correspond to rain events up to a 25 mm rainfall). Soil amendment by itself is not capable of meeting geomorphic criteria and the pollutant concentrations from the amended soils are actually higher than from un-amended soils (Glanville, et al. 2003, Pitt, et. al. 2005). See **Appendix A- LID 7**.

3.2.8 Tree Cluster

Tree conservation at development sites should be given priority as a technique to maintain a natural hydrologic regime. When tree conservation is not an option, new trees can be planted in pervious areas of development sites. Trees clusters planted on turf or barren ground with the explicit goal of establishing mature forest canopy, reduces stormwater runoff volume and peak flow. Additionally, tree clusters improve water quality, generate organic soils, absorb greenhouse gases, create wildlife habitat, and provide shading to mitigate temperature increases at development sites (Shaw and Schmidt, 2003; Cappiella, 2005).

Tree clusters function similarly to forested areas by intercepting rainfall and allowing the processes of evapotranspiration (ET) and infiltration to reduce stormwater runoff. Some planting clusters are designed to receive sheet flow, particularly from pervious areas. Soils at tree cluster sites must remain undisturbed during construction or be amended to achieve the desired benefits.

Tree clusters provide multiple benefits, including rainfall interception, runoff reductions through increases in evapotranspiration and infiltration and sustaining baseflow which cumulatively act to mitigate changes to the pre-development water balance while providing a landscaped aesthetic. Good or excellent stream condition is correlated with 45 to 60% tree cover in a watershed. Clearly, preserving existing forest is the best option for maintaining water balance, however even individual trees have an impact.

Trees also show enormous potential to remove other pollutants, such as metals, pesticides, and organic compounds. The process of using plants to remove contamination from soil and water is called phytoremediation. This process has mainly been applied to soil and groundwater but could easily be applied to stormwater runoff. Trees such as poplars that can absorb large quantities of water through evapotranspiration are typically used for phytoremediation because this type of consumption contains and controls the migration of contaminants (US EPA, 1998). One sugar maple (300 mm diameter) along a roadway was shown to retain 60 milligrams (mg) cadmium, 140 mg chromium, 820 mg nickel and 5,200 mg lead from the environment in one growing season (Coder, 1996).

Forest conservation and tree planting also enhance the appeal of a development, increase land and building values, and can reduce construction costs and energy use. Trees also provide a wide range of environmental, economic and community benefits, such as air quality improvement and wildlife habitat. See **Appendix A- LID 8**.

3.2.9 Filter Strips

Filter strips (a.k.a. vegetated filter strips and grassed filters) are vegetated areas that treat sheet flow from adjacent impervious areas. Filter strips) slow runoff velocities and settle out sediment and attached pollutants. Small berms provide some storage. In some soils, storage and infiltration occurs in the underlying soils. Originally used as an agricultural treatment practice, filter strips have evolved into an urban SWM practice. Filter strips contribute to a lower peak discharge by maintaining runoff in sheet flow, thereby resulting in a longer time of concentration.

With proper design and maintenance, filter strips can provide relatively high pollutant removal. Research suggests that pollutant concentration levels decrease and that steady state levels can be achieved within five metres of the pavement edge (Lantin and Barrett, 2005). However, maintaining sheet flow is a challenge. Consequently, urban filter strips are often "short circuited" by concentrated flows, which result in little or no treatment of stormwater runoff.

Combining filter strips with other best management practices is highly recommended. They can also provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for melt water infiltration. Because filter strip designs include few pipes or other structures, physical changes to the practice are not needed for wintertime operation. Furthermore, many of the pollutants in the snowpack can be treated through infiltration where groundwater contamination is not a concern (CWP, 1997). See **Appendix A- LID 9**.

3.2.10 Permeable Pavement

Permeable pavements, an alternative to traditional impervious pavement, can be used for low traffic surfaces such as parking lots, driveways, access roads, plazas, and walkways. Permeable pavement is generally discouraged for use in high traffic areas. In this context “High

Traffic" commonly refers to both high volume areas and frequent large vehicle use. Infrequent (low volume) truck or heavy vehicle traffic (i.e. garbage trucks) should not preclude the use of permeable pavements; however as with the design of all pavement surfaces, vehicular size, weight and traffic patterns must be included in design calculations and mechanical strength assessments. Permeable pavers can be integrated with conventional non-porous pavements (asphalt and concrete), allowing for high traffic routes to be limited to the conventional pavement areas while the permeable pavement areas accept and treat direct rainfall and the runoff from the impermeable surfaces.

Permeable paving techniques include interlocking concrete block pavers (open joint and porous stone pavers), plastic lattice or grid systems (grass pavers), pervious concrete, and porous asphalt. Porous asphalt and pervious concrete are pavement mixes with washed aggregate to eliminate fines. With all permeable pavements, the resulting surface voids allow stormwater to filter through the pavement into an underlying stone reservoir. Water then infiltrates or enters an underdrain system.

Permeable paving allows for filtration, storage, or infiltration of runoff, which can reduce stormwater flows compared to traditional impervious paving surfaces like concrete and asphalt. Assuming the permeable paver is designed with adequate pretreatment and soil infiltration testing, a conservative runoff reduction rate of 90% is assigned to designs that rely upon full infiltration. Other benefits include reduce snow removal costs due to rapid ice melting and drainage, reductions in urban heat island effect (pavers have less thermal conductivity and thermal capacity than traditional impervious pavement (Ferguson, 2005), and reduced tire noise (loudness and pitch). These systems provide an aesthetic alternative to traditional paving and are typically applied to smaller drainage areas and in general, permeable pavement systems can be used anywhere a traditionally paved system might have been installed.

(Source: Unilock® Canada)

Pollutant removal capacity is provided through infiltration which utilizes several pollutant removal mechanisms including filtering, soil adsorption and transfer to groundwater. It is important to note that infiltration is not intended to treat sites with high sediment or trash/debris loads, as they will cause the practice to clog and fail. See **Appendix A- LID 10**.

3.3 Overview of Low Impact Development (LID) Conveyance Controls

The Stormwater Master Plan for the AEGD calls for the implementation LID conveyance controls within the right-of-way to control road runoff and act as a conveyance system per the AEGD Transportation Master Plan. As part of the Transportation Master Plan, a 3m allowance within the standard local, collector and arterial road cross-sections have been reserved for the inclusion of LID conveyance systems (**Figure 3.1- 3.2**). It is intended that LID conveyance systems be implemented on all local, collector and arterial roads within the AEGD, per the AEGD Transportation Master Plan.

Figure 3.1: Proposed -4 Lane Arterial Roadway with Raised Median and 3m allowance for LID conveyance Controls

Figure 3.2: Proposed -2Lane Arterial Roadway with 3m allowance for 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 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).

3.3.2 LID conveyance Options

The following section(s) provide an overview of the suite of LID conveyance control techniques including general function, performance and water balance benefits. The LID techniques to follow include:

1. Grass Channels
2. Dry swales
3. Subsurface Perforated Pipe Exfiltration Systems (Soakaway pit variant)

3.3.3 Grass Channels

Grass channels have long been used for conveyance, particularly as roadway drainage. More recently, their benefits as a stormwater best management practice have been recognized. Grass channels are closer in hydrologic properties to natural zero order channels than drainage systems composed of curb and gutter, inlets, and pipes. Grass channels allow infiltration, discharge at a lower rate, and reduce pollutant loads. They are not capable of providing the same benefits as dry swales (see Dry Swales) as they lack the engineered soil media and storage volumes of that best management practice. Grass channels are most frequently applied for drainage alongside roads, highways, and parking lots however they are also well suited for use in conjunction with drive-lanes and rooftop drainage as well as within pervious surfaces, such as yards, parks and landscaped areas.


(Source: CWP)

Grass channels are not well suited for use in densely developed areas where surface space is at a premium and a large number of roadway crossings create numerous constrictions along the channel. Grass channels primarily serve low to moderate density commercial developments. Where development density, topography and soils permit, grass channels are a preferable alternative to both curb and gutter and storm drains as a stormwater conveyance system. When properly incorporated into an overall site design, grass channels can provide stormwater treatment, reduce impervious cover, accent the natural landscape, and provide aesthetic benefits.

Grass channels are less hydraulically efficient than curb and gutter conveyance systems. This results in longer travel times and lower peak discharges. Runoff reduction by grass channels is generally low, but is strongly influenced by soil type, slope, vegetative cover, and the length of channel. Recent research indicates that a conservative runoff reduction rate of 10 to 20% can be used depending on whether soils fall in hydrologic soil group A/B or C/D (Note: Runoff reductions correspond to rain events up to a 25 mm rainfall). The runoff reduction rates can be doubled if the swale is modified to incorporate soil amendments. Grass channels can also provide pretreatment for other stormwater best management practices, such as bioretention areas.

Research has shown the pollutant removal rates of conventional grass channels are variable, but generally moderate to low for most pollutants, especially nutrients and bacteria. Site specific factors such as channel slope, soil type, infiltration rate, channel distance and vegetative cover account for much of the variation. In general, the dominant pollutant removal mechanism operating in grass channels is infiltration, rather than filtering. See **Appendix A- LID 11**.

3.3.4 Dry Swales

Dry swales (also known as Bio-swales or Bio-filters) are essentially bioretention cells that are configured as a linear channel. The dry swale is a soil filter system that temporarily stores and then filters the desired water quality volume. Dry swales are similar to bioretention areas in that they rely on the same engineered media bed placed below the channel invert.

Runoff treated by the media bed flows into an underdrain, which conveys treated runoff back to the conveyance system further downstream. The underdrain system consists of a perforated pipe within a gravel layer placed below the engineered media bed. Dry swales may appear as simple grass channels with the same shape and turf cover, while others may have more elaborate landscaping. Swales can be planted with turf grass, tall meadow grasses, decorative herbaceous cover, or trees.

If properly designed and maintained, dry swales can provide stormwater treatment while accenting the natural landscape and providing improved site aesthetics. Dry swales can be implemented on a variety of development sites where density and topography permit their application. The linear nature of swales makes them well-suited to treat roadway or commercial/industrial runoff. Dry swales can also be used in or alongside parking lots in various configurations.

Limited data is available to define the runoff reduction rate for dry swales, but research indicates that they perform as well or better than bioretention with underdrains. Since an underdrain is an integral design feature for dry swales, the same values are used to define a conservative runoff reduction for the dry swale. While most dry swales are not designed to provide channel protection storage, the high degree of runoff reduction suggests that they have the potential to protect downstream channels from erosion. If space is available, they may be incorporated with extended detention. See **Appendix A- LID 12**.

3.3.5 Subsurface Perforated Pipe Exfiltration Systems (Soakaway pit variant)

Subsurface perforated pipe systems are essentially a variant/combination of a French drain type Soakaway pit and a conventional storm sewer system. These systems provide efficient conveyance, while encouraging infiltration and groundwater recharge. Perforated pipe systems are linear perforated pipes surrounded by gravel and wrapped in filter cloth, designed to encourage infiltration, thereby reducing runoff volumes, improving water quality and providing a water balance benefit. Like the Soakaway pit the amount of the water balance requirement met will depend on the amount of runoff stored and percolated into the native soils. Runoff reduction capability of these systems can be high, given that infiltration is the designed intent of the practice, however some overflows do occur when the infiltration storage capacity is exceeded.

Subsurface perforated pipe systems have been throughout Ontario to treat road runoff and can be used at commercial and industrial sites. These systems can be sized to convey any size storm as they are only limited by the pipe dimension and slope. Once installed these systems can be virtually invisible and can resemble a naturally landscaped grassed area. See **Appendix A- LID 4**.

3.4 End-of Pipe Dry Ponds Assessment

The purpose of this section is to assess implementation considerations with respect to the overall (environmental) compatibility of each of the 43 dry pond locations proposed for flood control within the AEGD study area (Note: associated with each dry-pond location, it was assumed that some degree of stream restoration works would be required to obtain a suitable outlet for the proposed facility based on existing surface drainage conditions and stream classification (Section 2.1.5)). The locations of the proposed dry ponds are shown on **Figure 3.3** – Stormwater Master Plan. Potential End-of-pipe dry ponds locations/drainage boundaries were identified using a combination of GIS, field investigations and previous studies. Evaluation criteria included:

- Up-gradient drainage area (approximate limit of 75ha)
- Integration with proposed road network, per the AEGD Transportation Master Plan
- Availability of a suitable outlet based on channel type. Channel classification was based on the stream assessment performed as part of the Phase 2 Subwatershed Study Section 2.1.1- Stream Classification System.
- Existing topography of proposed location and surrounding area
- Integration with existing environment and adjacent land form
- Potential for integration into the 'land buffer' of existing natural features

As part of the EA process, a series of fourteen (14) evaluation criteria were selected under the overarching Physical/ Natural Environment, Social/ Cultural and Economic criteria for the purpose of assessing the overall (environmental) compatibility of each of the dry pond locations for Secondary Plan Area and Additional Study Area identified in **Figure 3.3– Stormwater Master Plan**. (Note: Pond locations as shown on Figure 3.3 –are of approximate locations. Furthermore, for clarity and readability of pond labels, the size of pond location markers are not shown to scale).

The overall dry pond compatibility ratings are site specific (not regional) and as such at the site or local level, the compatibility of each pond varies from high compatibility to low compatibility, however as a whole the dry pond locations are an integral part of the preferred design for SWM within the AEGD. The overall (environmental) compatibility has been based on an average aggregate score generated using the 14 design criteria. A score of 1 indicated the dry pond location option is least compatible relative to the criteria. Alternatively, a score of 4 indicated that the dry pond location option was most compatible with satisfying the respective design criteria.

Provided in **Table 3.0** is a summary of the criteria used in the evaluation process. **Tables 3.1, 3.2** and **3.3** provide further information with respect to description of the criteria and the method uses in assigning a score to each criterion. Applying the fourteen evaluation criteria, a matrix illustrating the overall (environmental compatibility) of the forty-three l (43) potential SWM dry-ponds for the AEGD is presented in **Table 3.4, 3.5** and **3.6**, according the stage and phase of development within the AEGD. The dry-ponds identified as Secondary Plan Area (**Figure 3.3**) will be implemented as part of the proposed development up to the year 2031, with final locations and design details subject to subsequent detailed studies (See AEGD SWMP Implementation Document). Additional Study Area ponds final location and implementation are beyond 2031.

The intent of this preliminary analysis is to indicate the overall (environmental) compatibility and to provide an indication of the complexity inherent with the implementation of each pond at each respective location given the established criteria. At subsequent stages in the approval process (examples include final stages of the class EA process, the scope EIS, MESP/ MDP and Site Plan), it is suggested that this preliminary analysis be utilized in conjunction with the AEGD Subwatershed Study to identify subsequent study requirements and scope. The process followed for this dry pond assessment is consistent with the development of a Master Plan under the Class EA process (see AEGD Subwatershed Study – **General**).

Table 3.0: Description of the Criteria used in Identifying the Overall (environmental) Compatibility of Dry Pond Locations within the AEGD

Environmental Assessment Categories	Criteria
Physical/ Natural Environment	• Flood Control Benefit • Potential Water Quality & Erosion Control Benefit • Potential Terrestrial Habitat Benefit • Potential Aquatic Habitat Benefit • Suitable Outlet • Stream Restoration Considerations • Construction Phasing Consideration • Compatibility with the Existing and Proposed Road Network • Ability to Satisfy Regulatory Agencies
Social/ Cultural	• Aesthetic Value • Compatibility with Adjacent Land Use • Potential Disruption to Community • Archaeological/ Historical Impacts/Implications
Economic	• Capital (Construction and Property) Costs • Operation Maintenance (O&M)

Table 3.1: Description of Physical/ Natural Environment Criteria used in Identifying the Overall (environmental) Compatibility of Dry Pond Locations within the AEGD

Criteria	Description of Criteria	Measures for Assigning Scores
Potential Flood Control Benefit	• Potential for dry pond and associated stream restoration works to provide downstream flood control. Scoring based on the potential for the dry pond location to provide full downstream flood control as per MOE, 2003 flood control sizing requirements and additional flood control potential of stream restoration works.	Scoring ranges from 4 if location is most compatible with providing downstream flood control, to 1 if location is least compatible, i.e. no downstream flood control is created.
Potential Water Quality & Erosion Control Benefit	• Potential to improve water quality and erosion potential. Water quality potential based on existing water quality conditions in as stream and the ability of the facility to provide required water quality control. Erosion potential based on existing in stream erosion conditions and ability of dry pond facility and associated stream restoration works to improve/ reduce erosion potential.	Scoring ranges from 4 if there is a high potential for the proposed location to provide Level 1 quality control and erosion control (MOE, 2003), to a 1 if there is low potential for the proposed retrofit option to provide Level 1 quality control and erosion control.
Potential Aquatic Habitat Benefit	• Potential to improve aquatic habitats or systems. Aquatic scoring based on sensitivity of stream (fish type), stream order (size of stream) and type of habitat	Scoring ranges from 4 if high quality aquatic habitat is created through stream restoration, to 1 if no additional aquatic habitat is

	created	created.
Potential Terrestrial Habitat Benefit	• Potential to improve terrestrial habitats or systems. Terrestrial scoring based on sensitivity of adjacent terrestrial feature, potential disruption and type of habitat created.	Scoring ranges from 4 if high quality terrestrial habitat is created with minimal disruption to current habitat, to 1 if no additional terrestrial habitat is created or disruption potential is high.
Suitable Surface Outlet	• Potential to provide suitable facility surface outlet at each location. Scoring based on stream classification, capacity and current condition.	Scoring ranges from 4 if the proposed location has high potential to provide a suitable facility surface outlet, to a 1 if location has low potential.
Stream Restoration Implications	• Potential need for and extent of stream channel/floodplain restoration. Scoring based on extent of stream restoration required at each location.	Scoring ranges from 4 if the potential for stream restoration is minimal, to 1 if the extent of stream restoration is extensive.
Construction Phasing Considerations	• Potential implications of construction phasing on each location. Scoring based on location of facility in relation to proposed phasing (see AEGD Subwatershed Study (Part A)- Figure 5.1: Phasing Plan	Scoring ranges from 4 if the proposed location is within Phase 1 of construction, to 1 if the location is within phase 2. Intermediate scores represent relative proximity/distance from the boundaries of current construction phasing.
Compatibility with Proposed Road Network.	• Potential integration and/or interference with proposed road network per the AEGD Transportation Master Plan . Scoring based on location of proposed facility in relation to proposed road network and the extent of integration.	Scoring ranges from 4 if the potential for facility location integration with proposed road network is high, to 1 if the potential for integration with the road network is low.
Ability to Satisfy Regulatory Agencies	• Potential to satisfy the regulatory requirements of the respective Conservation authorities – HCA, NPCA and GRCA • Criteria includes placement of SWM facilities in relation to: o Valley lands o Floodplains o Provincially Significant Wetland (PSW) o Environmentally sensitive areas o Habitat of Endangered Species	Scoring ranges from 4 if the proposed facility location has a high potential to satisfy the requirements of the respective regulatory agency, to 1 if the proposed facility location has a low potential to satisfy the requirements of the respective regulatory agency.

Table 3.2: Description of Social/ Cultural Criteria used in Identifying the Overall (environmental) Compatibility of Dry Pond Locations within the AEGD

Criteria	Description of Criteria	**Measures for Assigning Scores**
Aesthetic Value	• Potential for location to be an asset to the community. Scoring based on potential aesthetic quality of facility location in relation to proposed land uses.	Scoring ranges from 4 if there is a good potential to integrate facility aesthetic with proposed land uses, to 1 if there is minimal potential for aesthetic integration.
Compatibility with Adjacent Land Use	• Potential compatibility of location with respect to proposed, existing and transitional land uses (See AEGD Subwatershed Study (Part A) – Figure 5.0 Land use).	Scoring ranges from 4 if location has high potential for compatibility with existing, proposed and transitional land uses (within or adjacent to natural heritage system), to a 1 if location has low compatibility potential.
Potential Disruption to Community.	• Potential disruption to community during and post construction. Scoring based on proposed facility location with respect to proposed, existing and transitional land uses and the associated construction disruption potential.	Scoring ranges from 4 if location has low potential for construction disruption with respect to existing, proposed and transitional land uses, to a 1 if location has a high potential for construction disruption.
Built Heritage/ Cultural Heritage and Archaeological	• Potential impacts of the proposed SWM alternative on Built Heritage/ Cultural Heritage and Archaeological 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 site potential are areas within a 300m catchment area from existing watercourses and as such policies In the Secondary Plan will require completion of archaeological assessments (Phase 2 Assessment) or other appropriate studies during the site plan/plan of subdivision approval process to address the management of such archaeological sites.	Scoring ranges from 4 if the potential for impacts to identified Built Heritage/ Cultural Heritage and Archaeological 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 3.3: Description of Economic Criteria used in Identifying the Overall (environmental) Compatibility of Dry Pond Locations within the AEGD

Criteria	Description of Criteria	Measures for Assigning Scores
Construction Costs	• The relative cost of construction and property acquisition. Scoring based on anticipated construction costs of facility location with associated land value costs given existing land use.	Scoring ranges from 4 if the relative cost, based on the identified factors, is low, to 1 if the relative cost is high.
Operation Maintenance	• The relative cost of operating and maintaining the facility based on factors overall operation frequency and intensity.	Scoring ranges from 4 if the relative cost, based on the identified factors, is low to 1 if the relative cost is high.

Table 3.4: Overall (environmental) Compatibility Evaluation Matrix for Secondary Plan Area Phase 1 Dry Pond Locations within the AEGD

			Physical and Natural Environment								Social and Cultural Environments				Financial Criteria		
Dry Pond #	Stage	Phase	Flood Control Benefit	Potential Water quality and erosion control Benefit	Aquatic Habitat Benefit	Terrestrial Habitat Benefit	Suitable Outlet	Stream Restoration implications	Construction Phasing Considerations	Compatibility with proposed and existing road network	Ability to Satisfy Regulatory Agencies	Aesthetic Value	Compatibility with adjacent land-use	Cultural heritage and archaeological	Archaeological / Historical	Capital costs	Operations and Maintenance Costs	**Aggregate Score**
3	1	1	4	2	1	2	4	4	4	4	4	2	3	3	3	2	4	**46**
18	1	1	4	2	2	2	4	3	4	4	4	2	3	3	3	2	4	**46**
19	1	1	4	2	2	2	3	3	4	4	4	2	3	3	1	3	4	**44**
20	1	1	4	2	2	1	4	3	4	4	4	2	4	4	2	4	4	**48**
21	1	1	4	2	2	3	4	3	1	4	1	2	2	2	1	3	4	**38**
22	1	1	4	2	3	3	4	2	1	4	1	2	2	2	1	1	4	**36**
23	1	1	4	2	3	3	4	2	1	4	2	2	2	2	1	1	4	**37**
24	1	1	4	2	3	3	4	2	1	4	4	2	2	2	1	1	4	**39**
26	4	2	2	2	3	3	4	4	2	3	4	3	2	2	4	4	2	**44**
	Note: Pond locations as shown on Figure 3.3 are of approximate locations. Furthermore, for clarity and readability of pond labels, the size of pond location markers are not shown to scale.																	

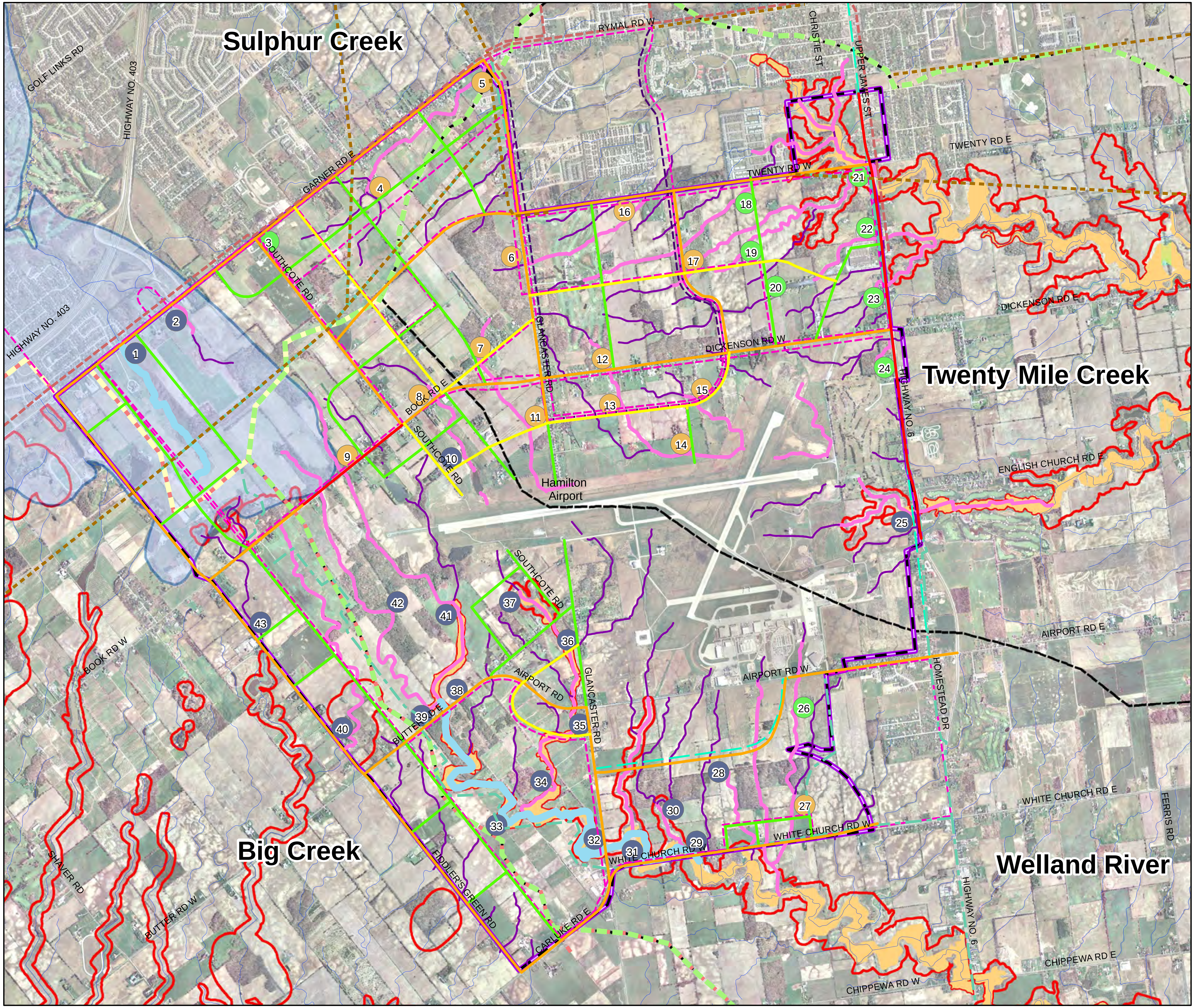
Table 3.5: Overall (environmental) Compatibility Evaluation Matrix for Secondary Plan Area Phase 2 Dry Pond Locations within the AEGD

			Physical and Natural Environment									Social and Cultural Environments				Financial Criteria		
Dry Pond #	Stage	Phase	Flood Control Benefit	Potential Water quality and erosion control Benefit	Aquatic Habitat Benefit	Terrestrial Habitat Benefit	Suitable Outlet	Stream Restoration implications	Construction Phasing Considerations	Compatibility with proposed and existing road network	Ability to Satisfy Regulatory Agencies	Aesthetic Value	Compatibility with adjacent land-use	Cultural heritage and archaeological	Archaeological / Historical	Capital costs	Operations and Maintenance Costs	**Aggregate Score**
4	1	2	4	2	3	2	4	2	4	4	4	2	3	3	2	3	4	**46**
5	1	2	4	2	2	2	4	3	4	4	4	2	3	3	1	1	4	**43**
6	1	2	4	2	3	1	3	2	4	4	4	2	4	4	3	4	4	**48**
7	1	2	4	2	3	1	3	2	4	4	4	2	4	4	3	4	4	**48**
8	1	2	4	2	3	2	3	2	4	4	4	2	3	3	2	3	4	**45**
9	1	2	4	2	2	1	4	3	4	4	4	2	4	4	3	4	4	**49**
11	1	2	4	2	3	2	3	2	4	4	4	2	3	3	1	1	4	**42**
12	1	2	4	2	3	2	3	2	4	4	4	2	3	3	3	1	4	**44**
13	1	2	4	2	3	2	3	2	4	4	4	2	3	3	3	1	4	**44**
14	1	2	4	2	3	3	3	2	4	4	4	2	2	2	3	1	4	**43**
15	1	2	4	2	3	3	3	2	4	4	4	2	2	2	3	1	4	**43**
16	1	2	4	2	1	2	4	4	4	4	4	2	3	3	3	2	4	**46**
17	1	2	4	2	3	2	3	2	4	4	4	2	3	3	1	1	4	**42**
27	1	2	4	2	3	2	3	2	4	4	4	2	3	3	1	1	4	**42**
	Note: Pond locations as shown on Figure 3.3 are of approximate locations. Furthermore, for clarity and readability of pond labels, the size of pond location markers are not shown to scale.																	

Table 3.6: Overall (environmental) Compatibility Evaluation Matrix for Additional Study Area Dry Pond Locations within the AEGD

			Physical and Natural Environment									Social and Cultural Environments				Financial Criteria		
Dry Pond #	Stage	Phase	Flood Control Benefit	Potential Water quality and erosion control Benefit	Aquatic Habitat Benefit	Terrestrial Habitat Benefit	Suitable Outlet	Stream Restoration implications	Construction Phasing Considerations	Compatibility with proposed and existing road network	Ability to Satisfy Regulatory Agencies	Aesthetic Value	Compatibility with adjacent land-use	Cultural heritage and archaeological	Archaeological / Historical	Capital costs	Operations and Maintenance Costs	**Aggregate Score**
1	2	-	4	2	1	2	4	4	1	4	2	2	3	3	2	4	4	**42**
2	2	-	4	2	3	2	4	2	1	4	2	2	3	3	1	3	4	**40**
10	2	-	4	2	3	2	3	2	4	4	4	2	3	3	3	3	4	**46**
27	2	-	4	2	2	1	3	3	4	4	4	2	4	4	3	2	4	**46**
28	2	-	4	2	3	1	4	2	4	4	4	2	4	4	3	4	4	**49**
29	2	-	4	2	1	1	4	4	4	4	2	2	4	4	1	4	4	**45**
30	2	-	4	2	1	1	4	4	4	4	2	2	4	4	3	4	4	**47**
31	2	-	4	2	1	1	4	4	4	4	2	2	4	4	2	4	4	**46**
32	2	-	4	2	1	1	4	4	4	4	2	2	4	4	1	4	4	**45**
33	2	-	4	2	1	1	4	4	1	4	3	2	4	4	3	4	4	**45**
34	2	-	4	2	1	1	4	4	1	4	3	2	4	4	3	4	4	**45**
35	2	-	4	2	1	1	4	4	1	4	3	2	4	4	2	4	4	**44**
36	2		4	2	1	1	4	4	1	4	3	2	4	4	1	4	4	**43**
37	2	-	4	2	2	1	4	3	1	4	3	2	4	4	3	4	4	**45**
38	2	-	4	2	1	1	4	4	1	4	4	2	4	4	1	4	4	**44**
39	2	-	4	2	1	1	4	4	1	4	4	2	4	4	1	4	4	**44**
40	2	-	4	2	2	1	3	3	1	4	2	2	4	4	3	4	4	**43**
41	2	-	4	2	1	1	4	4	1	4	3	2	4	4	3	4	4	**45**
42	2	-	4	2	1	1	4	4	1	4	4	2	4	4	3	4	4	**46**
43	2	-	4	2	3	2	3	2	1	4	4	2	3	3	1	3	4	**41**

Note: Pond locations as shown on Figure 3.3 are of approximate locations. Furthermore, for clarity and readability of pond labels, the size of pond location markers are not shown to scale.



Hamilton AEGD Study Subwatershed Plan

RECOMMENDED STORMWATER MASTER PLAN
Figure 3.3

Legend

- Study Area
- Grand River Conservation Authority
- Hamilton Conservation Authority
- Niagara Peninsula Conservation Authority

Transportation Master Plan

- Existing Transit Route
- Future Recreational Trail
- Major Arterial Road - 44 or 44.5 meters
- Major Collector Road - 33 meters
- Minor Arterial Road - 37 meters
- Minor Collector Road - 26 meters
- Proposed Multi-Use Pathway
- Proposed Rapid Transit
- Proposed Transit Route
- Proposed Transit Route Extension

Pond Location

- Secondary Plan Area: Phase 1
- Secondary Plan Area: Phase 2
- Additional Study Area

MNR Fish Habitat Buffers

- Support/Indirect Fish Habitat/Marginal Habitat (30m)*
- Seasonal/Warmwater Watercourse/Important/Marginal Habitat (30m)
- Coldwater watercourse/Critical Habitat (60m)
- High Recharge potential
- Floodplain
- Generic Regulation Lines**

NOTES:

***if watercourse is retained as an enhanced feature.**
****Generic regulations include a 30 m buffer on all watercourses.**

Meters
0 262.5 525 1,050 1,575

Map Created By: AS
Map Checked By: BH
Date Created: October 5, 2009
Date Modified:
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BUILDING A STRONG FOUNDATION HAMILTON

Hamilton
Planning & Economic Development Department

3.5 LID BMPs In relation To AEGD Land-uses

The following section details a review of the preferred stormwater management alternative for the AEGD as identified in through the EA process. The subsequent review examines the feasibility of the thirteen (13) LID Source and Conveyance control techniques and the end-of-pipe dry ponds, within the context of the AEGD, using general selection criteria that include:

- Existing soil types;
- Primary land-uses (Airport Related Business (ARB), Airside Industrial (AI), Light Industrial (IND) and Prestige Business Park (PBP));
- Individual land-uses, within the primary land-uses, under the sub-categories of:
    - Employment uses;
    - Employment Support uses; and
    - Amenities.
- The selection of appropriate LID measures for implementation within the various land-uses also examined:
    - Implementation practicality;
    - Construction cost;
    - Operation and maintenance costs;
    - The general willingness of developers to adopt and construct LID stormwater techniques within the various land-uses.
    - Sources of runoff (the typical characteristics of the runoff and therefore the opportunities for its treatment and use); and
    - Risk management based on the potential for high risk land-uses.

The section to follow details the rational and criteria for the selection and/or exclusion of individual LID techniques in relation to the four employment land use categories identified in the AEGD Secondary Plan and associated schedules. To follow is a planning level assessment using general selection criteria which does not include the specific design requirements and guidance for each specific LID technique, but rather is intended to link the appropriate Low Impact Development (LID) techniques to the individual land-use of the AEGD (ARB, AI, IND and PBP). A more detailed site assessment and LID BMP selection must be done at the individual site design stage using site specific design objectives to be defined through sub-sequent studies (see AEGD SWMP Implementation Document). Since LID measures are implemented as private sector projects, they are not subject to the municipal Class EA process.

3.5.1 Criteria for Evaluation

Evaluation of alternatives involves establishing alternative solutions based on the study objectives, technical considerations and criterion. The following section details this process.

The primary criteria considered in assessing overall applicability of each LID alternative for the respective land-uses (Airport Related Business (ARB), Airside Industrial (AI), Light Industrial (IND) and Prestige Business Park (PBP)) included the soil types and infiltration capacities within the AEGD study area, implementation practicality, construction and operation and maintenance costs and the individual sub-categories of employment/land uses (**Table 3.7**). Integrated within each of the primary selection criteria is the consideration of the general willingness of developers to adopt and construct various LID stormwater techniques with various land-uses.

Table 3.7: AEGD Land-uses and Respective Individual Employment and Employment SupportUses

Primary Land-use		Permitted Uses within the Primary Land use Categories	
		Employment Uses	Employment Support Uses
PBP	Prestige Business Park	• Business and Financial • R&D • Offices • Prestige/light industrial • Warehousing • Wholesale trade • Transportation • Communications • Government Services	• Commercial schools • Amenities*
IND	Industrial	• Light industrial • Warehousing • Repair Services • Wholesale trade • Office • Distribution • Transportation • Communication • Utilities	• Employment Support • Commercial schools • Amenities*
ARB	Airport Related Business	• Freight-forwarders • Regional integrator operations (i.e. FedEx, UPS) • on-site customs brokers • Light industrial • Warehousing • Wholesale trade • Distribution • Outdoor Storage • Office • Transportation • Communication • Utilities	• Commercial schools • Amenities*
AI	Airside Industrial	• Accommodations • Food and catering • Convention Centers • R&D • Offices • Business/financial services • Automobile Rental • Taxi terminals	• Supporting services o Retail o Offices o Gym o Services o Restaurants

*Amenities include : Health Services, Recreational facilities, Open Spaces, Offices, Entertainment, Convenience commercial, Gyms, Restaurants, Financial Establishments, Personal service, Labour association halls

3.5.2 Identification of Appropriate LID Techniques for the Primary AEGD Land uses

To reiterate, the selection of appropriate LID techniques for each primary land use (ARB, AI, IND and PBP) and sub-category of land-uses (Employment uses, Employment Support uses and Amenities) included consideration of the soil types and infiltration capacities within the AEGD study area, high risk land-uses, implementation practicality, construction cost, operations and maintenance costs and consideration of the general willingness of developers to adopt and construct LID stormwater techniques with various land-uses. Also included in the selection of appropriate LID techniques are consideration of the sources of runoff, the typical characteristics of the runoff and therefore the opportunities for its treatment and use (**Table 3.8**), as well as the acknowledgment of potential high risk land-uses (**Table 3.9**), within the AEGD Land-uses and Respective Individual Employment and Employment Support uses(**Table 3.10).**

Table 3.8 Summary of Sources of Runoff, Typical Characteristics and Opportunities for Treatment and Use (Source: TRCA, 2008-draft)

Source	Characteristics	Opportunities	Principles
Foundation drains, slab underdrains, road and parking lot sub-drains	Relatively clean, cool water	Suitable for direct infiltration or discharge to receiving watercourse	Should not be directed to stormwater management facility that is tributary to road/parking lot runoff.
Roof drains, roof terrace area drains, overflow from green roof areas	Moderately clean water, contaminants may include asphalt granules, leaves and organic fallout from airborne pollutants, potentially warm water	Infiltration with minor pretreatment through vegetated filter (lawn, grassed swale, storm garden). Recycling through collection in central cistern and reuse as irrigation supply or grey water supply for internal building systems (toilet flushing etc)	Where possible, should not de directed to end-of-pipe facilities in order to capitalize on potential for reuse and infiltration however, flow moderation (quantity control) prior to discharge into the receiving watercourse is required.
Road, sidewalk and parking lot surfaces	Potential for high contamination with hydrocarbons, metals, grit/sediment and chlorides Typically warm	Infiltration after pre-treatment. Filtration after pre-treatment Attenuation and treatment in wet pond, wetland or hybrid facility. Recycling for irrigation purposes after treatment in pond, wetland or hybrid facility	Runoff should be treated in a SWM pond/oil grit separator prior to infiltration or re-use for irrigation purposes. Water quality should be tested prior to use for irrigation purposes
Gas station, auto-repair facilities, outdoor storage, industrial sites **(High Risk Land-uses: Table 3.9)**	Potential for high levels of contamination - hydrocarbons, metals, organic and inorganic compounds, sediments and chlorides	Attenuation and treatment in wet pond, wetland or hybrid facility Potential requirement for pretreatment (oil/grit separator) Infiltration and recycling alternatives are not recommended	Runoff from these sources should not be infiltrated or used for irrigation. Spill containment/mitigation devices recommended contingent on size of storage facilities.

3.5.2.1 High Risk Land Use

As identified in **Table 3.9**, high risk land uses are those with the potential for high levels of contamination such as hydrocarbons, metals, organic and inorganic compounds, sediments and chlorides. Individual employment land-uses within the AEGD that are listed in **Table 3.9** will generally be discouraged from incorporating LID techniques that utilize infiltration as its primary function because of the associated risk to groundwater contamination (see **Part A-Subwatershed plan: Section 2.5.6 and 6.3**). However high risk land uses do not preclude the use of those LID techniques that utilize filtration, evapotranspiration (ET) or re-use as the primary processes. This can include bioretention, grassed swales, bio-swales etc which are lined and have an underdrain structure and are therefore impermeable (filtration only); green roofs (ET) or rainwater harvesting (ET and re-use). Additionally, the infiltration of rainwater not directly impacted by the respective high risk land use activity such as rainwater emanating from rooftops or directly falling on permeable surfaces is generally considered relatively 'clean' and should not be excluded from infiltration without careful consideration at the individual site plan scale.

Table 3.9: High Risk Land Uses

• Landfills, waste transfer stations, & putrescible waste disposal • Storage of hazardous wastes or liquid industrial wastes • Lagoons for sewage treatment • Auto wrecking & salvage yards • Commercial or industrial dry cleaning of textiles • Storage of fertilizers • Foundries, nonferrous metal smelting & refining, & casting operations • Metal finishing operations • (electroplating, electrocoating, galvanizing, painting, application of baked enamel)	• Vehicle stampings • Wood & wood product preservation & treatment • Airports • Bulk liquid trucking • Warehousing, bulk storage or retail sale of: - Petroleum fuels, oils, chlorinated solvents, - Household or industrial cleaning products - Agricultural pesticides, herbicides, fungicides & fertilizers • Manufacturing of: • Petroleum products or asphalt batching (including processing) • Motor vehicles, trucks, & bus bodies • Aircraft & aircraft parts	• Manufacturing (cont'd) - Rail cars - Mobile homes - Ships & boats - Industrial chemicals - Printing inks - Adhesives - Small electrical appliances - Electric lamps - Wet batteries - Dry electrical industrial equipment - Vehicle engines - Cable & wire - Pharmaceuticals & medicines - Paints & varnishes - Major electric appliances - Plastics & synthetic resins - Lighting fixtures	- Wet electrical equipment - Steering & suspension parts - Motor vehicle wiring - Jewellery & precious metals - Reinforced fiberglass - Electronic components (semiconductors, printed circuit boards, cathode ray tubes) - Unfinished fabricated metal products - Wheels & brakes - Leather products - Soaps & toilet preparations

The following is a summary of the feasibility screening analysis for the various LID techniques for each of the four (4) primary land-uses types, (ARB, AI, IND and PBP) as well as the sub-categories of Individual Employment and Employment Support uses as per **Table 3.7**. Full LID selection matrixes for the PBP/ AI and IND/ARB with respect to the individual employment land-uses, Employment Support uses and amenities is provide in **Table B1** and **B2** in **Appendix B**.

Provide below in **Table 3.10** is a summary of the feasibility analysis results for the thirteen (13) LID techniques in relation to the four (4) primary AEGD land-use categories. In developing **Table 3.10**, the respective individual employment and Employment Support uses of each primary AEGD land-use category was considered and is reflected by a "partial" feasibility ranking. Implementation details for each AEGD land-use type is presented in subsequent sections and has been included in the AEGD SWMP Implementation Document (under separate cover).

Table 3.10 Summary of Feasibility Analysis of LID Techniques in Relation to Individual AEGD Primary Land-uses

		Rainwater Harvesting	Green Roofs	Downspout Disconnection	Soakaway Pits	Bioretention	Special Bioretention	Compost Amendments	Tree Clusters	Filter Strips	Permeable Pavement	Grass Channels	Dry Swales (Bio-Swales)	Perforated Pipe Systems
LID Source Controls	**PBP**	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
	AI	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
	IND	*Yes*	$	*Yes*	Partial	Partial	$	*Yes*	*Yes*	*Yes*	$	*Yes*	Partial	*Yes*
	ARB	*Yes*	$	*Yes*	Partial	Partial	$	*Yes*	*Yes*	*Yes*	$	*Yes*	Partial	*Yes*
LID Conveyance Controls	**Road ROW**	n/a	n/a	n/a	Yes, see perforated pipe systems	Yes, see Dry Swales	Yes, See Dry Swales	Yes, See Grass Channels	n/a	Yes, as pre-treatment only	n/a	*Yes*	Yes	*Yes*

Yes *– Indicates that the LID technique is feasible in relation to AEGD primary land-use and Individual Employment and Employment Support Uses*

$ – Indicates that LID technique has been found to be cost prohibitive for implementation within the respective AEGD primary land-use. Note this does not eliminate the technique for potential implementation but strongly suggests that a cost analysis be performed prior to implementation.

Partial – Indicates that the LID techniques may be suitable within specific sub-areas (individual employment and Employment Support uses) within the primary AEGD land-use, and the reader is directed to ***Tables 3.8 and 3.9*** *for site specific assessment details and the* Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC-2010).

Note: Site specific characteristics such as seasonally high groundwater table elevation, source protection, slope, soils as well as cost, constructability, implementation considerations etc. may alter the specific feasibility in relation to each site. In all cases, site specific assessments and feasibility analyses must be performed prior to LID source and conveyance control selection, design and implementation. AEGD SWMP Implementation Document (under separate cover).

Prestige Business Park (PBP)

In relation to the PBP land use, it is assumed that the high urban design standards in combination with the eco-industrial approach will attract businesses and developers with a higher regard for aesthetic values, green space integration and overall sustainability. In this land-use, the entire suite of 13 LID source control techniques are implementable with the following exceptions:

- Implementation of infiltration techniques such as soakaway pits, bioretention, special bioretention, and dry swales within the individual employment and Employment Support uses of Light industrial and transportation of the PBP land-use should be further assessed due to the possibility of groundwater impacts from these potentially high risk land-uses (see **Section 3.5.2.1**- High Risk Land use). Final decision to include or exclude these techniques from the above employment uses can be completed on a site by site basis at the site plan stage.

- Permeable pavement installations should be generally excluded from the employment land-use of transportation due to possible groundwater impacts and the anticipated high traffic volumes. Permeable pavement is generally discouraged for use in high traffic areas. In this context “High Traffic” commonly refers to both high volume areas and large vehicle size (See **Section 3.2.10**- Permeable Pavement), however <u>infrequent</u> truck or heavy vehicle traffic (i.e. garbage trucks) should not preclude the general use of permeable pavement.

- The full suite of LID techniques are applicable to the Employment Support Uses and Amenities within the PBP land-use designations, with the exception of the impracticality of rainwater harvesting and green roofs in open spaces.

Airside Industrial (AI)

In relation to the AI land use (like PBP) it is assumed that the high urban design standards in combination with the eco-industrial approach will attract businesses and developers with a higher regard for aesthetic values, green space integration and overall sustainability. In this land-use the entire suite of 13 LID source control techniques are implementable with the flowing exceptions:

- Implementation of infiltration techniques such as soakaway pits, bioretention, special bioretention, and dry swales should generally be avoided in the employment uses of taxi terminals and automobile rentals due to the possibility of groundwater impacts from these potentially high risk land-uses. (see **Section 3.5.2.1**- High Risk Land use). Final decision to include or exclude these techniques from the above employment uses can be completed on a site by site basis at the site plan stage.

- Permeable pavement installations should be excluded from employment land-uses such as taxi terminals and automobile rentals due to possible groundwater impacts and anticipated high traffic volumes. Permeable pavement is generally discouraged for use in high traffic areas. In this context "High Traffic" commonly refers to both high volume areas and large vehicle size (See **Section 3.2.10**- Permeable Pavement), however <u>infrequent</u> truck or heavy vehicle traffic (i.e. garbage trucks) should not preclude the general use of permeable pavement.

- The full suite of LID techniques are applicable to the Employment Support Uses and Amenities within the AI land-use designations, with the exception of the impracticality of rainwater harvesting and green roofs in open spaces.

<u>Light Industrial (IND)</u>

Within the IND land-use designation, the low urban design standards are expected to produce lower property values and thus lower return on investment for developers, thereby in effect making the most costly LID source control techniques such as green roofs, permeable pavement and special bioretention cost prohibitive. Furthermore, within these areas, selected employment land-uses may increase the potential for groundwater impacts. Within the IND land-use designation, the following conclusions have been drawn.

- LID techniques that are fully applicable to all Employment uses, Employment Support uses and Amenities in the IND land-use designations include:
    - Rainwater harvesting (except in open spaces);
    - Downspout disconnection;
    - Tree clusters;

  - Filter Strips;
  - Grass Channels; and
  - Compost Amendments

- Within the Employment Support Uses and Amenities land-uses of the IND (**Table 3.7**), the risk of groundwater impacts is minimal. Therefore, additional LID techniques are fully applicable to Employment Support Uses and Amenities within the IND land-use designations, these include:
  - Soakaway pits;
  - Bioretention; and
  - Dry Swales

- Implementation of infiltration techniques such as soakaway pits, bioretention, special bioretention, dry swales and permeable pavement should be generally avoided in the employment uses of light industrial, warehousing, transportation, repair services and utilities due to the possibility of groundwater impacts from these potentially high risk land-uses (see **Section 3.5.2.1**- High Risk Land use). Final decision to include or exclude these techniques from the above employment uses can be completed on a site by site basis at the site plan stage.

- The construction costs of green roofs, special bioretention and permeable pavement in this area of low urban design standards may be cost prohibitive for those Employment uses, Employment Support uses and Amenities within the LIND land-use. Furthermore, there exists a developer reluctance to incorporate green roofs into light industrial land-uses and operation and maintenance concerns generally further limit the use of special bioretention.

<u>Airport Related Business (ARB)</u>

Within the ARB land-use designation, like the IND, the low urban design standards are expected to produce lower property values and thus lower return on investment for developers, thereby making selected LID source control techniques cost prohibitive. Furthermore, within these areas, selected employment land-uses may increase the potential for groundwater impacts. Within the ARB land-use designation, the following conclusions have been drawn.

- LID techniques that are fully applicable to all Employment uses, Employment Support uses and Amenities in the ARB land-use designations include:
  - Rainwater harvesting (except in open spaces);
  - Downspout disconnection;
  - Tree clusters;
  - Filter Strips;
  - Grass Channels; and
  - Compost Amendments

- Within the Employment Support Uses and Amenities land-uses of the ARB, the risk of groundwater impacts is minimal. Therefore, additional LID techniques are fully applicable to Employment Support Uses and Amenities include:
  - Soakaway pits;
  - Bioretention; and
  - Dry Swales

- Implementation of infiltration techniques such as soakaway pits, bioretention, special bioretention, dry swales and permeable pavement should be avoided in the employment uses of light industrial, warehousing, transportation, utilities, freight forwarders, regional integrators, outdoor storage and distribution due to the possibility of groundwater impacts from these potentially high risk land-uses. (See **Section3.5.2.1**- High Risk Land use). Final decision to include or exclude these techniques from the above employment uses can be completed on a site by site basis at the site plan stage.

- The construction costs of green roofs, special bioretention and permeable pavement in this area of low urban design standards may be cost prohibitive for those Employment uses, Employment Support uses and Amenities within the ARB land-use. Furthermore, there exists a developer reluctance to incorporate green roofs into ARB land-uses and operation and maintenance concerns generally further limit the use of special bioretention.

<u>Other Considerations</u>

For LID techniques that utilize infiltration as the primary stormwater management mechanism, the required percentage of lot areas and the construction cost may be variable from site to site due to the variability of soil permeability within the AEGD study area. All site plan designs will require on-site testing of infiltration rates to confirm construction and operation and maintenance costs. *See AEGD SWMP Implementation Document (under separate cover) and the* Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC - 2010).

3.6 Stream Restoration Measures – Riparian Planting

As part of the recommended Stormwater Master Plan, stream restoration measures have been identified. These measures are limited to defining minimum stream corridor widths and to riparian vegetation plantings to provide flow/water quality attenuation, enhance stream shading, minimize stream bank erosion, and create a vegetated buffer along all headwater features (**Figure 3.3**).

A defined stream corridor has been established adjacent to and downstream of each drainage feature to the downstream limit of the study area or the upstream limit of the mapped floodplain, as follows:

- 15 m from each side of the bank full channel of the drainage feature for Seasonal and Warm water Fish Habitat
- 30 m from each side of the bank full channel of the drainage feature for Coldwater Fish Habitat

The final widths of the defined stream corridors adjacent to each dry pond, will be the greater of these corridor widths and the floodplain width based on detailed hydrologic/hydraulic studies to be completed as development proceeds.

In addition, native, woody, riparian vegetation will be planted within these corridors to achieve a fisheries target of either 50% or 75% woody, riparian vegetation cover for seasonal/warm water fish habitat or coldwater fish habitat, respectively.

3.7 Economics of LID Source and Conveyance Controls

LID stormwater techniques represent an innovative, state of the art approach to managing stormwater by first and foremost treating runoff (precipitation) at its source, as a resource to be managed and protected rather than a waste.

Regardless of the relative newness of LID for managing stormwater, considerable effort has been made to quantify the associated costs. Recent works by the US Environmental Protection Agency (EPA) titled 'Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices' (2007) examined 17 Greenfield and Redevelopment case studies from the U.S.A and Canada and provided a comparison of the construction costs of LID SWM vs. Conventional SWM Design. **Table 3.11** provide a summary of selected case study project, the LID techniques, and a comparison of the construction costs associated with conventional SWM costs as compared to the LID SWM construction costs. On average, the EPA found a construction cost savings of 25% using LID as compared to conventional stormwater management.

Table 3.11: Summary of Construction Cost Comparison for Selected LID Case Studies

Project	LID Technique	Construction Costs			Cost Savings
		Conventional SWM	LID SWM	Cost Difference	
2nd Avenue SEA St.	1,3,4,6	$868,803	$651,548	$217,255	25%
Auburn Hills	1,3,4,6,7	$2,360,385	$1,598,989	$761,396	32%
Bellingham City Hall	1	$27,600	$5,600	$22,000	80%
Bellingham Donovan Park	1	$52,800	$12,800	$40,000	76%
Garden Valley	1,2,4,5,7	$324,400	$260,700	$63,700	20%
Kensigton Estates	2,3,5,6,7	$765,700	$1,502,900	- $737,200	-96%
Laurel Springs	1,2,3,4	$1,654,021	$1,149,552	$504,469	30%
Mill Creek	2,3,4	$12,510	$9,099	$3,411	27%
Prairie Glen	1,2,3,4,6,7	$1,004,848	$599,536	$405,312	40%
Somerset	1,4	$2,456,843	$1,671,461	$785,382	32%
Tellabs Corp. Campus	1,4,6,7	$3,162,160	$2,700,650	$461,510	15%
Crown Streets -CAN	1,6	$364,000	396,000	$-32,000	-9%
1-Bioretention, 2-Reduced lot area, 3-Reduced Impervious Area, 4- Swale, 5-permeable Pavement, 6-Vegetative Landscaping, 7-Wetlands, 8- Green roofs					

Conclusions from the 2007 EPA document, reiterated in literature and in other Canadian municipalities, are as follows:

- In the vast majority of cases, implementing well-chosen LID practices saves money for developers, property owners, and communities while protecting and restoring water quality.

- Site specific factors influence project outcomes, but in general, for projects where open spaces were preserved and cluster development designs employed, infrastructure costs were lower.

- In some cases, initial costs might be higher because of the cost of green roofs, increased site preparation costs, or more expensive landscaping practices and plant species. However, in the vast majority of cases, significant savings were realized during the development and construction phases of the projects due to reduced costs for site grading and preparation, stormwater infrastructure (pipes, inlets, outlets etc.) site paving, and landscaping.

Additional benefits not monetized in **Table 3.11** include but not limited the following:

- Environmental Benefits
  - Pollution abatement
  - Protection of downstream watercourses
  - Groundwater recharge
  - Water quality improvement
  - Reduction in CSOs
  - Habitat Improvement

- Land Value and Quality of Life
  - Increased property value & tax revenues
  - Increased lot yield
  - Aesthetic value
  - Public spaces

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 (m^3/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 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).

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**.

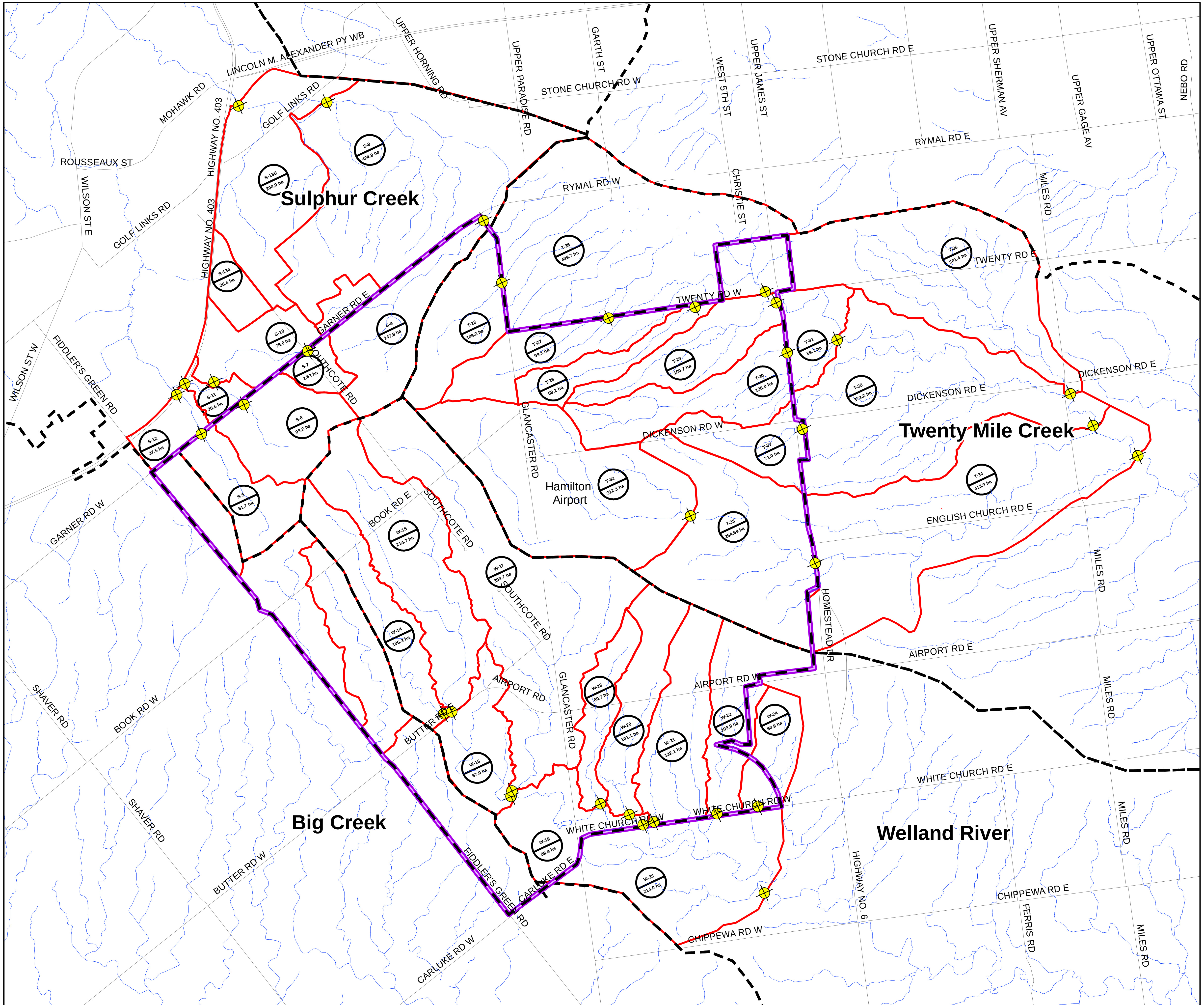
The STANDHYD routine in SWMHYMO was used to simulate the proposed conditions hydrology and peak runoff flows from urban catchment areas. The STANDHYD routine requires the following inputs:

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 areas.

Hamilton AEGD Study Subwatershed Plan

HYDROLOGICAL SUBCATCHMENTS

Figure 4.0



Legend

- Flow Node Location
- Study Area
- Hydrologic Catchments

Meters

0 355 710 1,420 2,130

N

Map Created By: AS
Map Checked By: BH
Date Created: October 5, 2009
Date Modified:
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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**.

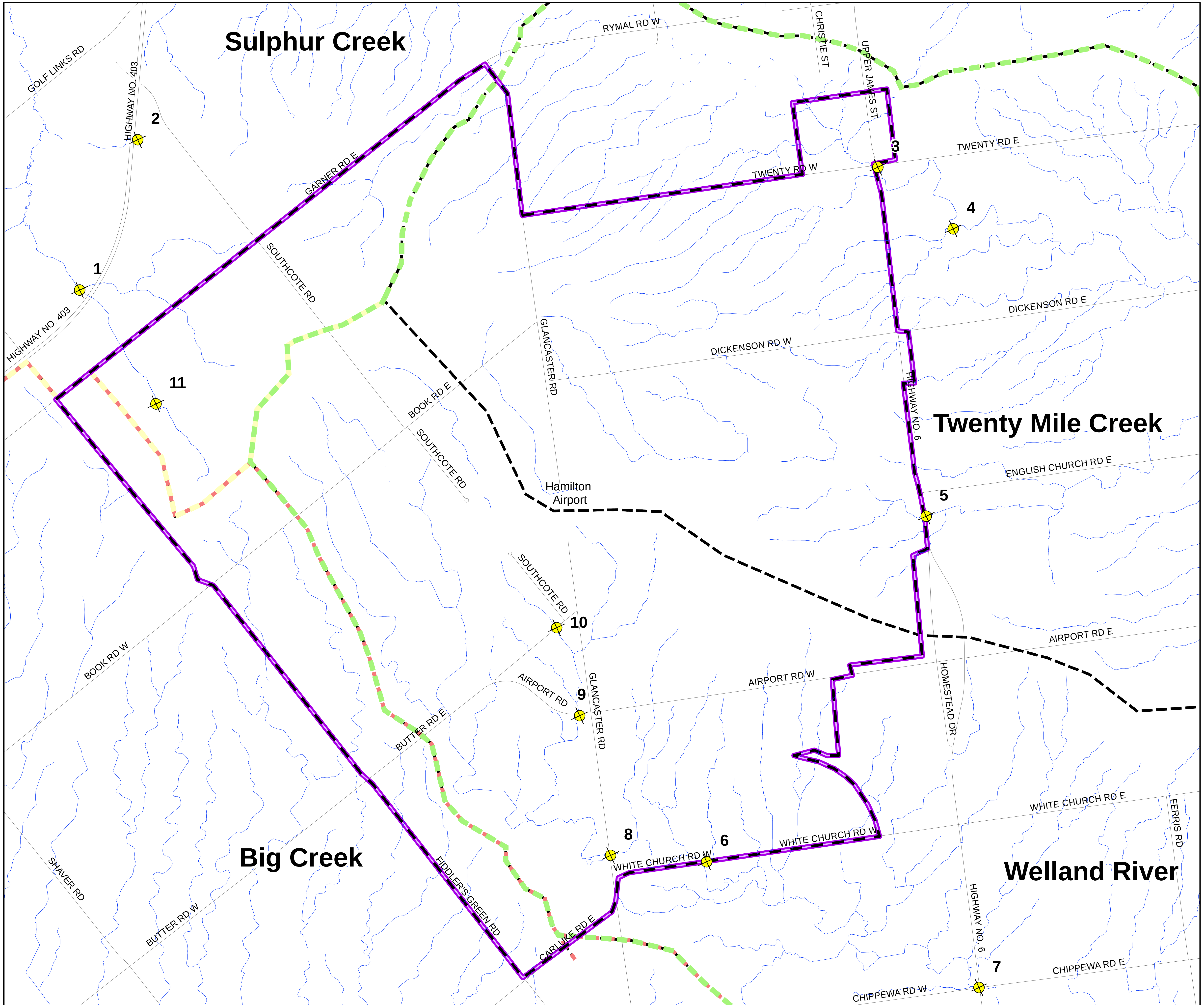
4.1.2 Previous Hydrologic Estimates for the Study Area - Known Flow Locations

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 AEGD Study Subwatershed Plan

FLOW REFERENCE LOCATION
Figure 4.1

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

Map Created By: AS
Map Checked By: BH
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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

4.1.3 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 (m^3/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 (Q_{post} 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 (m^3/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 300m^3/ha and 400m^3/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
Depth (m)		Permanent Pool	0
		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>
<tr><th colspan="4">Table 4.6
Storm Water Management Facility T29 - Preliminary Design Characteristics</th></tr>
<tr><td colspan="3">Total Tributary Area (hectares)</td><td>100.7</td></tr>
<tr><td colspan="3">Impervious (%)</td><td>56</td></tr>
<tr><td colspan="3">Composite Runoff Coefficient</td><td>0.61</td></tr>
<tr><td colspan="3">Pre Development Peak Flow (m^3/s)</td><td>3.16</td></tr>
<tr><td colspan="3">Post Development Peak Flow (m^3/s)</td><td>21.50</td></tr>
<tr><td colspan="3">Level of Water Quality Protection (1)</td><td>n/a</td></tr>
<tr><td colspan="3">Type</td><td>Dry Pond</td></tr>
<tr><td colspan="3">Permanent Pool Requirement (m^3/ha)</td><td>0</td></tr>
<tr><td colspan="3">Extended Detention Requirement (m^3/ha) for Erosion Control (15mm released over 24hrs)</td><td>92</td></tr>
<tr><td colspan="3">Flood Attenuation Requirement (m^3/ha)</td><td>438</td></tr>
<tr><td colspan="2" rowspan="4">Depth (m)</td><td>Permanent Pool</td><td>0</td></tr>
<tr><td>Extended Detention</td><td>0.64</td></tr>
<tr><td>Attenuation</td><td>2.36</td></tr>
<tr><td>Total (excl. freeboard)</td><td>3.0</td></tr>
<tr><td rowspan="7">Storage Volume (m^3)</td><td rowspan="2">Permanent Pool</td><td>Required</td><td>n/a</td></tr>
<tr><td>Provided</td><td>n/a</td></tr>
<tr><td rowspan="2">Extended Detention (2)</td><td>Required</td><td>9,214</td></tr>
<tr><td>Provided</td><td>9,214</td></tr>
<tr><td rowspan="2">Attenuation</td><td>Required</td><td>44,106</td></tr>
<tr><td>Provided</td><td>44,106</td></tr>
<tr><td colspan="2">Total Provided</td><td>53,320</td></tr>
</table>

4.1.4 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.

Modeling Input Parameters

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.

Meteorological Input Data

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).

Soil Type and Land Use

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 m^3/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.

4.1.5 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.

4.1.5.1 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.

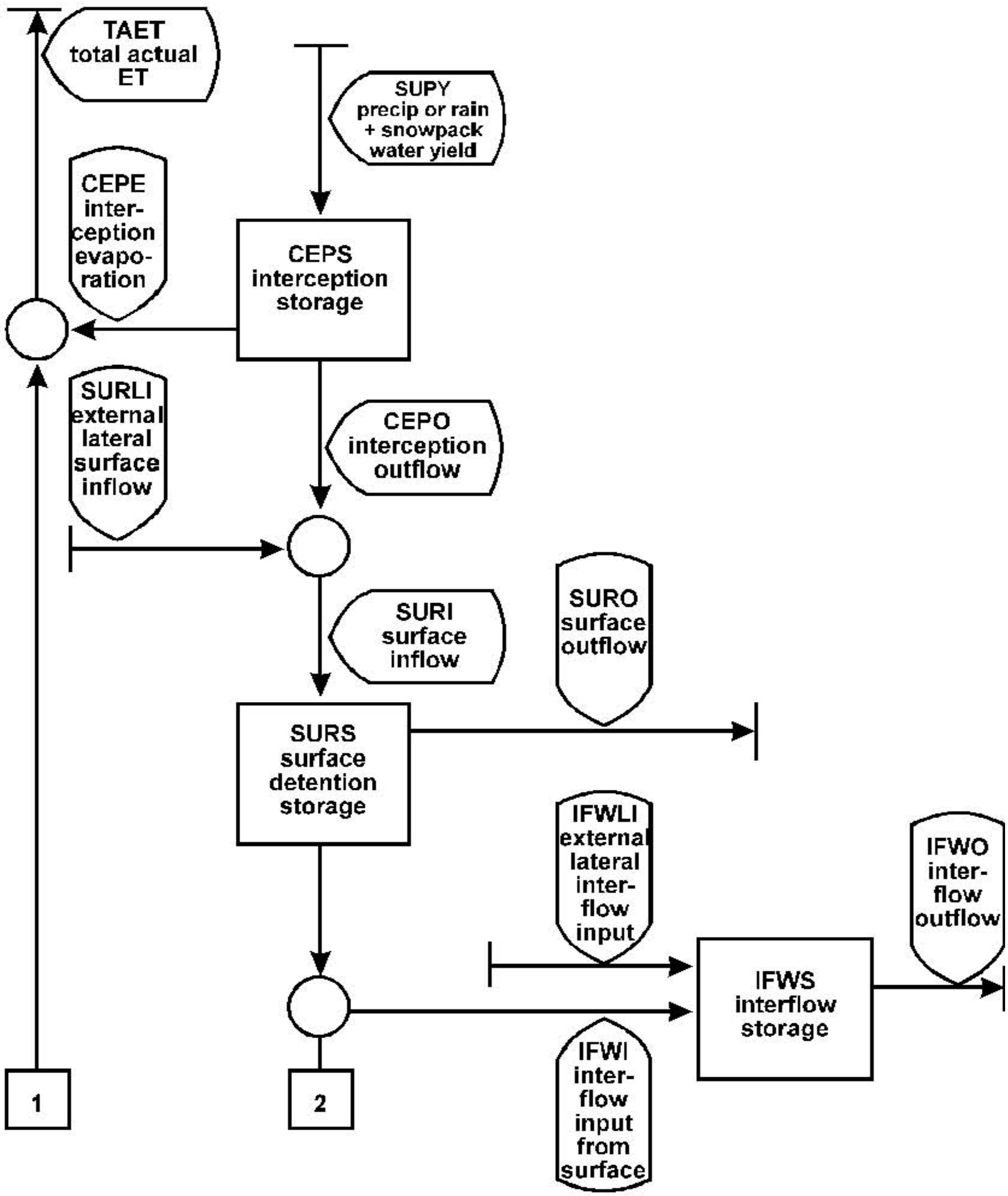


Figure 4.2 Flow Diagrams of Water Movement and Storage Modeled in the PWATER section of the PERLND Application Module (Part 1)

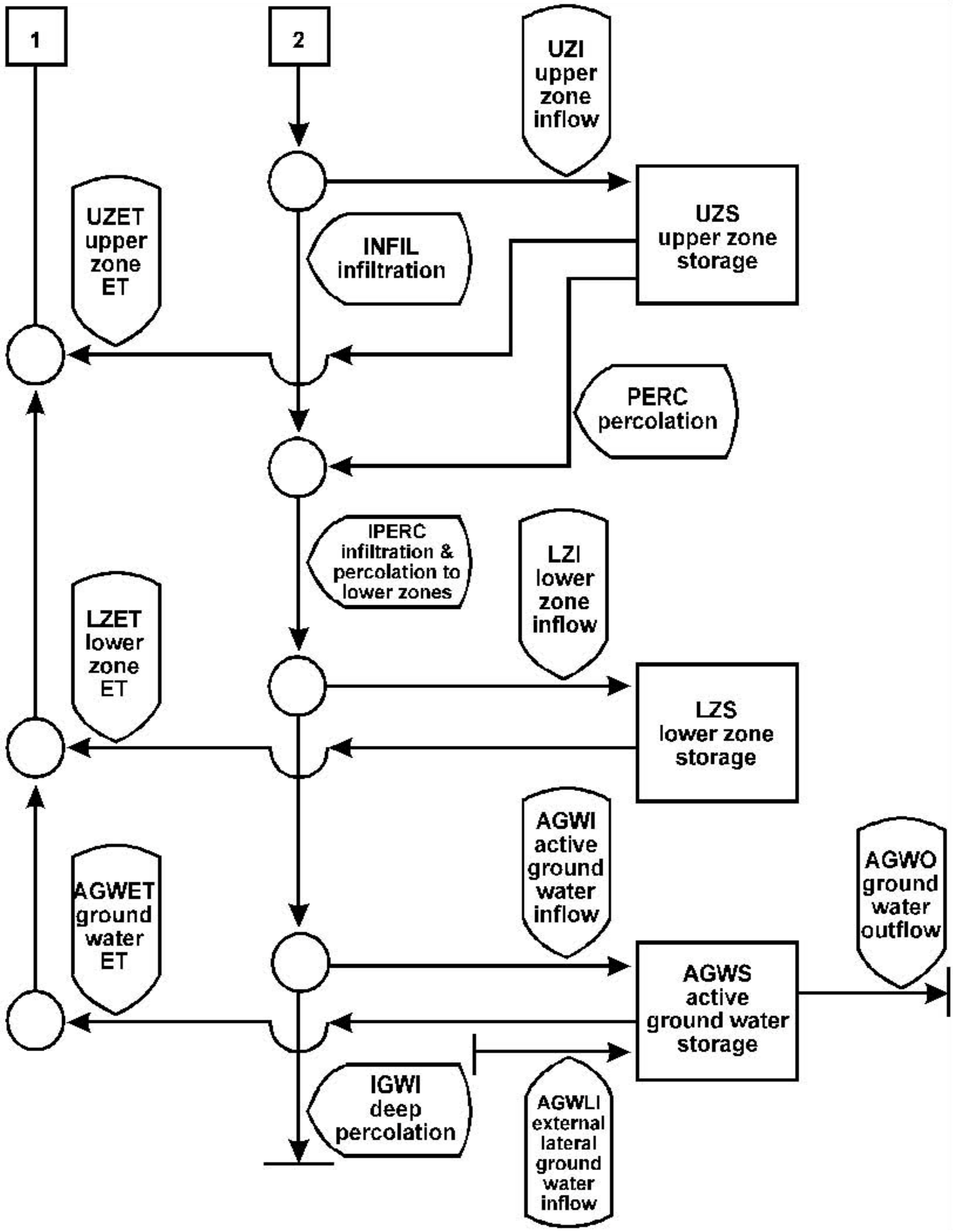


Figure 4.3 Flow Diagrams of Water Movement and Storage Modeled in the PWATER section of the PERLND Application Module (Part 2)

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 (m^3 / 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**.

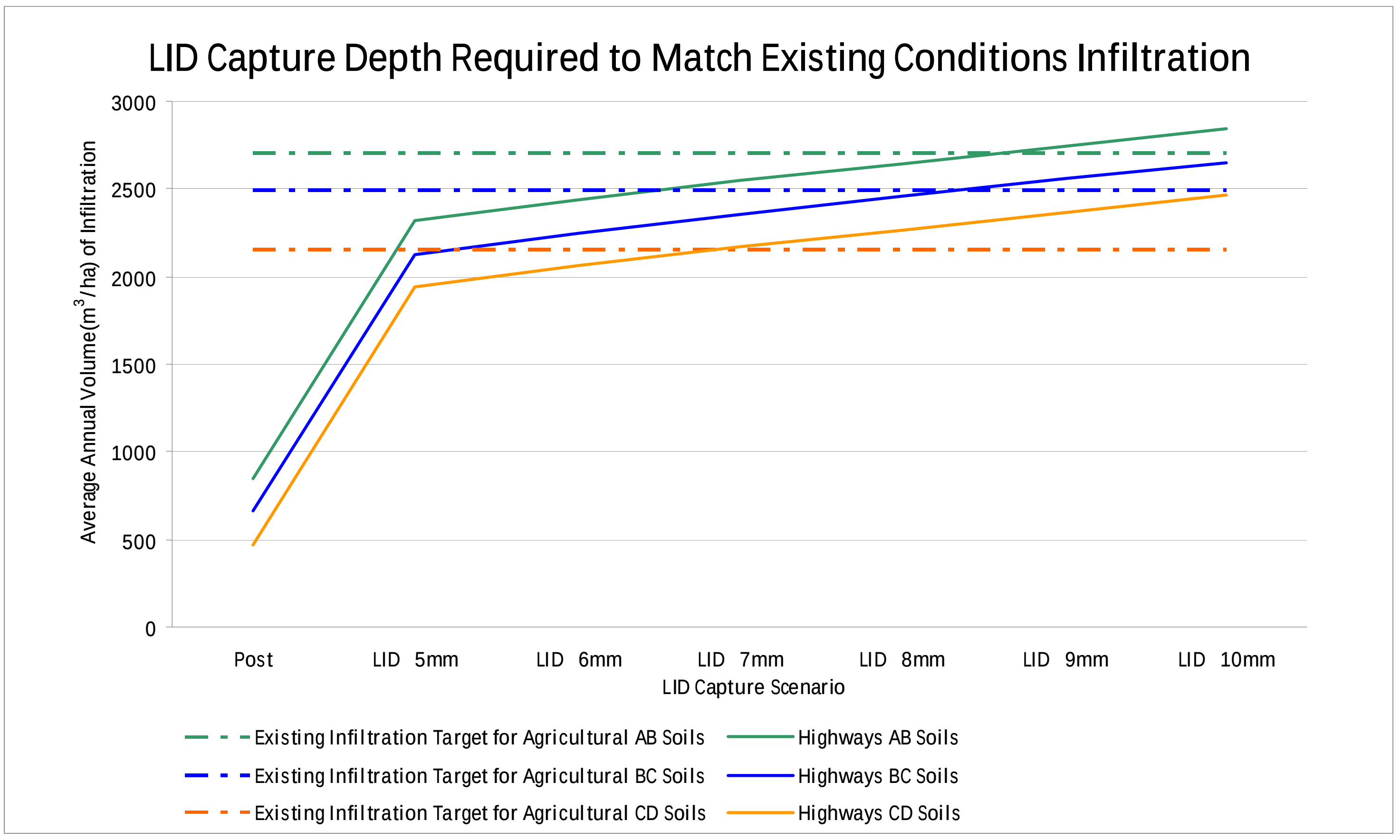


Figure 4.4: Required LID Capture Depths for Highways

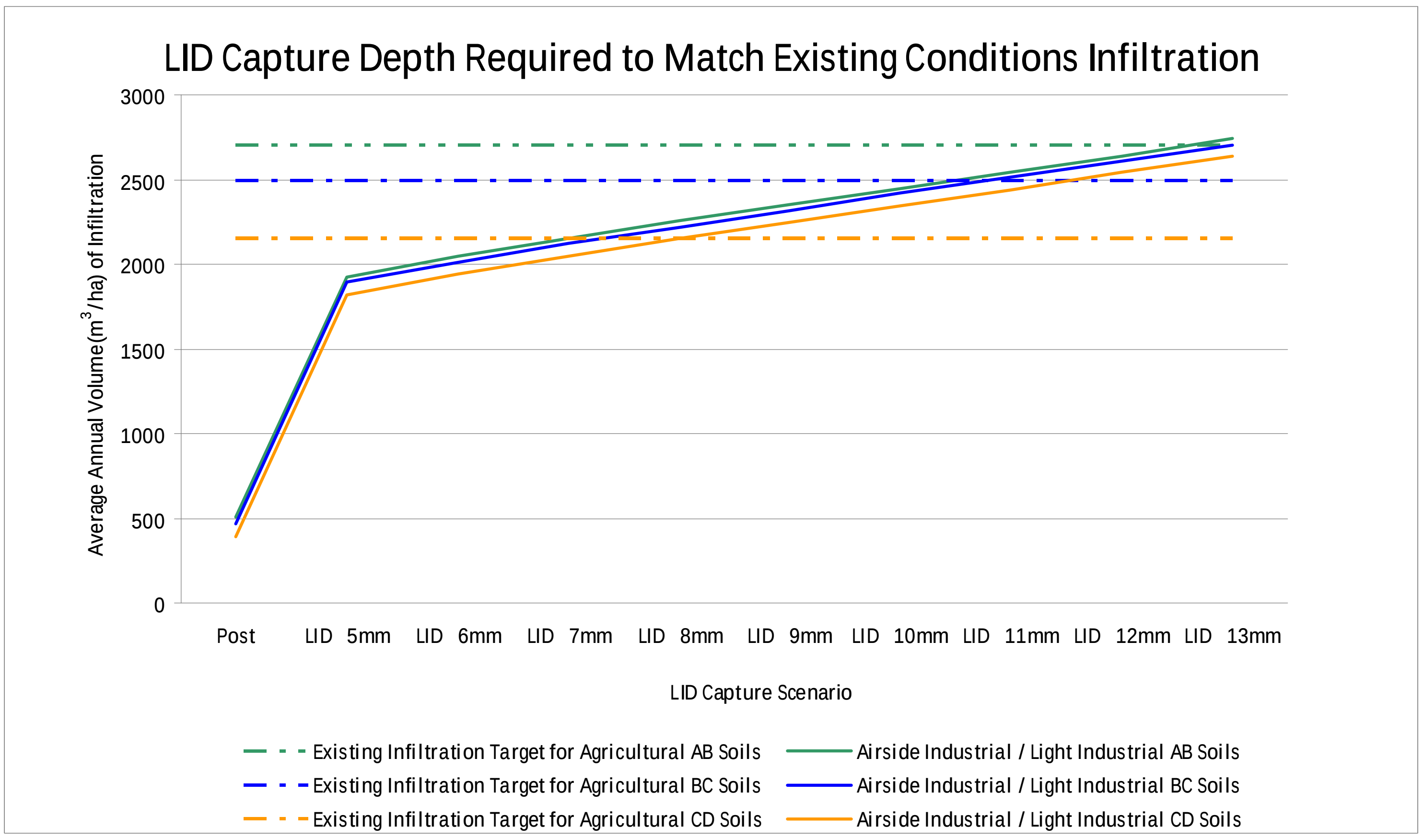


Figure 4.5: Required LID Capture Depths for Airside Industrial / Light Industrial

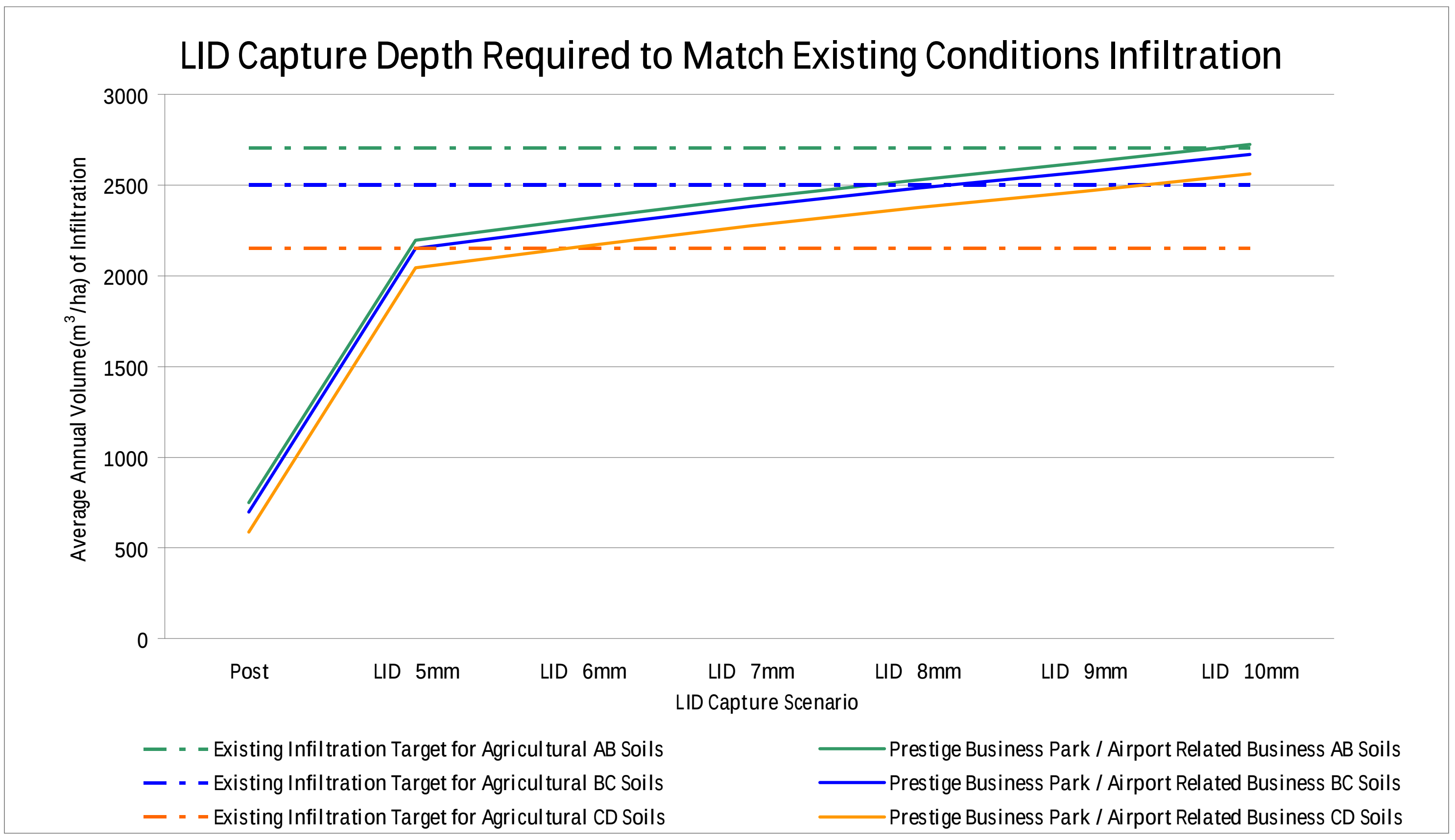


Figure 4.6: Required LID Capture Depths for Prestige Business Park / Airport Related Business

Table 4.10: LID Capture Target (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

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:

4.1.5.2 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

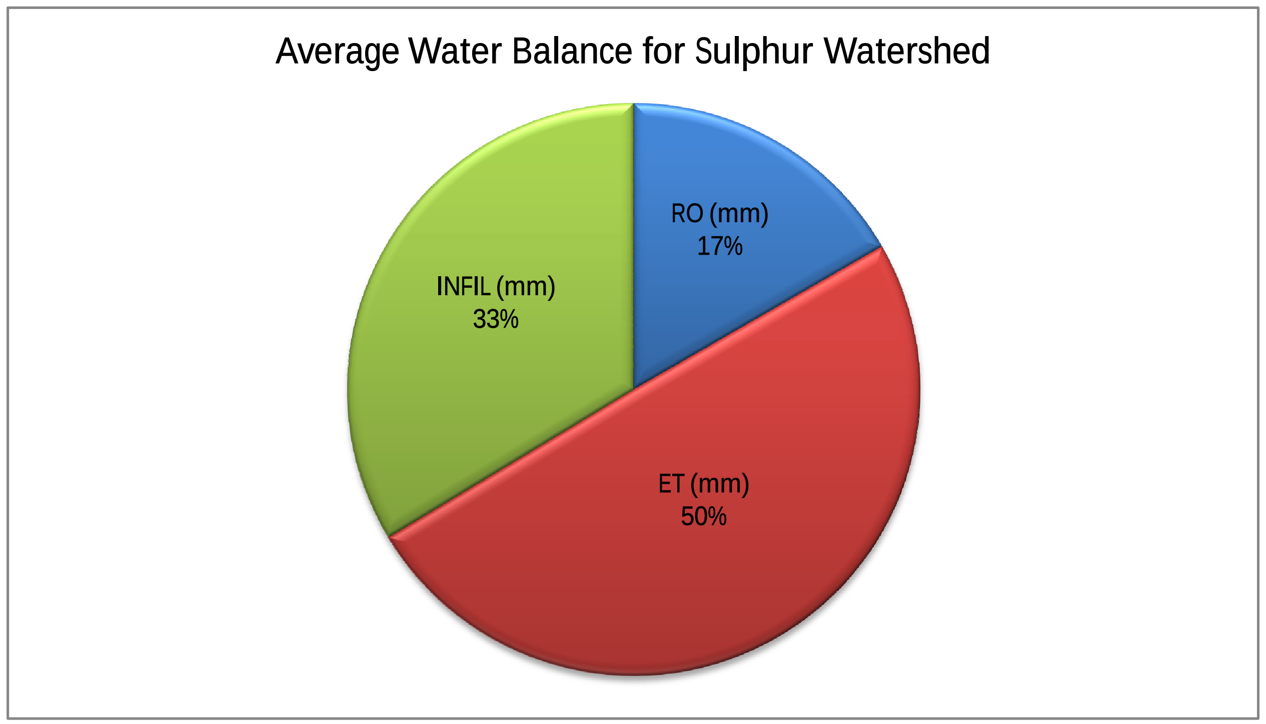
- Rainfall (Supply) = 645mm
- Runoff (RO) = 83mm (13%)
- Evapotranspiration (ET) =338mm (54%)
- Infiltration (Infil) = 205 (33%)

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 4.7 - Water Balance and Land Use Composition (Sulphur Creek Watershed)

Predevelopment Conditions

Sulphur Creek Watershed – Water Balance					
Sub-Catchment	**S-5**	**S-6**	**S-7**	**S-8**	**AVERAGE**
Area (ha)	82	99	26	148	
SUPPLY (mm)	646	645	644	643	645
RO (mm)	21	29	257	108	103
ET (mm)	338	337	241	318	308
INFIL (mm)	254	249	132	200	209



Land Use	Land Use Composition (ha) Sulphur Creek Watershed
Residential	26.2
Commercial	20.3
Institutional	12.7
Utility/Open Space	29.4
Woodlot	27.9
Highway	12.2
Row Crop/Pasture	226.2

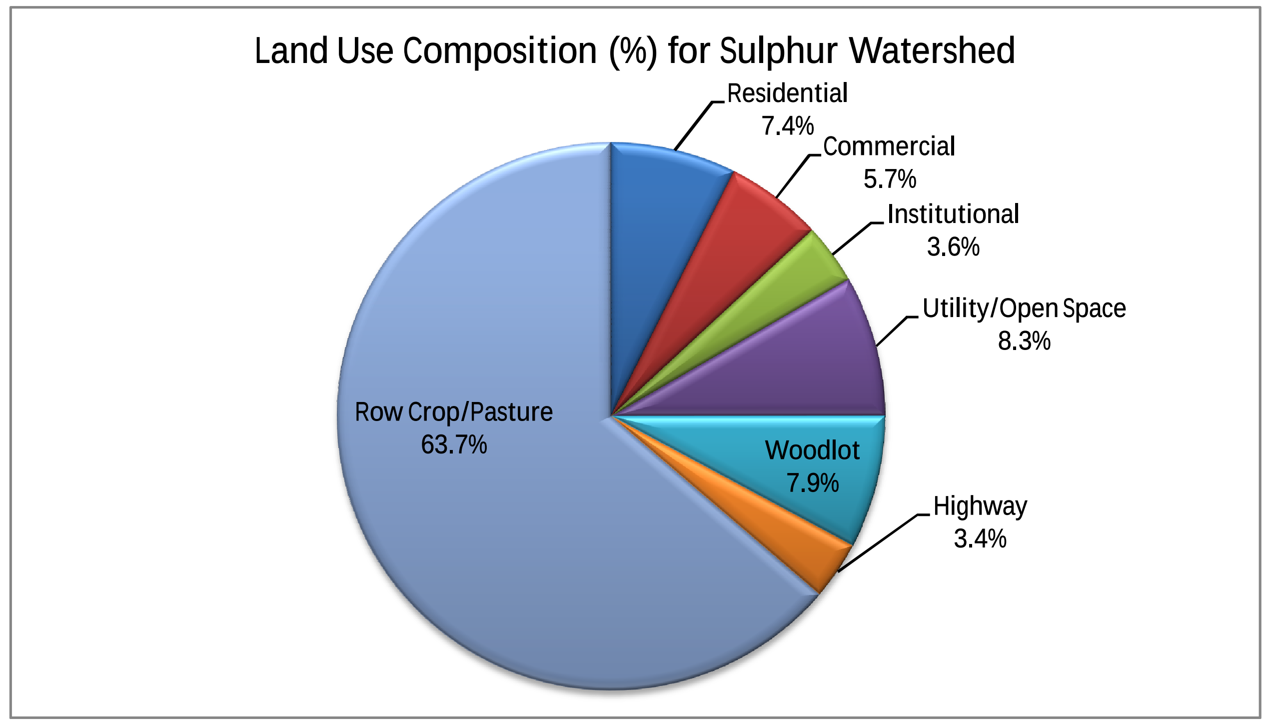
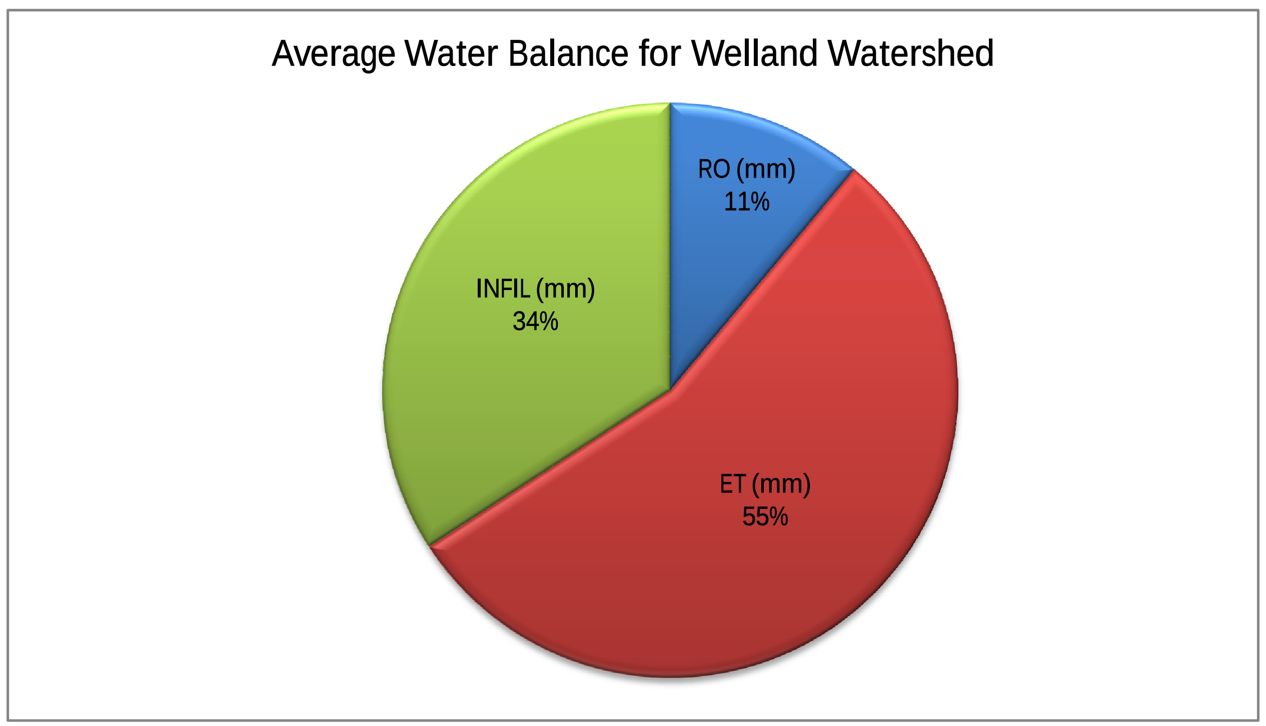


Figure 4.8 - Water Balance and Land Use Composition (Welland Creek Watershed)

Predevelopment Conditions

Welland Creek Watershed – Water Balance											
Sub-Catchment	W-14	W-15	W-16	W-17	W-18	W-19	W-20	W-21	W-22	W-24	AVERAGE
Area (ha)	106	215	87	394	61	90	101	132	110	61	
SUPPLY (mm)	646	645	645	645	646	646	646	646	646	644	645
RO (mm)	24	40	50	92	71	63	75	75	88	114	69
ET (mm)	353	349	347	336	353	345	345	340	332	323	342
INFIL (mm)	241	232	225	200	205	216	207	211	206	192	213

Land Use	Land Use Composition (ha) Welland Creek Watershed
Residential	52.0
Commercial	5.5
Institutional	3.6
Airport Land	287.7
Woodlot	223.0
Highway	58.4
Row Crop/Pasture	725.9



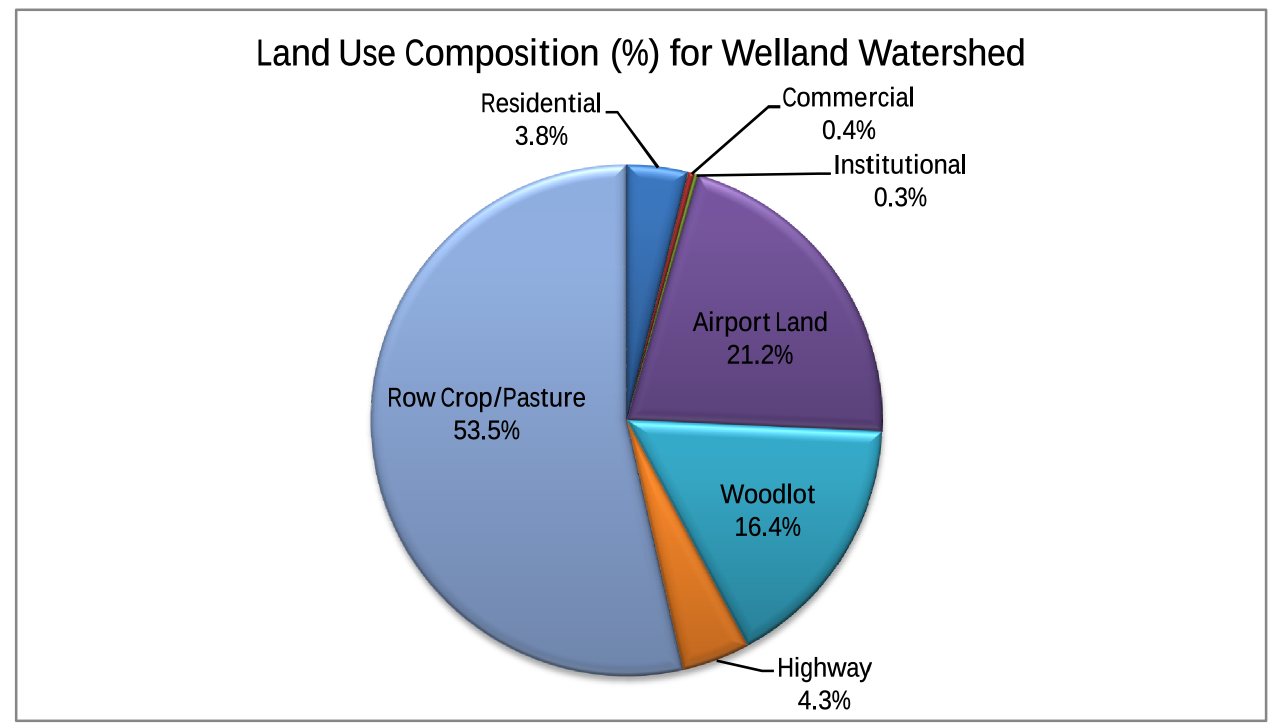
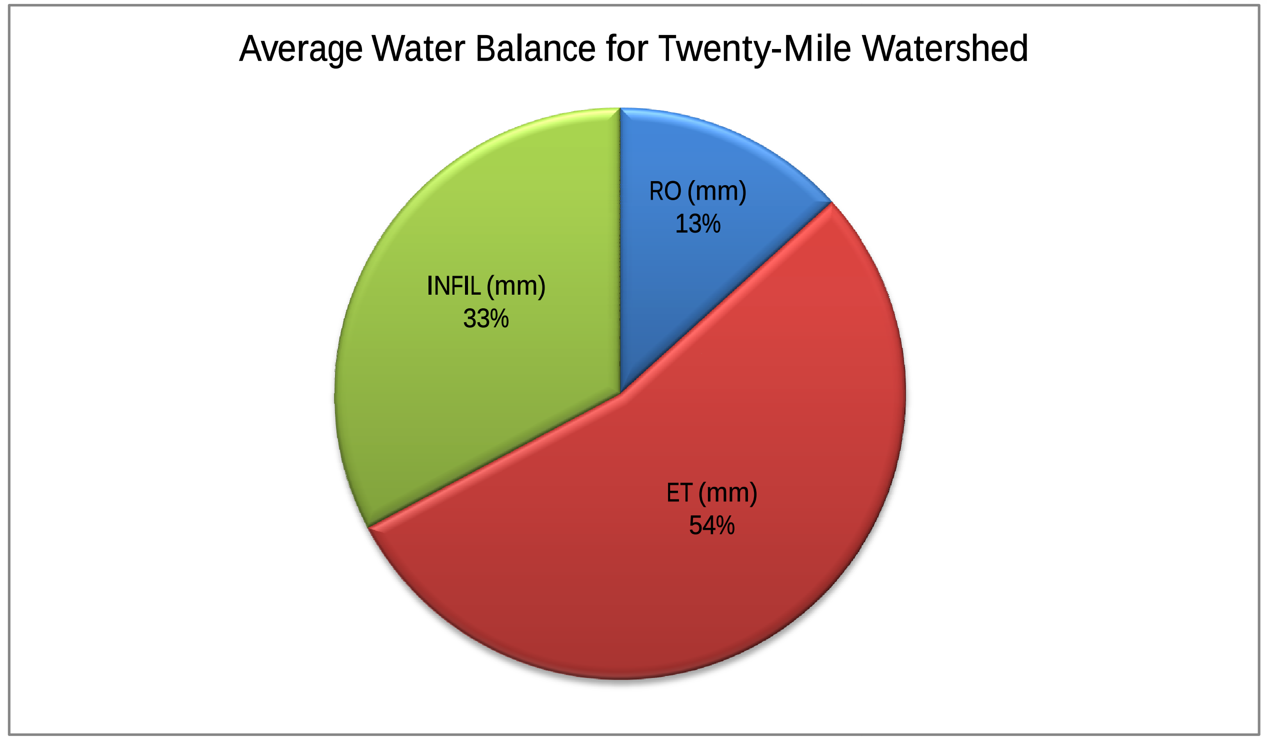


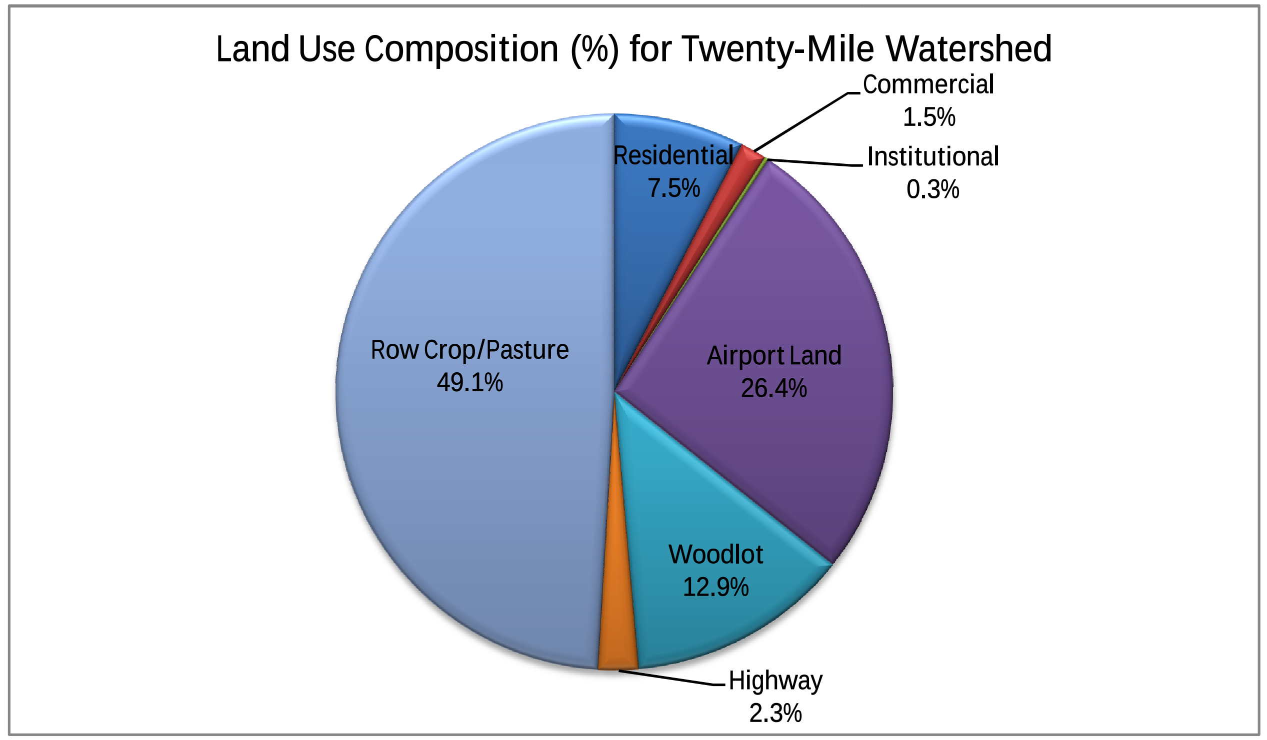
Figure 4.9 - Water Balance and Land Use Composition (Twenty Mile Creek Watershed)

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



4.1.5.3 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.

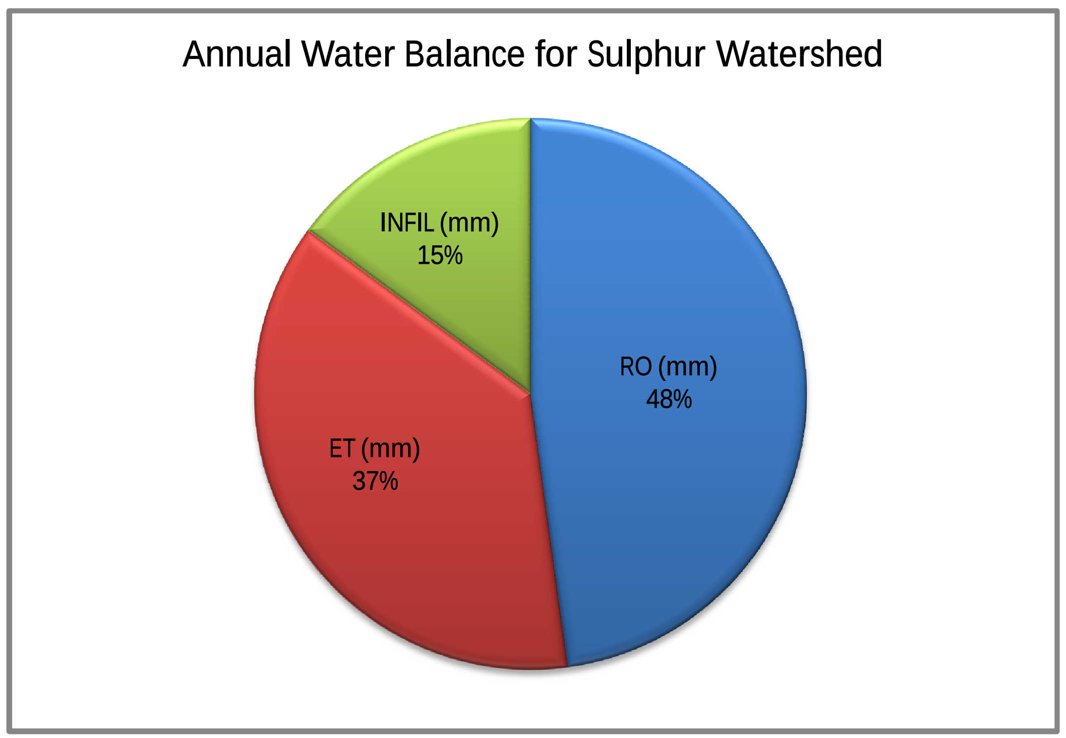
Due to reduced moisture retention there is less evaporation/evapotranspiration from impervious areas than from pervious areas. For all three watersheds the evapotranspiration drops from the existing to the proposed conditions generally from approximately 50% of the rainfall to 40% of the rainfall. Due 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 4.10 - Water Balance and Land Use Composition (Sulphur Creek Watershed)

Post Development Conditions (uncontrolled)

Sulphur Creek Watershed – Water Balance					
Sub-Catchment	**S-5**	**S-6**	**S-7**	**S-8**	**AVERAGE**
Area (ha)	82	106	26	148	
SUPPLY (mm)	641	641	641	642	641
RO (mm)	277	310	346	292	306
ET (mm)	257	235	219	244	239
INFIL (mm)	106	95	77	103	95

Land Use	Land Use Composition (ha) Sulphur Creek Watershed
Residential	7.1
Commercial	0.0
Airport Lands	0.0
Woodlot	31.9
Utility/Open Space	28.7
Highway	17.1
Row Crop/Pasture	10.5
Prestige Industrial	48.80
Eco Prestige Industrial	217.90



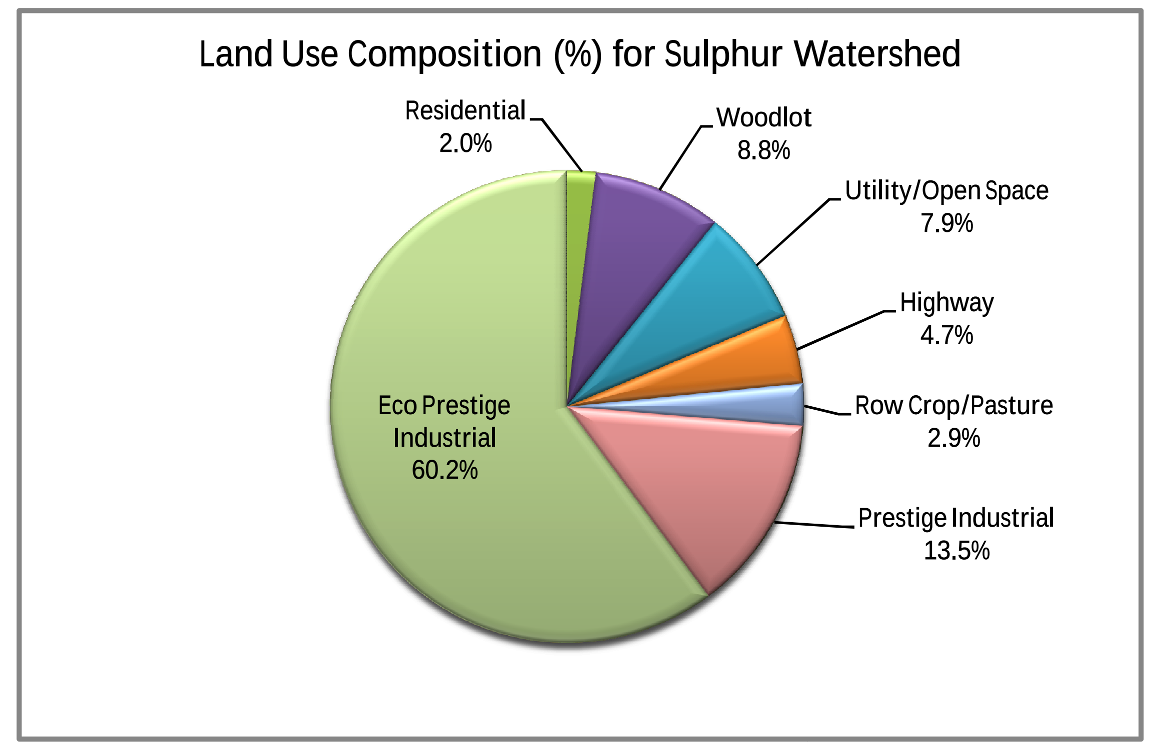
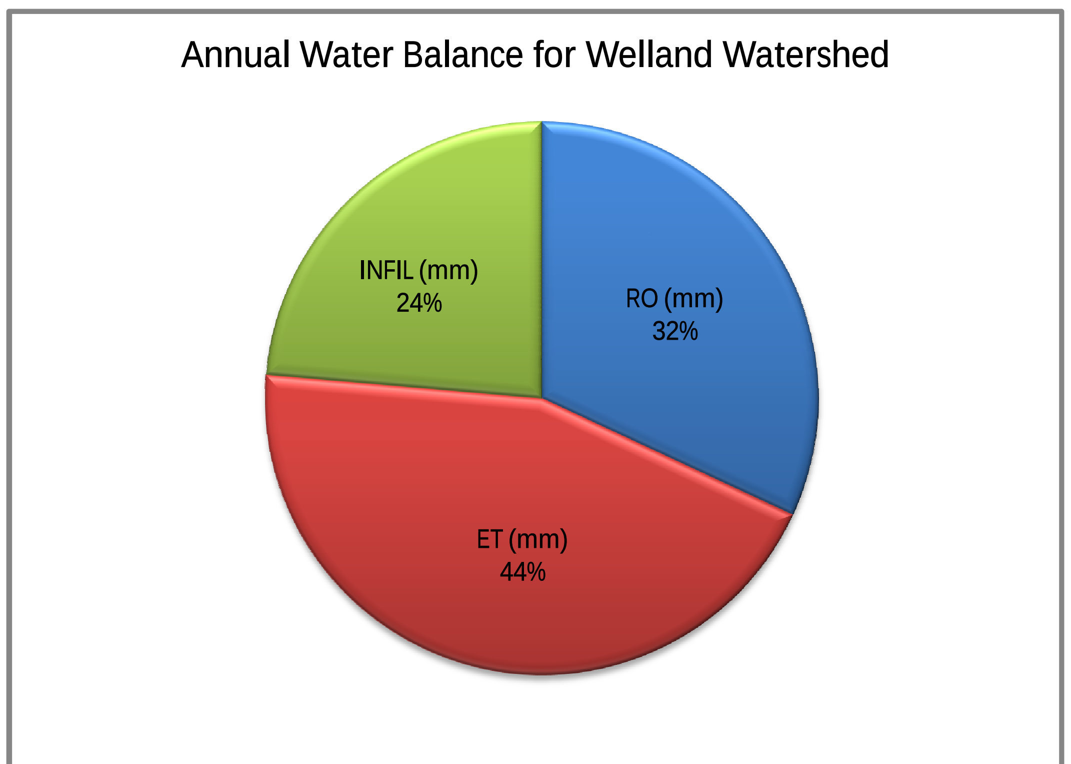


Figure 4.11 - Water Balance and Land Use Composition (Welland Creek Watershed)

Post Development Conditions (uncontrolled)

Welland Creek Watershed – Water Balance											
Sub-Catchment	W-14	W-15	W-16	W-17	W-18	W-19	W-20	W-21	W-22	W-24	AVERAGE
Area (ha)	106	215	87	394	61	90	101	132	110	61	
SUPPLY (mm)	643	642	644	640	641	643	640	642	640	642	642
RO (mm)	185	207	203	246	141	280	165	185	236	174	202
ET (mm)	280	278	275	266	313	247	304	292	273	289	282
INFIL (mm)	164	148	152	125	178	110	166	157	129	168	150

Land Use	Land Use Composition (ha) Welland Creek Watershed
Residential	14.3
Commercial	0.0
Airport Lands	326.6
Woodlot	220.8
Highway	80.4
Row Crop/Pasture	289.2
Prestige Industrial	142.50
Eco Prestige Industrial	281.80



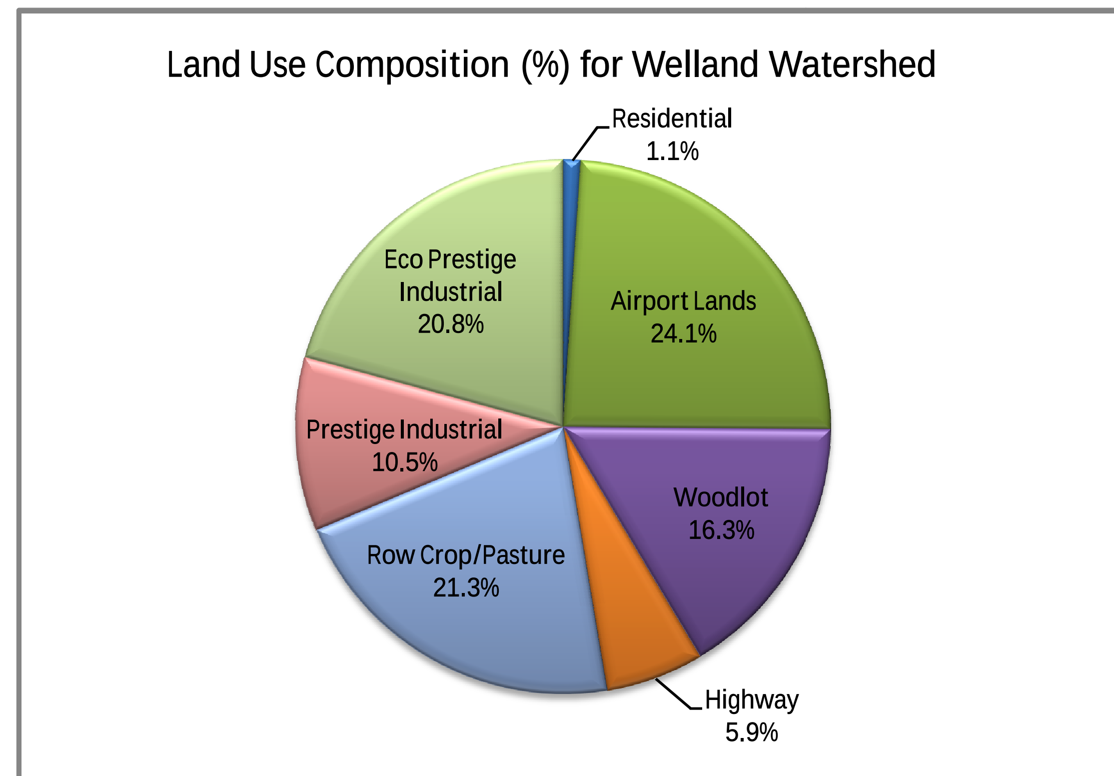
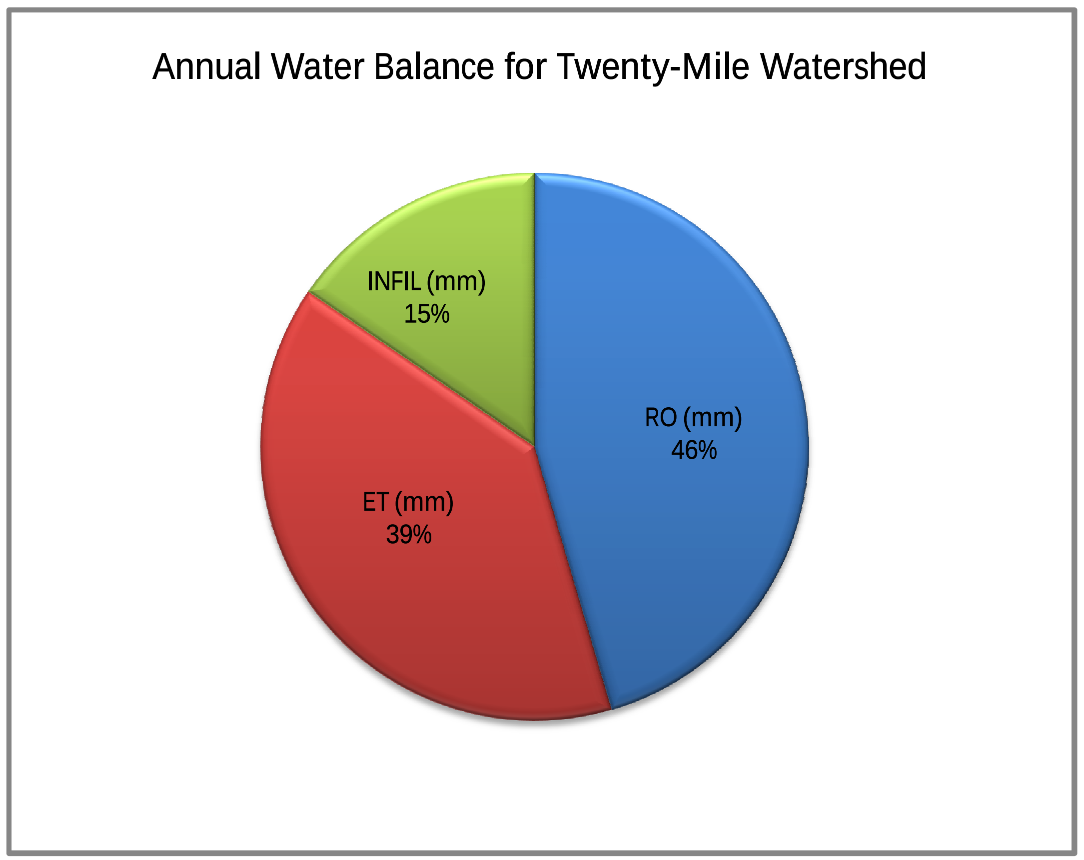


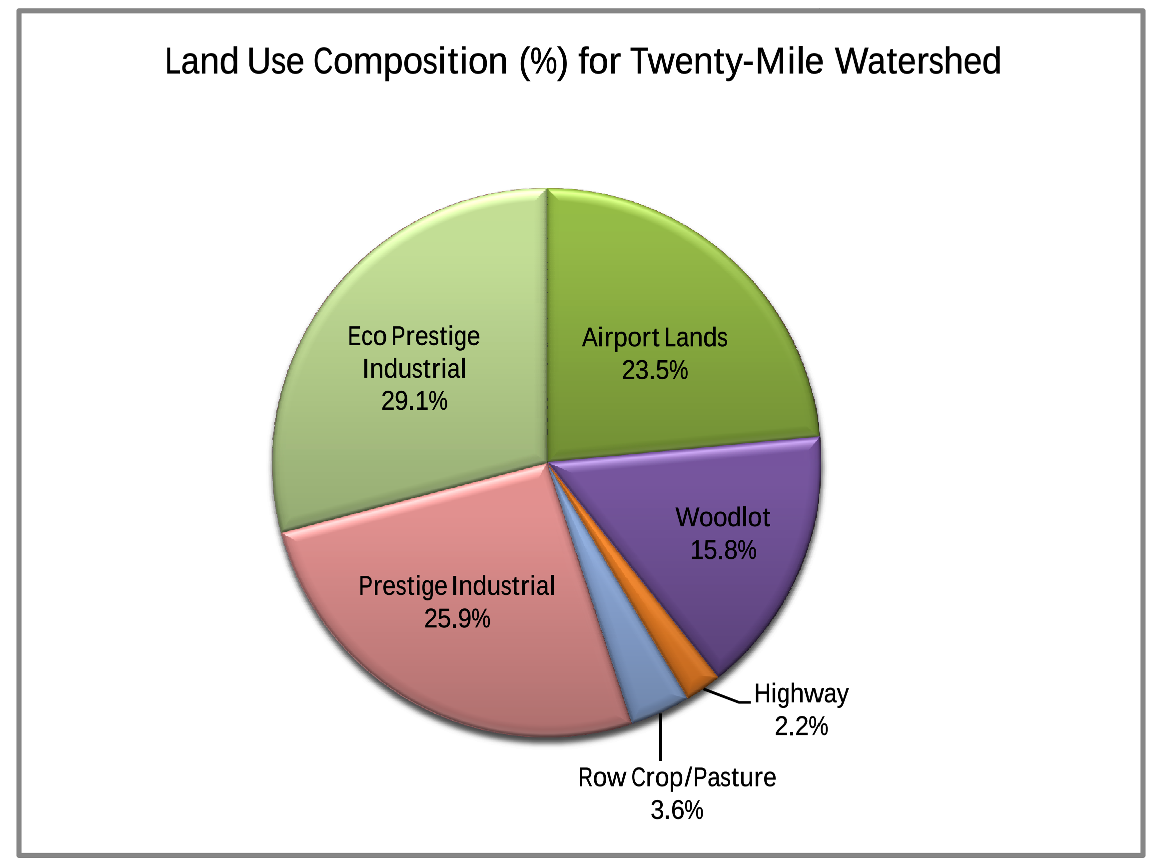
Figure 4.12 - Water Balance and Land Use Composition (Twenty Mile Creek Watershed)

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



4.1.5.4 Proposed Conditions with LID Capture Annual Water Budget

Applying the infiltration targets identified in **Table 4.10**: LID Capture Target (m^3/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 (m^3/ 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

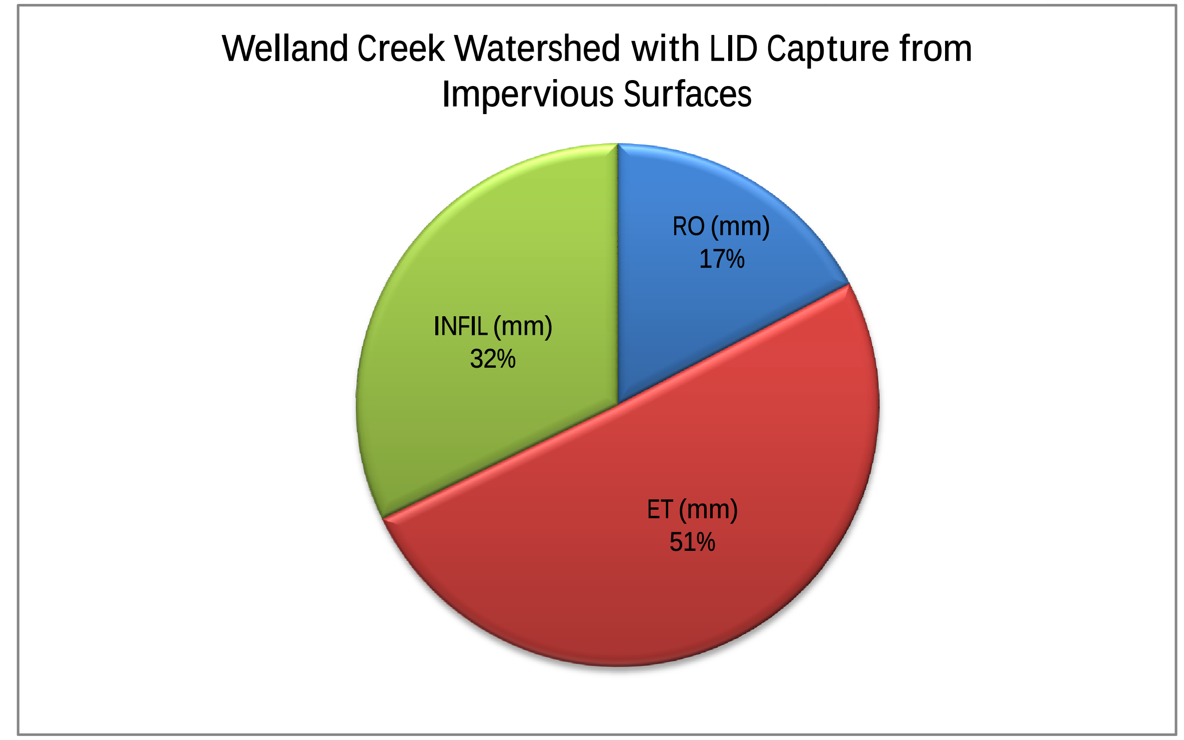
Welland River Watershed	
Post with LID capture	Pre Development
Rainfall (Supply) = 642mm Runoff (RO) = 110mm (18%) Evapotranspiration (ET) =320mm (50%) Infiltration (Infil) = 204 (32%)	Rainfall (Supply) = 645mm Runoff (RO) = 69mm (11%) Evapotranspiration (ET) =342mm (55%) Infiltration (Infil) = 213 (34%)
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%)

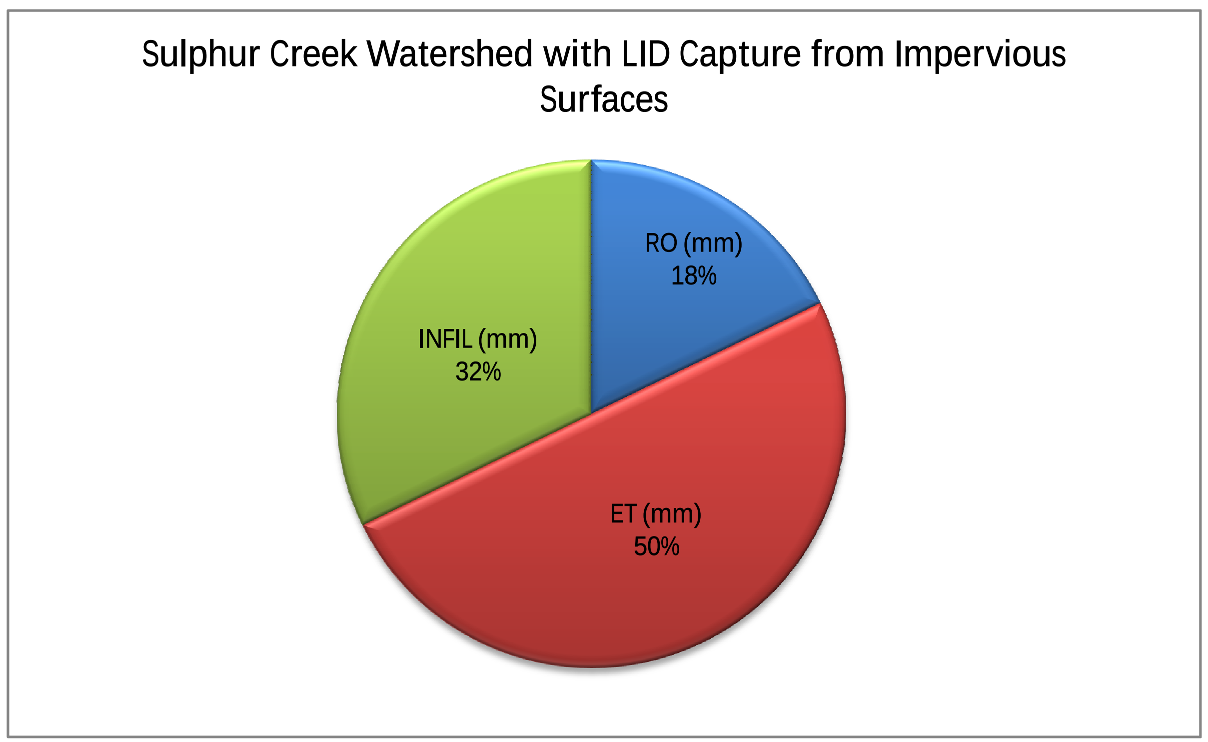
Watershed	Area (ha)	Overall Watershed Capture Volume	Overall Watershed Capture Imp Area	Hydrologic Soil Class				Watershed Imperviousness			Average Imperviousness of proposed land uses
		mm	m^3 / ha	A	B	C	D	Ex (%)	Fut (%)	% Δ	
*For the catchments located within the study area (as illustrated in **Figure 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*

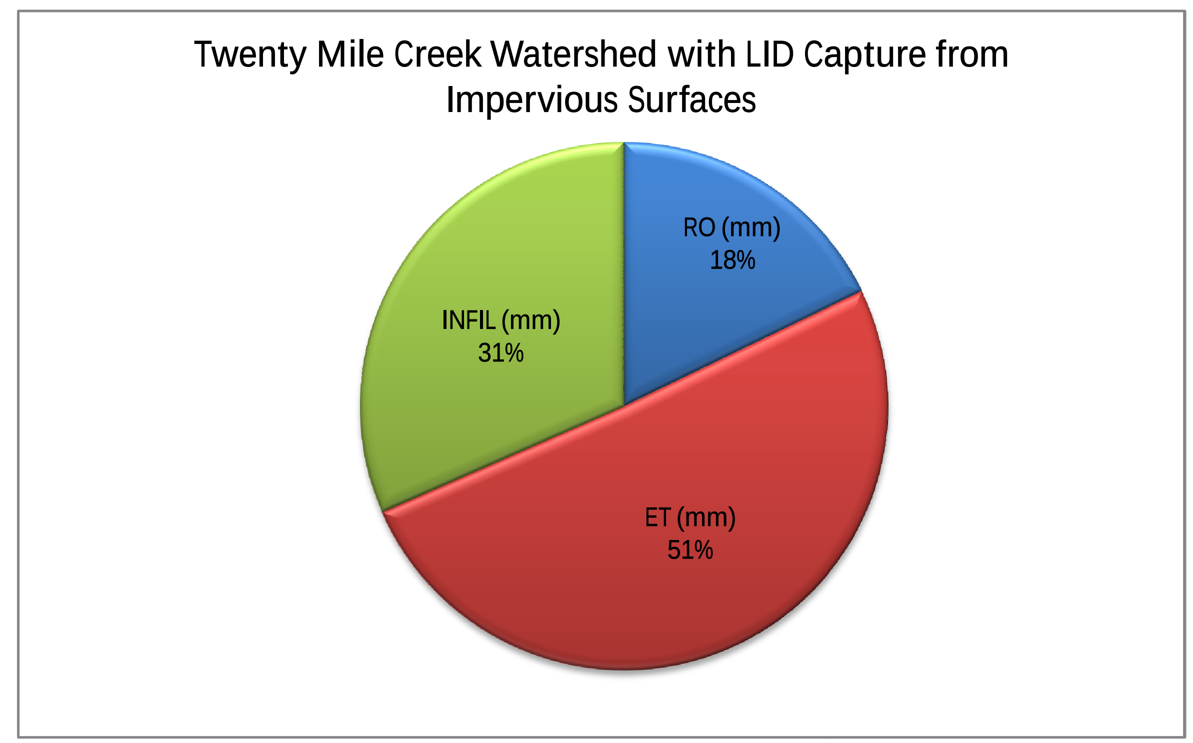
Figure 4.13 - Water Balance (Sulphur Creek, Welland Creek, & Twenty Mile Creek Watershed)

Post Development Conditions with LID Capture

Parameter	Sulphur Creek	Welland Creek	Twenty Mile Creek
Rainfall (SUPPLY) (mm)	641	642	641
Runoff (RO) (mm)	114	118	114
Evapotranspiration (ET) (mm)	320	320	324
Infiltration (INFIL) (mm)	206	204	202







4.1.5.5 Summary of Stormwater Management Objectives determined through Hydrologic Modeling

Hydrologic modeling has been completed to demonstrate the infiltration capture targets (m^3/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.

4.1.6 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.

4.1.6.1 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

4.1.6.2 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

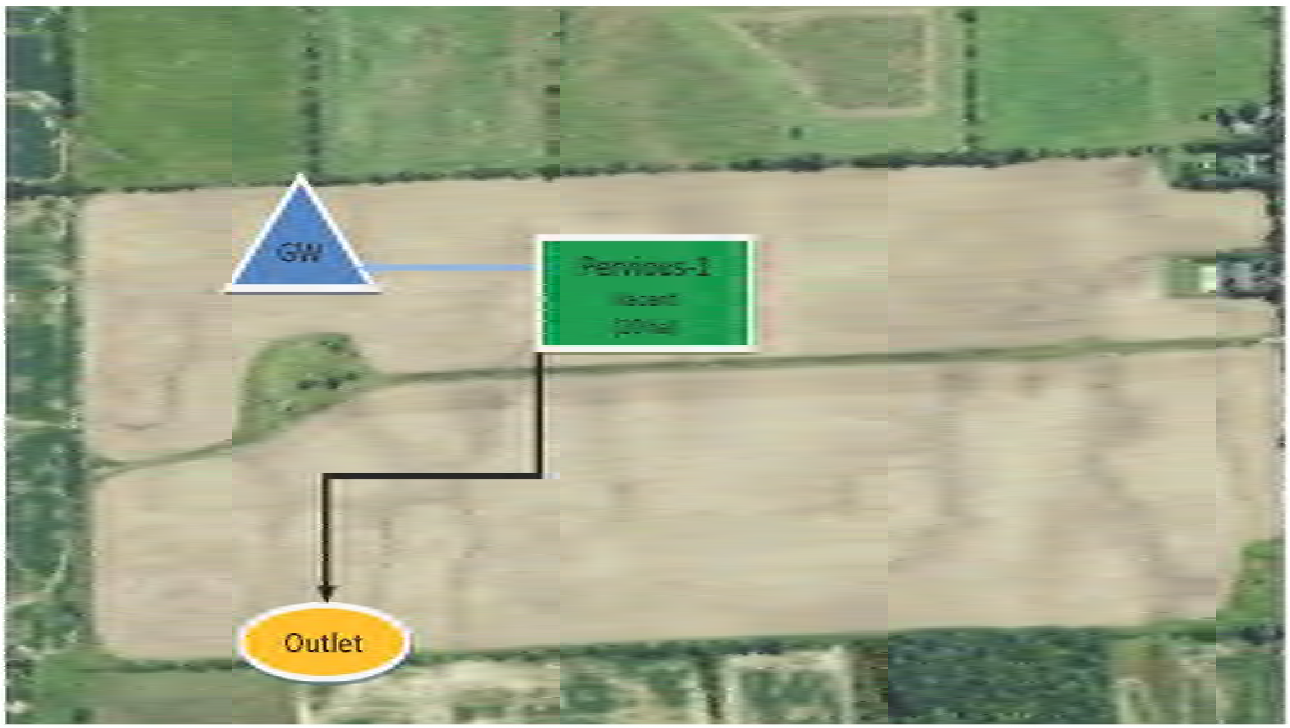


Figure 4.14: Site Plan Test Case - Post Development Conventional SWM

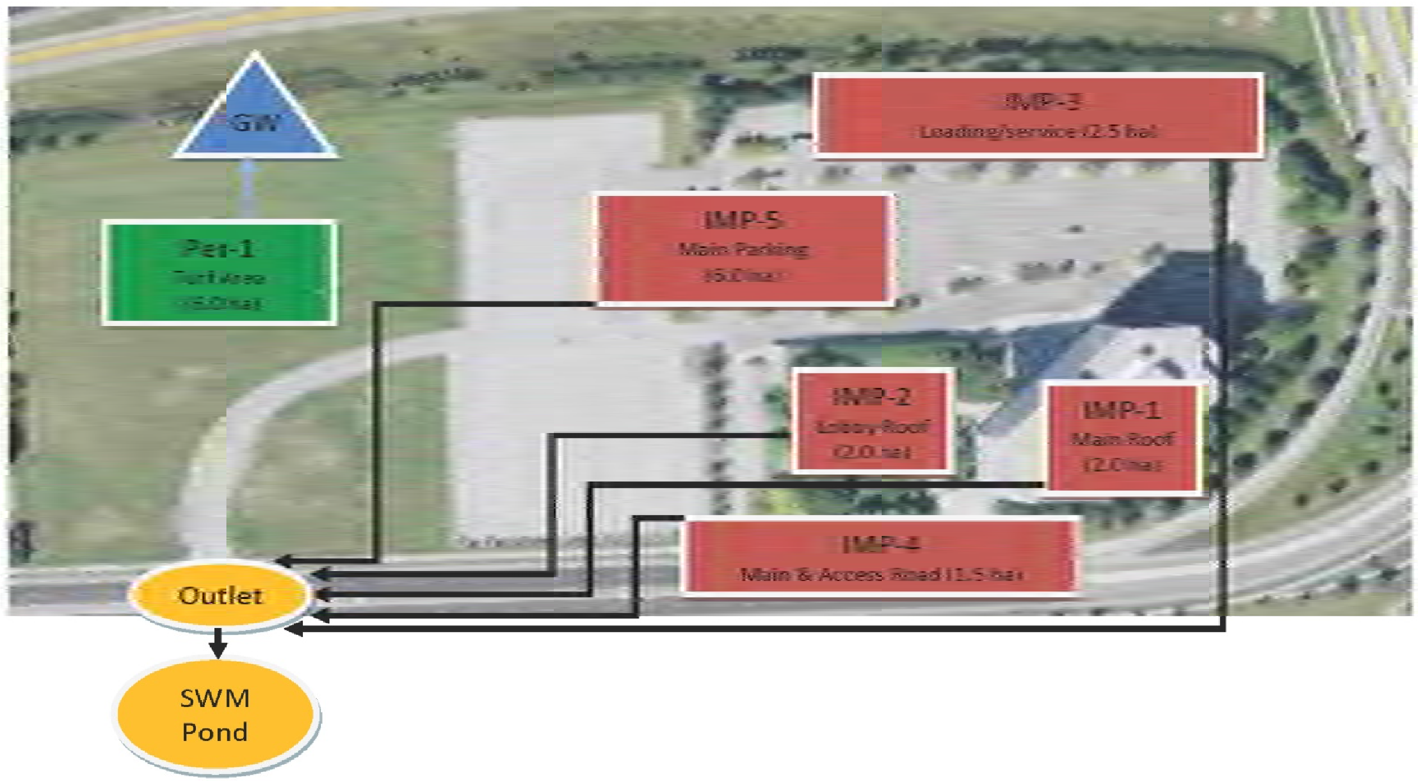
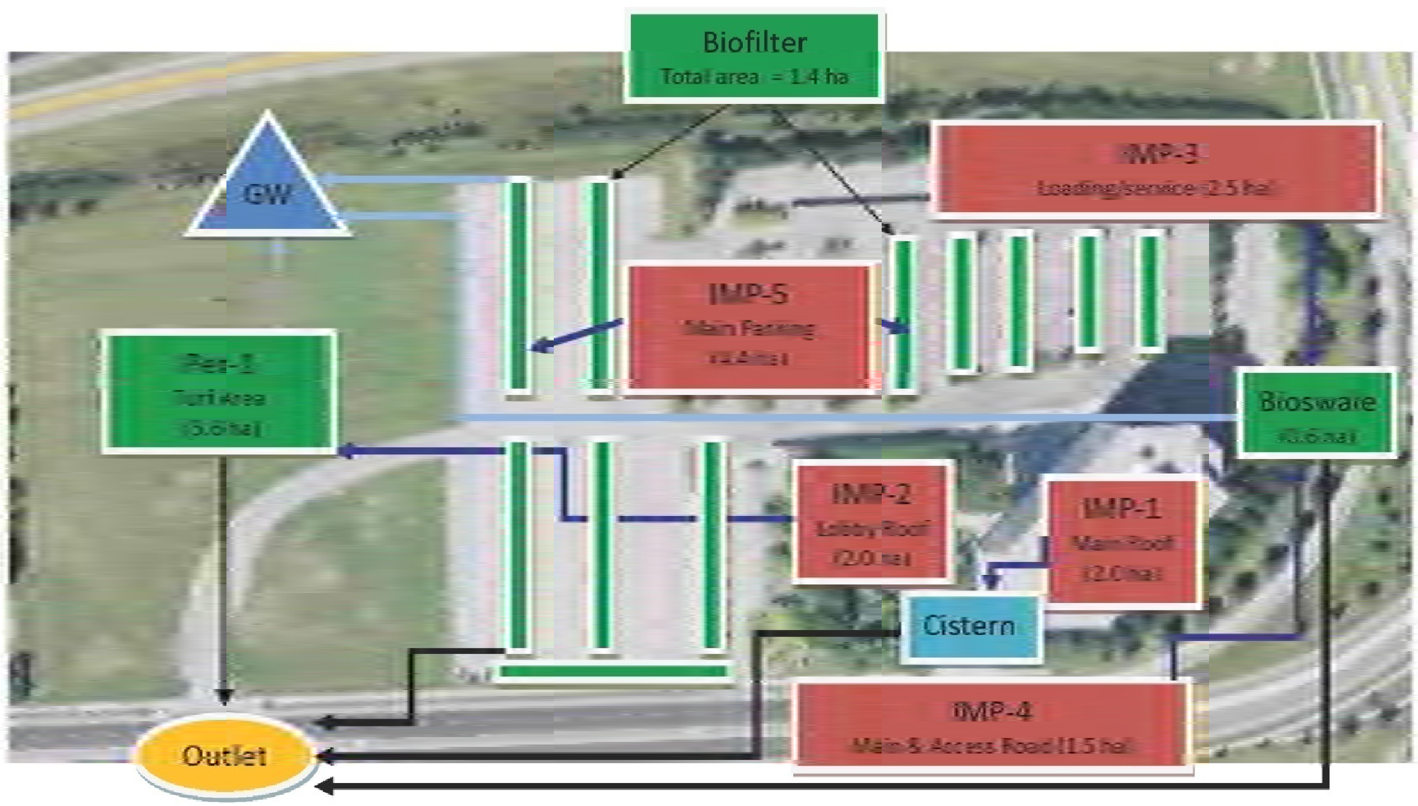


Figure 4.15: Site Plan Test Case - Post Development with UD



4.1.6.3 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.

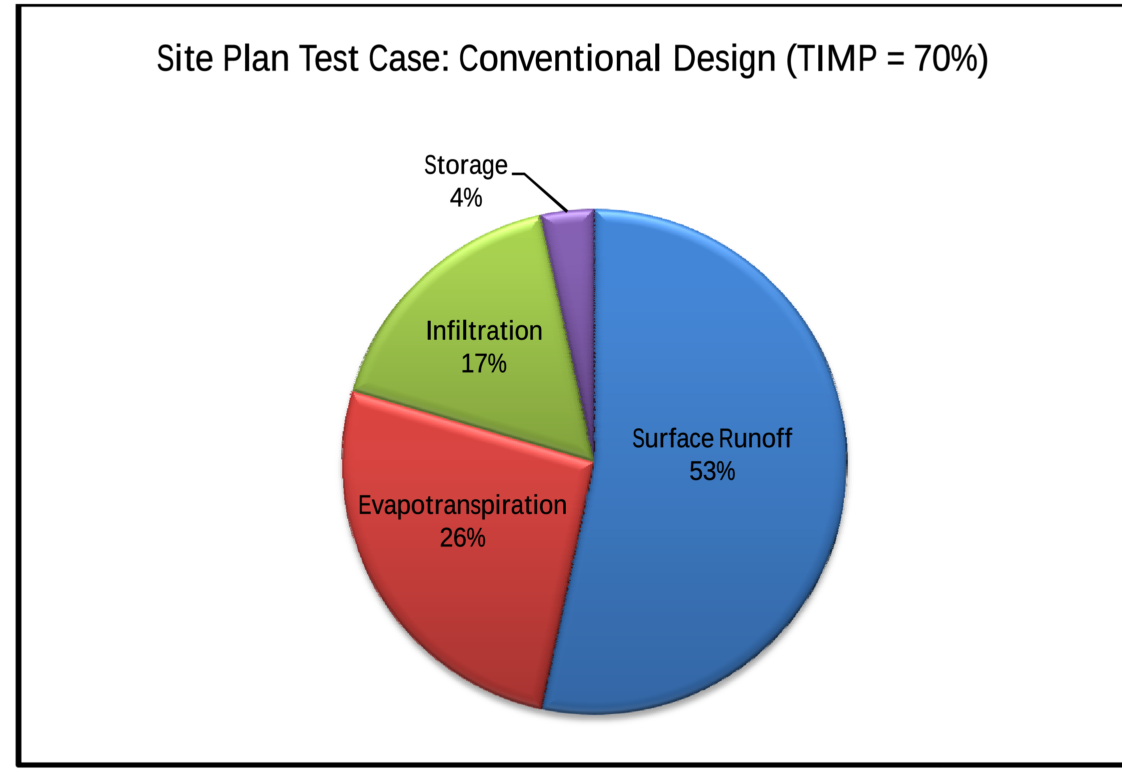
The results as presented above represent only one singular site plan example whereby specific LID techniques have been applied in an attempt to match the pre-development water balance. The implications of the results in are presented below:

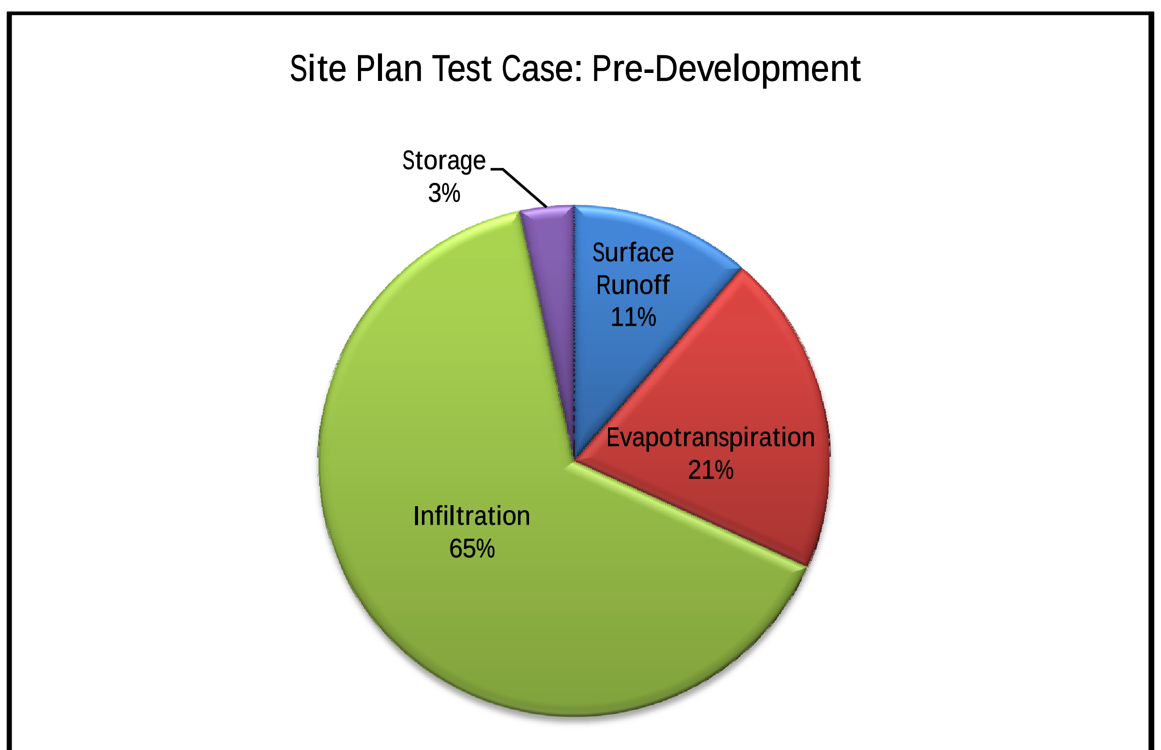
- A small increase in the percentage of total site area dedicated to LID techniques could be implemented to restore the pre-development infiltration on this site or alternatively the individual selection of the LID techniques could be modified to include techniques that more directly influence infiltration. 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.

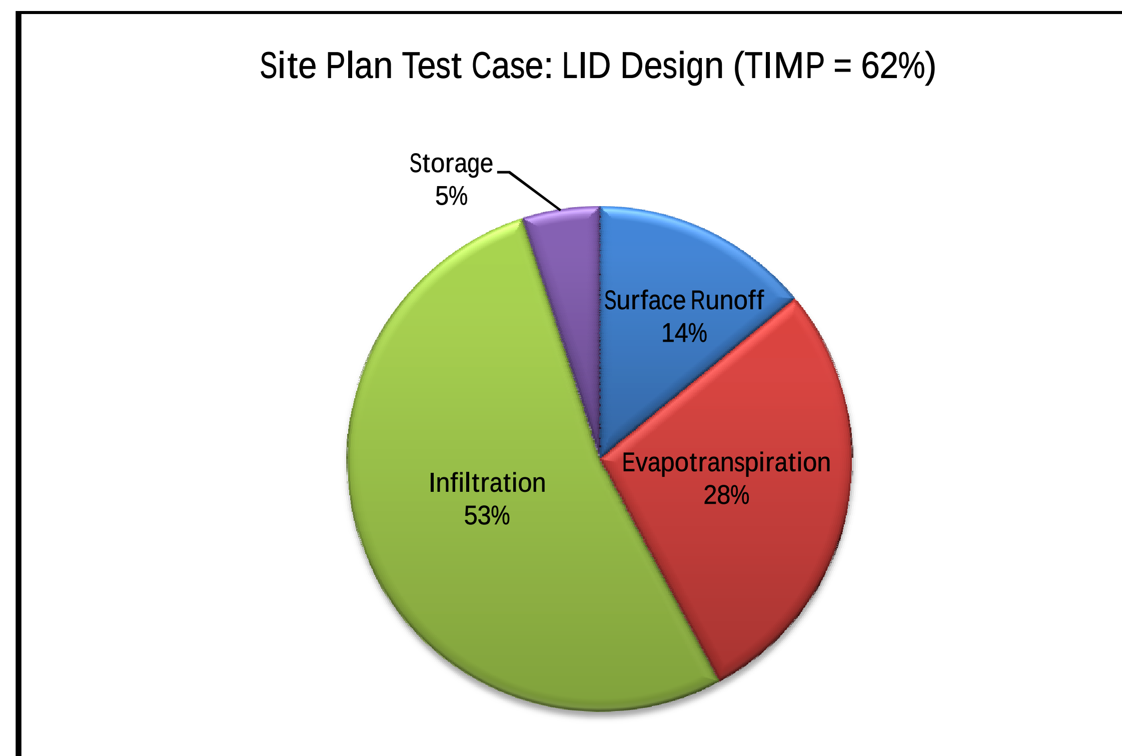
- This site plan was intentionally designed to incorporate rainwater harvesting as it is expected that many designers will adopt this practice in recognition of the Eco-Industrial design approaches which form the foundation of the treatment train approach (LID source and conveyance controls) proposed 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			
Variable	Pre-Development	Conventional Design (TIMP = 70%)	LID Design (TIMP = 62%)
Precipitation	675	675	675
Surface Runoff	77	360	94
Evapotranspiration	138	177	188
Infiltration	438	115	354
Storage	23	23	33
Error	0	0	7







4.1.6.4 Site Plan Results: Events based Results (25mm 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).

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.

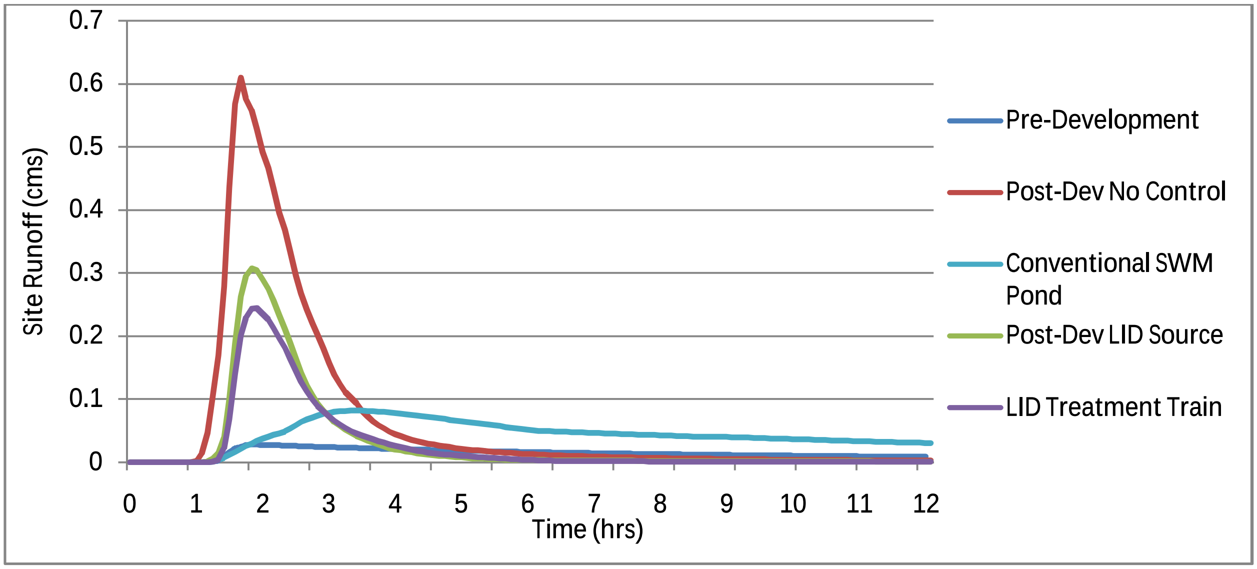


Figure 4.17: Runoff Characteristics of a 25 mm 6hr Event for a 20ha Site Plan Test Case

4.1.6.5 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**).

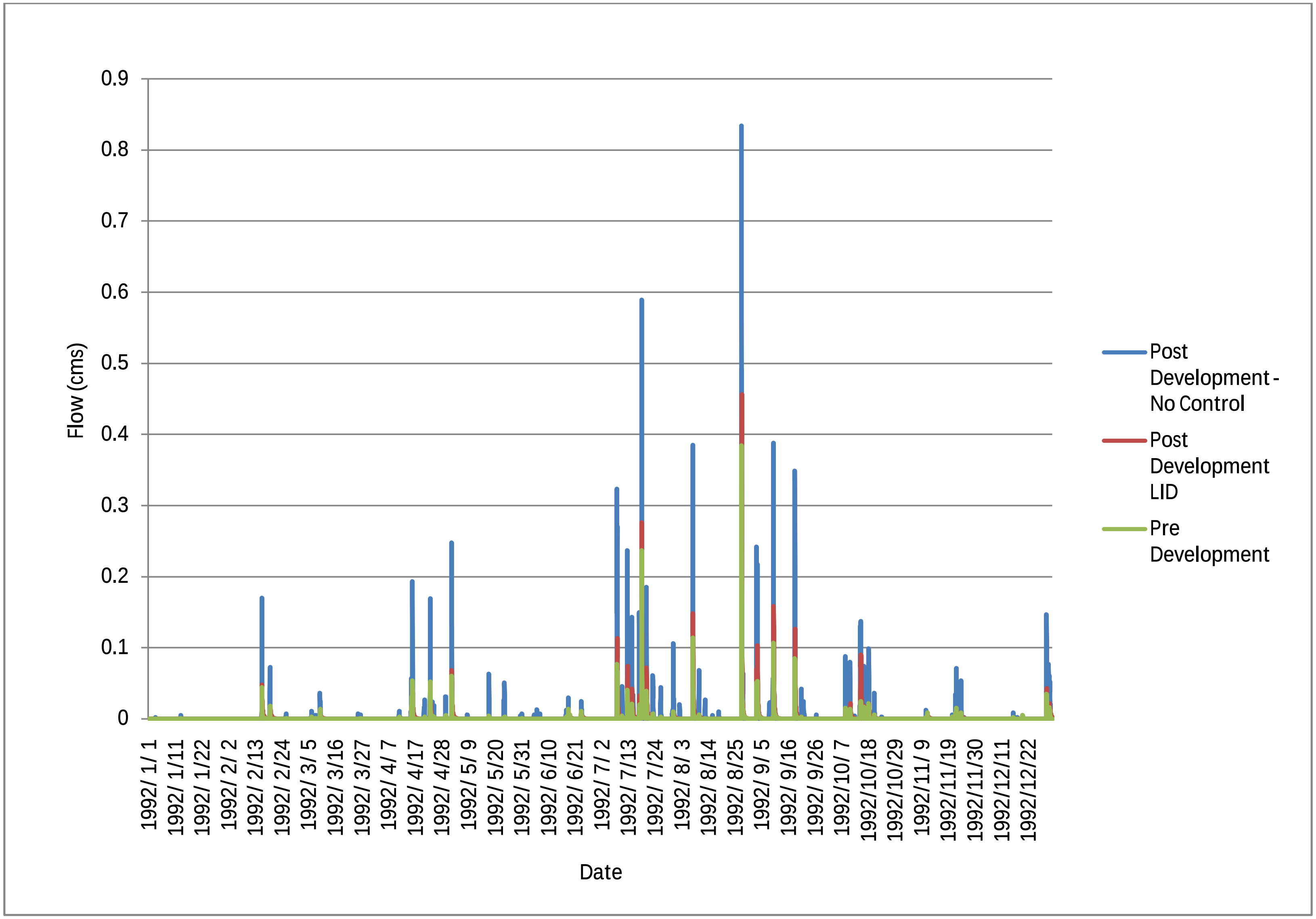


Figure 4.18: Site Plan Test Case – Continuous Modeling results for 1992

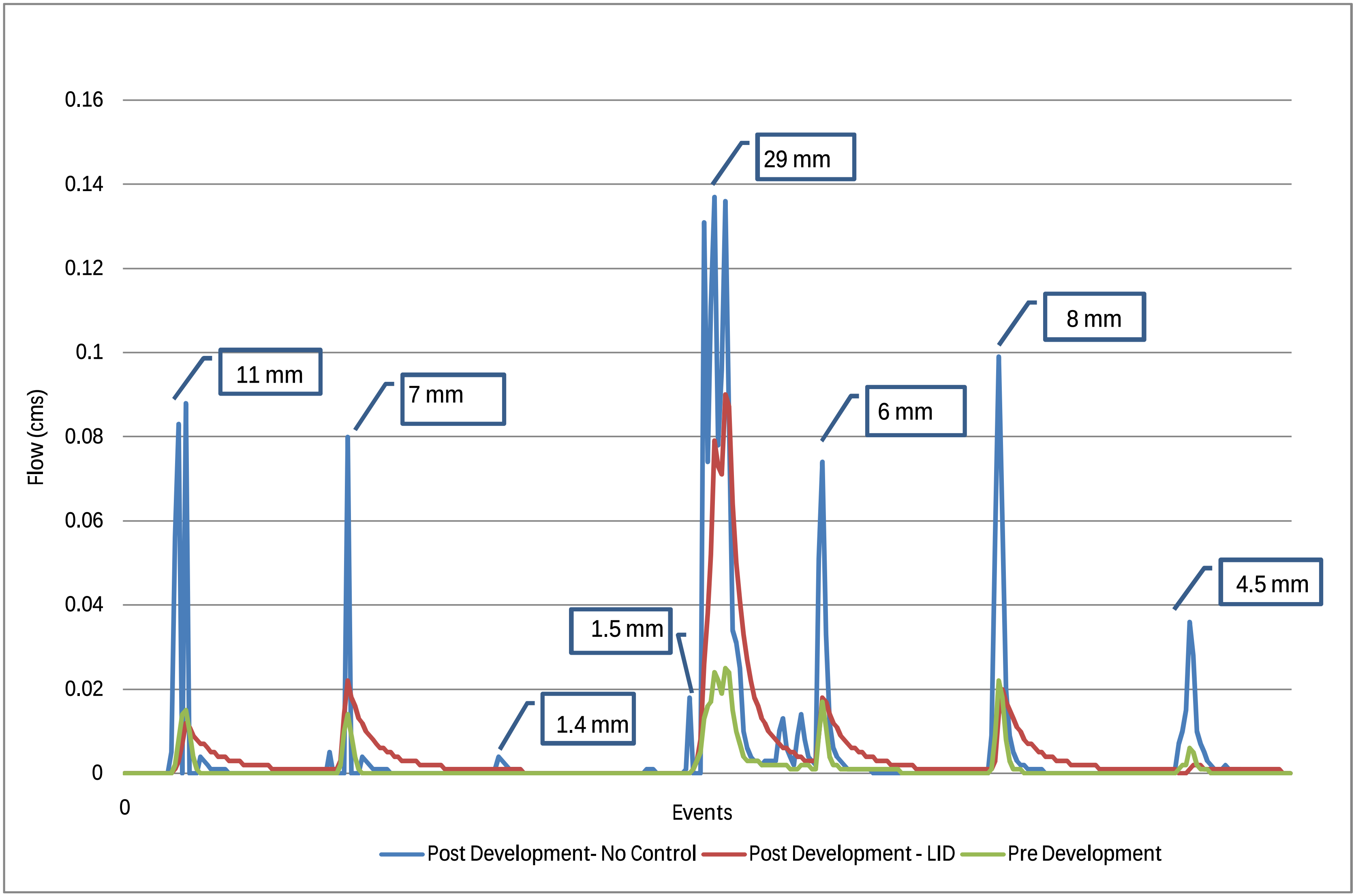


Figure 4.19: Site Plan Test Case – Continuous Modeling results for Various Rainfall Events (Oct 8 – Oct 21, 1992)

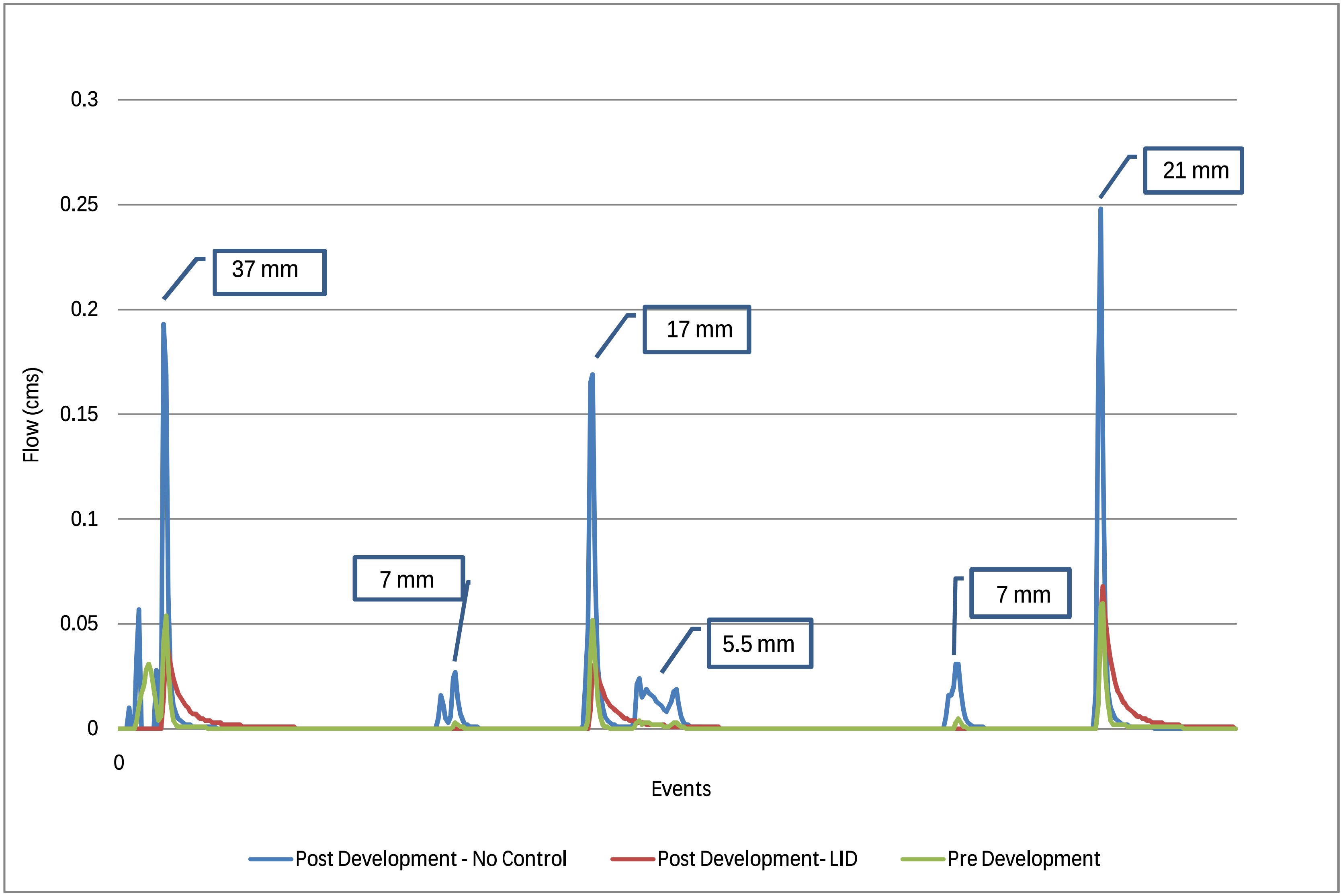


Figure 4.20: Site Plan Test Case – Continuous Modeling results for Various Rainfall Events (April 16 – May 4, 1992)

4.1.7 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. 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 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.

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.

4.1.7.1 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)

4.1.7.2 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 m^3/s) and 5.5km (0.95 m^3/s) of 2 lane local road.

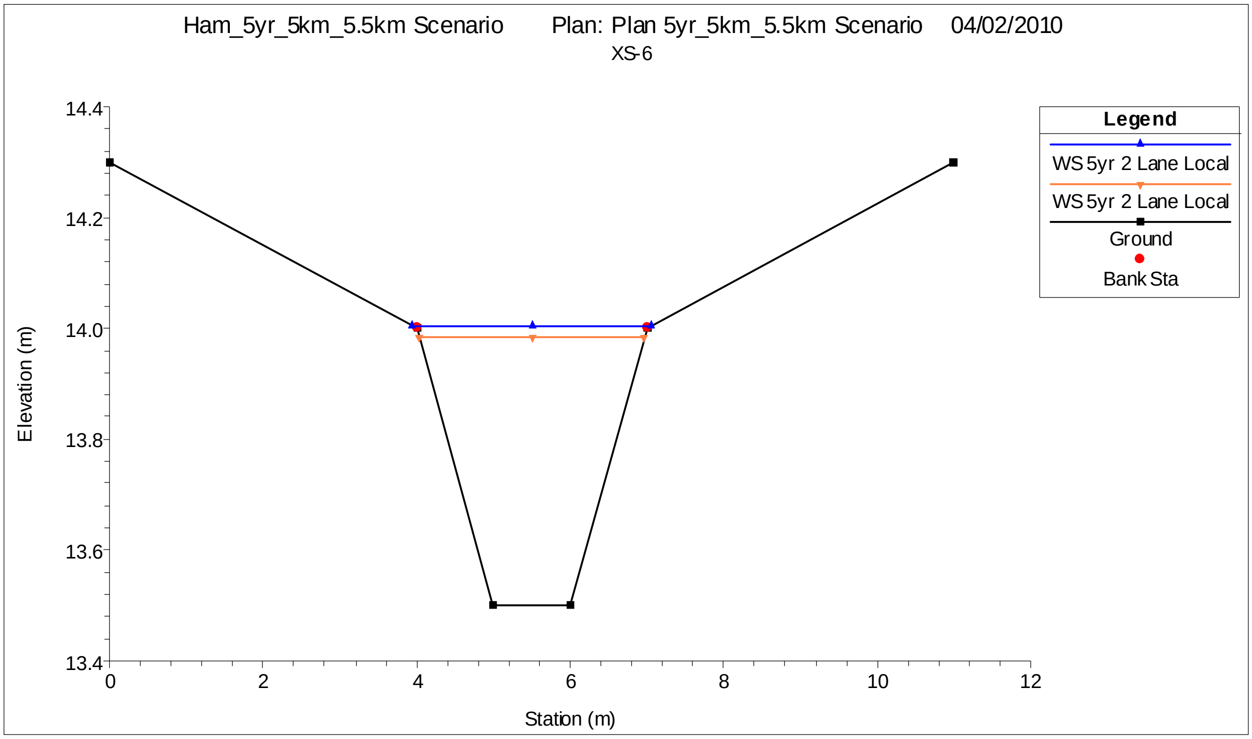


Figure 4.20 – Surface water elevation of the various runoff flow accumulation from 5km and 5.5km of 2 lane local road.

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).

4.1.7.3 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.

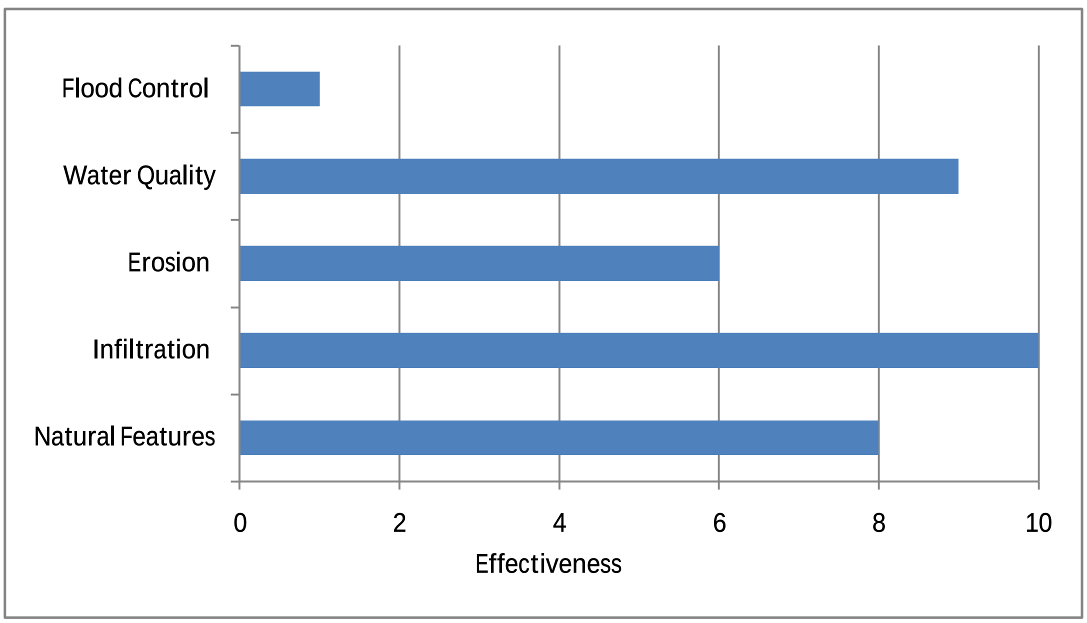


Figure 5.0: General Effectiveness of LID Techniques in Relation to Water Balance Design Criteria

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

<u>Magnitude</u>

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.

<u>Duration</u>

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.

<u>Frequency</u>

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.			

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 <u>Minimum</u> 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)

In preparing this section the following documents were reviewed:

- MOE Stormwater Management Planning and Design Manual (2003);
- Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC - 2010).
- City of Hamilton Landscape and Design Guidelines for Stormwater Facilities (October, 2008); and
- City of Hamilton, Criteria and Guidelines for Stormwater Infrastructure Design (2007);

5.2.1 Construction Costs

This section provides detailed information regarding the portion of the Development Charges relating to stormwater management within the AEGD study area for Secondary Plan Area-Phase 1 and 2 development lands. As per the 2009 City of Hamilton Development Charges Update, all components of drainage works that require development funding have been considered and included in the following assessment, with storm drainage infrastructure classified into three major groups (open watercourses, storm sewers and stormwater management facilities) and 5 categories (A-E) as follows:

- A – Open Watercourses: Erosion Control and Channel System Improvements
- B – Open Watercourses: Erosion Control – Anticipated future works
- C – Stormwater Management (Quality and/or Quantity Facilities)
- D – Over sizing of Trunk Sewers
- E – Culverts and Bridges: Anticipated Future Works

It is important to note that LID Source Controls and Conveyance Controls will be developer funded and as such as are not included in the DC cost estimates. General estimates of LID source and conveyance controls costs are provided in subsequent sections for reference.

5.2.1.1 DC Cost Estimate Summary

The following section summarizes the cost associated with the 5 categories of storm drainage infrastructure as per the AEGD Stormwater Management Master Plan. **Table 5.1** provides a summary of the associated costs of the AEGD Stormwater Management Master Plan for the 5 categories of storm drainage infrastructure.

Table 5.1: Summary of the associated costs for the 5 categories of storm drainage infrastructure as per the AEGD Stormwater Management Master Plan.

Category	**Comment**	**Cost ($)**
A	No identified erosion control and/or channel systems improvements	$ 0
B	On-site erosion control is included in Cat C SWM Quantity control. • Costs conservatively reflect the high potential for 250m of stream restoration/ outlet modification associated with the construction of each dry-pond quantity control facility	$ 2,625,000 (Included in Category C costs)
C	Quantity control costs reflect dry pond costs within Secondary Plan Area- Phase 1 and 2. See Stormwater Master Plan Figure for facility locations. • Table 4.10 Provide full costing details.	Phase 1- $ 16,304,000 Phase 2- $ 29,559,000 (includes Category B costs)
D	No trunk sewers in access of 1200mm in diameter are identified at this level of investigation as internal road network configuration is unknown and should be investigated at the site plan stage for possible oversized trunk sewer requirements.	$ 0
E	Costs are included in Transportation Master Plan cost estimates. Costs have been intentionally omitted from the storm drainage costing to avoid double counting.	$ 0 (See Transportation Master Plan for bridge and culvert cost estimates)
Total Cost		**$ 45,865,000**

Table 5.2 below provides full costing details for Category B and C.

Table 5.2: Detailed Stormwater Infrastructure costs- Category B (Erosion Control –onsite) and C (Quantity Control) for the AEGD Stormwater Master Plan

Stage	Phase	Pond Location	Drainage Area	Quantity Control Target	Estimated Storage Volume	Assumed Max. Depth	Estimated Facility Footprint	Land Cost (@$815,430/ha	Estimated Capital Cost (@$11,400/ha)	Category B Additional Cost (Stream restoration/outlet improvements)		Engineering / Design, Legal & survey (15%)	Total Construction Cost	Total Cost incl. land Cost	Development Charges
			(ha)	(m^3/ha)	(m^3)	(m)	(ha)	($)	($)	Length (m)	(2009 $)	(2009 $)	(2009 $)	(2009 $)	(2009 $)
1	1	3	26	390	10140	1.5	0.68	$ 551,231	$ 296,400	250	$ 187,500	$ 44,460	$ 528,360	$ 1,079,591	$ 1,079,591
1	1	18	59	390	23010	1.5	1.53	$ 1,250,870	$ 672,600	250	$ 187,500	$ 100,890	$ 960,990	$ 2,211,860	$ 2,211,860
1	1	19	35	390	13650	1.5	0.91	$ 742,041	$ 399,000	250	$ 187,500	$ 59,850	$ 646,350	$ 1,388,391	$ 1,388,391
1	1	20	41	390	15990	1.5	1.07	$ 869,248	$ 467,400	250	$ 187,500	$ 70,110	$ 725,010	$ 1,594,258	$ 1,594,258
1	1	21	35	390	13650	1.5	0.91	$ 742,041	$ 399,000	250	$ 187,500	$ 59,850	$ 646,350	$ 1,388,391	$ 1,388,391
1	1	22	45	390	17550	1.5	1.17	$ 954,053	$ 513,000	250	$ 187,500	$ 76,950	$ 777,450	$ 1,731,503	$ 1,731,503
1	1	23	40	390	15600	1.5	1.04	$ 848,047	$ 456,000	250	$ 187,500	$ 68,400	$ 711,900	$ 1,559,947	$ 1,559,947
1	1	24	70	390	27300	1.5	1.82	$ 1,484,083	$ 798,000	250	$ 187,500	$ 119,700	$ 1,105,200	$ 2,589,283	$ 2,589,283
1	1	26	75	390	29250	1.5	1.95	$ 1,590,089	$ 855,000	250	$ 187,500	$ 128,250	$ 1,170,750	$ 2,760,839	$ 2,760,839
		9	426				11.08	**$ 9,031,703**	**$ 4,856,400**	250	**$ 1,687,500**	**$ 728,460**	**$ 7,272,360**	**$ 16,304,063**	**$ 16,304,063**
1	2	4	75	390	29250	1.5	1.95	$ 1,590,089	$ 855,000	250	$ 187,500	$ 128,250	$ 1,170,750	$ 2,760,839	$ 2,760,839
1	2	5	75	390	29250	1.5	1.95	$ 1,590,089	$ 855,000	250	$ 187,500	$ 128,250	$ 1,170,750	$ 2,760,839	$ 2,760,839
1	2	6	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	7	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	8	75	390	29250	1.5	1.95	$ 1,590,089	$ 855,000	250	$ 187,500	$ 128,250	$ 1,170,750	$ 2,760,839	$ 2,760,839
1	2	9	75	390	29250	1.5	1.95	$ 1,590,089	$ 855,000	250	$ 187,500	$ 128,250	$ 1,170,750	$ 2,760,839	$ 2,760,839
1	2	10	40	390	15600	1.5	1.04	$ 848,047	$ 456,000	250	$ 187,500	$ 68,400	$ 711,900	$ 1,559,947	$ 1,559,947
1	2	11	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	12	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	13	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	14	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	15	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	16	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
1	2	17	35	390	13650	1.5	0.91	$ 742,041	$ 399,000	250	$ 187,500	$ 59,850	$ 646,350	$ 1,388,391	$ 1,388,391
1	2	27	50	390	19500	1.5	1.30	$ 1,060,059	$ 570,000	250	$ 187,500	$ 85,500	$ 843,000	$ 1,903,059	$ 1,903,059
		15	**825**				**21.45**	**$ 17,490,974**	**$ 9,405,000**	**250**	**$ 2,812,500**	**$ 1,410,750**	**$ 13,628,250**	**$ 31,119,224**	**$ 31,119,224**
		24	**1251**				**32.53**	**$ 26,522,676**	**$ 14,261,400**		**$ 4,500,000**	**$ 2,139,210**	**$ 20,900,610**	**$ 47,423,286**	**$ 47,423,286**

5.2.1.2 LID Source and Conveyance Control Estimates

This section provides detailed information regarding LID Source Controls and Conveyance Controls. To reiterate, it is important to note that LID Source Controls and Conveyance Controls will be developer funded and as such as are not included in the DC cost estimates.

The ability of the developer/proponent to select individual LID Source and Conveyance Control which best suit the individual site conditions and land owner needs adds great complexity and variation to cost estimates for such measures. In an effort to provide a benchmark cost for the various LID techniques, **Table 5.3** provides cost estimates for controlling a 25mm event, on site using the various source and conveyance controls. The 25mm event represents an "idealized" target for LID design and is typically utilized for sizing and LID design for the following reasons:

- Control of the 25mm event historically represents control of approximately 90% of the total annual rainfall events
- Control of the 25mm event typically satisfies erosion control criteria, as well as water quality, infiltration and the preservation of natural features.

The benchmark costs presented in **Table 5.3** represent the costs associated with each practice, assuming that it is the stand-alone on-site practice. In reality, as part of the AEGD Stormwater Master Plan, LID techniques would be applied in series using a treatment train approach, whereby portions of the overall Environmental Targets (**Table 5.0)** would be satisfied using various measures. However to accurately compare construction costs of various LID techniques, a stand-alone approach is necessary. General estimates of LID source and conveyance controls costs are provided for reference/ estimates only.

Table 5.3: Costs Associated with LID Source and Conveyance Controls for a 25 mm Event

LID Technique	Cost of LID Techniques (per hectare) *Costs represent control of a 25mm event and that the LID technique is a stand-alone practice*
Rainwater Harvesting	$ 155,000
Green Roofs	$ 630,000
Downspout Disconnection	No Cost for new developments
Soakaway Pits	$125,000
Bioretention	$52,000
Special Bioretention	
Stormwater Planter	$275,000
Stormwater Tree Pits	$300,000
Compost Amendment	Unknown
Tree Clusters	$20,000*
Filter Strips	$30,000*
Permeable Pavement	$175,000
Grass Channel	$52,000
Dry Swale	$125,000

Construction costs for green roofs, special bioretention variants (stormwater planter and stormwater tree pits) and permeable pavement may be cost prohibitive for Light Industrial (IND) and Airport Related Business (ARB) as these land-uses have minimum standards for urban design. From experience, commercial developers find such LID measures as bringing little to no return on investment in areas of low design standards.

The above estimates are intended to reflect moderate/average site conditions, therefore infiltration potentials may be limited due to tight soils in many areas of the AEGD. For LID techniques that utilize infiltration as the primary stormwater management mechanism, the required percentage of lot areas and the construction cost may be variable from site to site depending on in-situ soils (percentage of A, B, C soils) – see Section 4.1.5.1 –Figures 4.4-4.6 and Table 4.10. Site plan designs will require on-site soil testing using the Guelph Permeameter test (Low Impact Development Stormwater Management Planning and Design Guide Version 1.0 (TRCA/CVC - 2010)) or equivalent to confirm infiltration rates, design specification and therefore costs.

5.2.2 Operations and Maintenance Costs

5.2.2.1 Operation and Maintenance Costs for LID techniques

Operation and maintenance costs presented in **Table 4.15**, these costs represent the best available data for operating and maintaining LID SWM facilities. As such the costs provided are intended to be used as a planning tool only.

Table 4.15: Maintenance Costs for LID Techniques in the AEGD

LID Technique	Cost of LID Techniques in Relation to AEGD land-use (per hectare treated)				
	PBP	**IND**	**ARB**	**AI**	**Range and (average)/ha/yr**
Rainwater Harvesting	Unknown	Unknown	Unknown	Unknown	**Unknown**
Green Roofs	$27,000	$40,500	$40,500	$27,000	**$27,000-$40,500 ($33,750)**
Downspout Disconnection	Minimal	Minimal	Minimal	Minimal	**Minimal**
Soakaway Pits	Unknown	Unknown	Unknown	Unknown	**Unknown**
Bioretention	$3,120	$3,120	$3,120	$3,120	**($3,120)**
Special Bioretention					
Stormwater Planter	$21,000	$30,000	$24,000	$17,500	**$17,500-$30,000 ($23,000)**
Stormwater Tree Pits	$56,000	$79,000	$62,000	$46,000	**$760,00-$1,315,000 ($1,000,000)**
Compost Amendment	Unknown	Unknown	Unknown	Unknown	**Unknown**
Tree Clusters	$20,000	$20,000	$20,000	$20,000	**$2.65/tree**
Filter Strips	Minimal	Minimal	Minimal	Minimal	**Minimal**
Permeable Pavement	$7,300	$10,200	$8,000	$6,000	**$6,000-$10,200 ($7,800)**
Grass Channel	$1,560	$1,560	$1,560	$1,560	**($1,560)**
Dry Swale	Unknown	Unknown	Unknown	Unknown	**Unknown**

5.2.2.2 Operation and Maintenance Costs for Dry Pond End-of-Pipe Facilities

Dry pond facilities are a well understood stormwater management technique in terms of operations and maintenance. The facilities typically require little operations and maintenance. **Table 4.16** below provides typical operations maintenance activities for dry ponds in comparison to other stormwater BMPs.

Table 4.16 Maintenance Requirements for Dry ponds in Comparison to Other BMPs

Operation or Maintenance Activity	Dry Pond	Infiltration Basin	Infiltration Trench (Soakaways pits, Perforated Pipe Systems etc.)	Underground Storage (RWH, Permeable Pavement etc.)	Filters (Bioretention, Bio-swales, Bio-filters etc.)
Inspection	■	■	■	■	■
Grass Cutting	■	■	■	■	■
Weed Control	■	■			□
Upland Vegetation Replanting	□	□	□		
Removal of Accumulated Sediments	■	■	■	■	■
Outlet Valve Adjustment	□				
Trash Removal	■	■	■	■	■
Infiltration Basin Floor Tiling		■			
Closing Infiltration Facility Inlet in Winter Months		■			

■ Normally Required □ May be Required (Source: MOE, 2003)

6.0 AEGD Implementation Document

Unique to the AEGD Subwatershed/Stormwater Master Plan is the development of the AEGD Subwatershed/Stormwater Master Plan Implementation Document (2010) (under separate cover). This document is designed 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.

7.0 Additional Studies and Recommendations

There are a number of implementation actions that are necessary from a planning and operations/maintenance perspective that need to be addressed to ensure that LID measures are properly designed, constructed, operated and maintained, including the following:

- Incorporation of LID designs, concepts into municipal planning and standards documents
- Education of municipal staff in the review/approval of LID measures in development applications
- City should review existing operation and maintenance budgets to ensure that operations and maintenance associated with City-owned LID measures are considered (eg. Landscape-based stormwater management measures). Traditional operations and maintenance budgets to not appropriately cover or consider maintenance of landscaping elements of LID measures.
- Preparation of a manual for developers/consultants on LID measures, design, construction, operation and maintenance
- Monitoring and reporting requirements for landowners in order that municipal/CA staff can be assured that LID measures are properly maintained and functioning
- Appropriate bylaws and easements that give municipal staff authority to inspect, and repair as necessary LID facilities on private property

- Specific wording for site plan conditions, requirements for performance bonds/warrantees that ensure that LID measures are properly designed, constructed and monitored for a sufficient post construction period to ensure that they are functioning effectively
- 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.

8.0 References

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