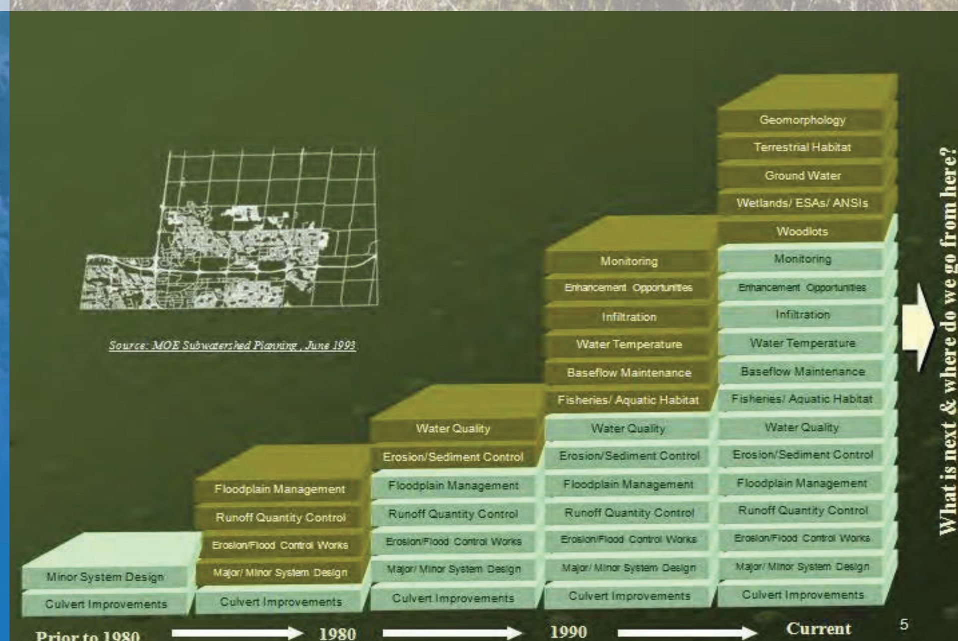
Storm Water Management Guidelines

October 2016



Markham Stormwater Management Guidelines

The City of Markham

October 2016

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ACKNOWLEDGEMENTS

The City of Markham Stormwater Management Guidelines have been developed through a collaborative effort between City of Markham staff and Consultants. While the full list of contributors is too exhaustive to include, the City wishes to acknowledge the efforts and contributions of the following individuals:

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PREFACE TO USERS

This guideline is a living document, and will be regularly reviewed and updated as the regulations, design practices, and technologies continue to evolve and change. Users of this document are advised to contact Markham staff for the most current version of this document.

The purpose of those guidelines is to provide high-level technical guidance to the designer, practitioners, and the development industry in the planning and design of stormwater management infrastructure that will meet the requirements and standards of the City of Markham. Although the guidelines provide technical and practical guidance, users must exercise judgment in planning, designing, and implementing stormwater management works. The designer will remain fully responsible for ensuring that the design and construction of stormwater management systems is conducted in accordance with good engineering practice and standards that address the specific needs and site conditions of their project.

The criteria outlined in this document may be augmented or, in some cases superseded, by legislative requirements or unique situations. The guidelines are not intended to specify limitations on the creative design process. Designers have flexibility in devising solutions; however Markham must approve the final stormwater management plan.

Use of these guidelines or issuance of approval does not release the designer from design responsibilities. Users of these guidelines are responsible for the integrity and design of the various facilities proposed. Markham reserves the right to provide the final decision regarding the interpretation and intent of the guidelines as well as the acceptability of deviations/exceptions from the guidelines proposed by the designer.

At the time these guidelines were prepared, guidelines specific to the planning and design of Low Impact Development Best Management Practices (LID BMPs) were being prepared as part of various parallel initiatives. Requirements for implementing LID BMPs have been identified as part of the Subwatershed Planning Study for the Markham Future Urban Area, and the application of LID BMPs for stormwater management is endorsed by the Province of Ontario, Toronto and Region Conservation Authority and Markham. Design guidelines specific to the application of LID BMPs are being developed by the Ministry of the Environment and Climate Change for application across the Province. In addition, Markham is developing guidelines for implementing LID BMPs through a consultative process. Guidelines specific to implementing LID BMPs are anticipated to be released in 2017, and should be used in conjunction with the guidance provided herein for planning and designing stormwater management infrastructure. In the interim, proponent in consultation with the City and TRCA staff should implement requirements for LIDs based on the TRCA's LID Planning and Design Guidelines.

1.0 INTRODUCTION

1.1 History of Stormwater Management in Markham

The City of Markham (Markham) is at the forefront of stormwater management in Ontario and throughout its history has been a leader in the development and adoption of innovative stormwater management concepts, techniques and designs. This section provides a summary of the evolution of stormwater management policy and guidelines within Markham.

In 1978, Markham adopted a Municipal Services document which provided guidance on land development requirements including procedures and standard drawings. The 1978 document included design guidance which standardized both above and below ground services, including storm sewers.

In 1983 Markham released "Storm Water Management in the Town of Markham, Experience - Policies and Criteria-Modeling for the Department of Engineering" (1983 Criteria Document). The 1983 Criteria Document set objectives in stormwater management and presented policies, in addition to analytical modelling guidelines; its goals included:

- Preventing the loss of life;
- Minimizing property damage, health hazards, inconvenience from surface ponding, downstream flooding and erosion;
- Minimizing polluted discharges to watercourses;
- Minimizing the impairment of aquatic life; and
- Protecting habitat and baseflow considerations.

Notably, the methods of prevention were not described in detail within the 1983 Criteria Document.

Markham followed up the 1983 Criteria Document with a release in October 1989 detailing the Design of On-site Detention (OSD) systems and the Simplified Hydrologic Computation Method. The objective was to present principles of on-site detention design, and to provide practitioners a step-by-step approach for design and computation of OSD storage based on Markham's preferred approach as related to solutions for on-site detention described in the Urban Drainage Design Guidelines for Ontario (MNR, 1987).

In 1995 the Markham Stormwater Management Guidelines were released bringing together the objectives of the 1983 Criteria Document, the provincial Urban Drainage Guidelines, and the then new ecosystem approach for Subwatershed Planning (1993). The 1995 Markham Guidelines integrated the principles of peak flow control from the previous directives with new emerging principles in stormwater management, namely water quality and habitat protection, rehabilitation and restoration, baseflow management and erosion control. The Guideline focused on processes to prepare stormwater management plans (SWMPs) and select, design, and construct Best Management Practices (BMPs).

This current document builds from Markham's legacy of innovative and forward-thinking stormwater management policy and guidelines. It is intended to embody several emerging trends and directions, while offering insight to practitioners, regulators, and the public.

Figure 1.1 provides a graphical representation of the evolution of stormwater management planning and design, along with related practices. It has been Markham's goal to continually remain 'in-step' with this evolution by maintaining current and contemporary policy and guidelines.

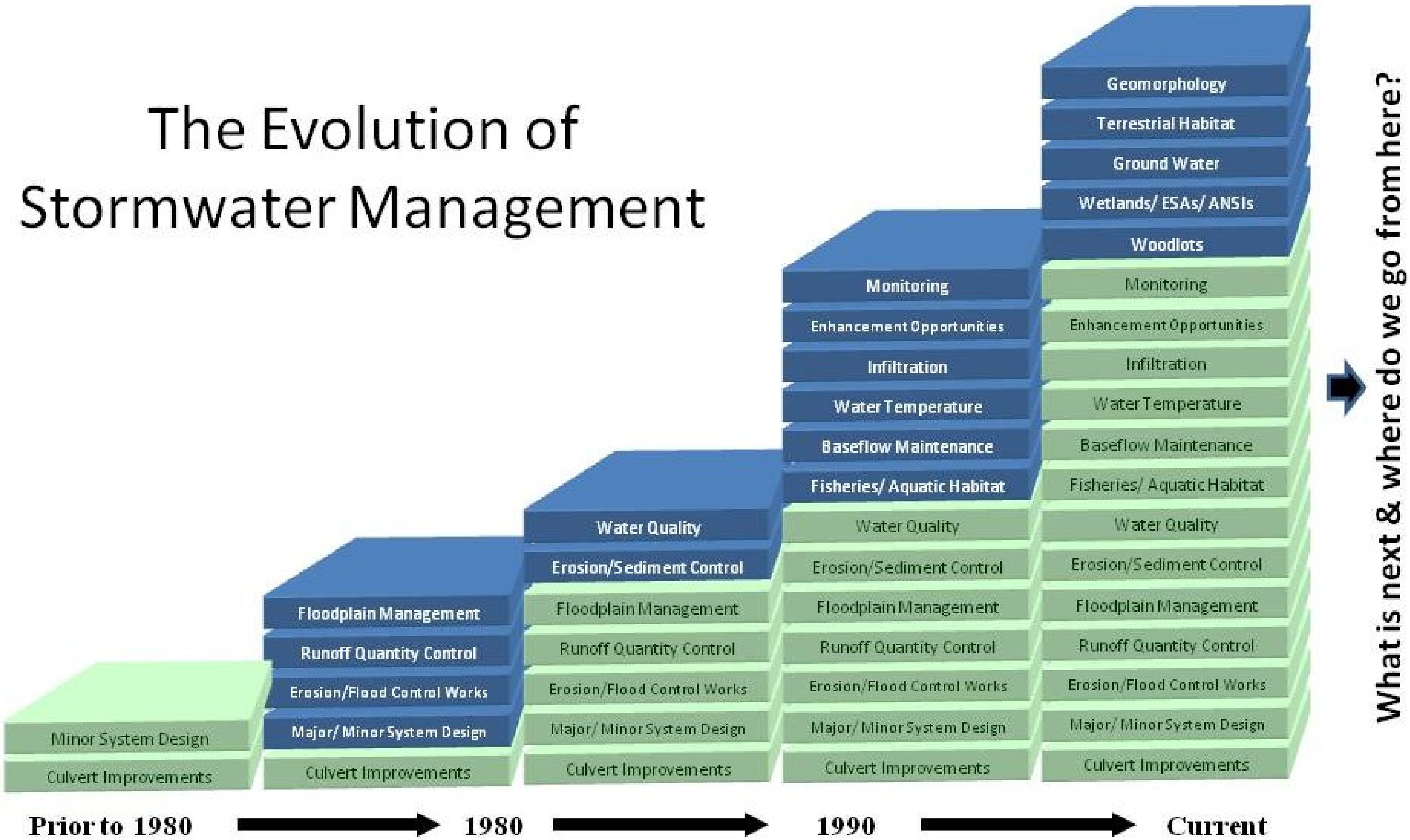

Figure 1.1 Evolution of Stormwater Management Practice in Ontario (Adapted from Ministry of the Environment, 2003)

1.2 Purpose of this Document

The Stormwater Management (SWM) Guidelines are intended to be used by practitioners in the design of storm drainage infrastructure within the municipality. The Guidelines are to be used in concert with other relevant and companion documentation to support the planning and design process for new land developments and redevelopments (infills/intensification). The Guidelines provide standards including desired attributes of stormwater infrastructure as related to Markham's governing policies.

The Stormwater Management Guidelines are intended to provide hierarchal guidance, direction and consistency for the various stages of development, specifically related to the planning, design and review of:

- Master Environmental Servicing Plan (MESP),
- Functional Service Report (FSR)
- Stormwater Management Reports.

This guideline also assists practitioners by detailing specific submission requirements including:

- Series of study specific process,
- Deliverables and requirement tables
- Submission checklists.

1.3 Other Relevant Documents

Markham and its key stakeholder agencies including Toronto and Region Conservation Authority (TRCA), Region of York, Ministry of Natural Resources and Forestry (MNRF), Ministry of the Environment and Climate Change (MOECC), and others, have prepared a variety of documents which support and complement the planning and design of stormwater and environmental management systems. Practitioners and regulators should be familiar with the direction offered in these companion documents (and any new updated versions) in order that future designs of stormwater-based systems can be effective and consistent with the broadest set of environmental considerations. The following offers some of the relevant information which practitioners should be familiar with. The following list may not be complete or current, hence proponents should pre-consult with the various agencies and Markham to confirm the requirements and applicable guidance documents for the specific projects.

Municipal

- Markham Stormwater Retrofit Plan (2015)
- York Region Official Plan (2015)
- City of Markham Official Plan (OP) (2013)
- Markham's Green Print Sustainability Plan (2011)
- Environmental Policy Review and Consolidation (Town of Markham, 2009)

TRCA

- The Living City Policies (May 2014)
- Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (CVC/TRCA, Revised July 2013)
- Stormwater Management Criteria Version 1.0 (August 2012)
- Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0, (TRCA/CVC, 2010)
- Rouge River Watershed Fisheries Management Plan (TRCA/MNR, 2010
- Don River Watershed Plan (2009)
- The Rouge River Watershed Plan and Implementation Guide (2007)
- Erosion and Sediment Control Guidelines for Urban Construction, Greater Golden Horseshoe Area Conservation Authorities (GGHA CAs, 2006)
- Valley and Corridor Monitoring Program (1994)

Provincial

- MNR Draft Guidance for Development Activities in Redside Dace Protected Habitat, (February 2011)
- Endangered Species Act (2007 and as amended)
- The Clean Water Act (2006 and as amended)
- The Provincial Policy Statement (2005 and as amended)
- The Greenbelt Act / Greenbelt Plan (2005 and as amended)
- Stormwater Management Planning and Design Manual, MOE (2003)
- Technical Guide, River & Stream Systems: Flooding Hazard Limit, MNR (2002)
- Oak Ridges Moraine Conservation Act (2001 and as amended)
- Ministry of Transportation (MTO) Drainage Management Manual (1997)
- Ontario Water Resources Act (1990 and as amended)
- Conservation Authorities Act (1990 and as amended)
- Water Management Policies, Guidelines and Provincial Water Quality Objectives (MOEE, July 1994)
- Ontario Regulation 166/06: Toronto and Region Conservation Authority Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses
- Thermal Mitigation Checklist for Stormwater Management Ponds Discharging into Redside Dace Habitat – Version 1.1 (MNRF Aurora District, June 18, 2014 and as amended).

1.4 Document Organization/Outline

The Stormwater Management Guidelines have been organized in to the following twelve (12) chapters:

- Chapter 1 - Provides a summary of the evolution of stormwater management (SWM) in Markham and provides context with respect to the development of this current guideline.
- Chapter 2 – Details the ecosystem-based approach to SWM, the multidisciplinary integrated design process and its role in this guideline. This chapter also summarizes relevant planning, policy and design documents, in addition to providing stormwater practitioners with guidance as to various approval authorities and the related legislation and guidelines.
- Chapter 3 – Describes the multi-phased stormwater management planning, design and approval process and its relationship to the broader land-use planning process. It describes various environmental planning studies, their specific requirements, methodology and deliverables as they relate to these Guidelines.
- Chapter 4 – Provides an overview of the typical analytical methods available to establish the hydrologic and hydraulic characteristics for a study area and or site. Summaries of single event and continuous model input requirements, typical uses, methodologies and deliverables are included. This chapter also describes design flow calculations.
- Chapter 5 – Details relevant environmental design criteria, specific to water quantity, quality, erosion, water balance (infiltration) and the protection of natural features for new and infill type developments within Markham. It describes both general environmental criteria to be used in the absence of completed environmental studies, in addition to area-specific criteria developed as part of relevant watershed/subwatershed studies and/or Master Environmental Servicing Plans (MESPs) etc.
- Chapter 6 – Summarizes the planning and design of SWM infrastructure including source, conveyance and end-of-pipe controls for use within Markham.
- Chapter 7 – Outlines the Erosion and Sediment Control (ESC) requirements for development in Markham.
- Chapter 8 – Summarizes the requirements for operation and maintenance plans which are required as part of Engineering Submissions.
- Chapter 9 – Provides an overview of Markham’s requirements for assumption of stormwater management infrastructure.
- Chapter 10 – Provides general guidance regarding the approach to the applied for the design of valley systems and watercourses applying natural channel design principles.
- Chapter 11 – Provides a summary of the City’s requirements for watercourse and stormwater management facility monitoring.

1.5 Document Context

In developing the following SWM Guidelines, Markham supports and recognizes the following as they relate to the SWM:

- The requirement to undertake comprehensive environmental studies at the initial stages of the planning process,
- The requirement to support innovation, evaluate new approaches, and embrace new technologies and techniques; and
- The need to undertake SWM planning and design as part of an interdisciplinary approach which includes, but not limited to:
    - Water Resource Engineers
    - Land use Planners;
    - Terrestrial and Aquatic Ecologists;
    - Geoscientists (Hydrogeologists and Fluvial Geomorphologists), and
    - Landscape Architects

2.0 STORMWATER MANAGEMENT: AN ECOSYSTEM BASED APPROACH

2.1 Overview

Over the past two decades, there has been a clear and noticeable shift in the planning and design of new communities and their supporting infrastructure. Formerly, community planners and engineers established land uses and servicing infrastructure with little regard to natural system protection and function. The role of the drainage engineer was to capture the water as efficiently as possible and convey it to the nearest outlet. Current planning and design approaches have adopted a much more central value of the natural and social environment, and many communities are now designed with an “environment-first” perspective. This shift towards an ecosystem–based approach to stormwater management replaces the former land use and infrastructure planning process. The ecosystem-based approach integrates the concepts of community and development sustainability with the requirements of the natural system. Naturally this overarching shift has changed the way which communities are planned and operated including changes to the way stormwater is managed and valued. An ecosystem approach to stormwater management adopts a broad definition of the environment including natural, physical, social, cultural and economic issues.

In order to provide effective and sustainable ecological protection and management, water resources are a key element in the overall function of natural ecosystems sustaining their health and existence. Therefore the protection of the functions of water and stormwater resources, through proper and effective stormwater management is paramount to a sustainable community.

2.2 Integrated Planning and Design Process

Planning and design processes need to recognize the role of stormwater management to the protection of ecological attributes and functions of the watershed. An integrated planning and design process requires that the constraints and opportunities afforded by the physiography (land based approach) be considered concurrent with the ecological features (ecosystem approach) of the watershed in the planning and design of stormwater management systems.

The integrated planning and design process requires the involvement of a multidisciplinary team. The team would typically include a broad cross-section of disciplines, including:

- Engineers (Water Resources, Civil, Geotechnical)
- Land use Planners;
- Terrestrial and Aquatic Ecologists;
- Geoscientists (Hydrogeologists and Fluvial Geomorphologists); and
- Landscape Architect/Urban Designers.

Additional expertise may be required based on the characteristics and complexity of the landscape, as well as the environmental and social considerations of the proposed project. Although the relative contribution of each discipline may vary throughout the planning and design processes, the continued involvement of the multidisciplinary team from concept to implementation is critical in order to ensure project objectives are addressed as the process moves forward. Where possible, the integrated planning for stormwater management practices should be conducted as early as possible in the planning process (i.e. Conceptual Master Plan or Secondary Plan level), in order to clearly establish the criteria for stormwater management planning from an integrated and multi-disciplinary perspective.

LID BMPs need to be considered at the earliest stage of site design, with the objective of sustainability and low maintenance. Each LID practice would typically incrementally reduce and/or treat volume of stormwater on its path to the receiver. LID practices are typically applied to meet stormwater management targets for water quality, geomorphic (erosion management) and water budget objectives.

2.3 The Ecosystem Approach

Like many growing municipalities in Ontario, Markham has embraced environmental principles in its community and neighbourhood planning. Markham's Official Plan outlines many of these values including policies related to:

- Watershed and Subwatershed Planning
- Groundwater and Surface Water Resources
- Stormwater Management
- Natural Environmental Hazards
- Other Environmental Hazards
- Emerging Preparedness

Markham achieves these principles through an integrated land use and environmental planning process which involves the preparation of various plans at various stages of development.

Land Use Planning	Environmental & Stormwater Planning
Official Plan	Watershed Plan
Secondary Plan	Subwatershed Plan
Tertiary Plan (Neighbourhood)	Master Environmental Servicing Plan (MESP)
Plan of Subdivision/Site Plan	Functional Servicing Report (FSR)
Detailed Plan	Stormwater Management Report

Specifically, it is the policy of Markham's Council through the Official Plan:

- **To work** in cooperation with the Toronto and Region Conservation Authority and other partners in the preparation and update of the Don, Rouge, Duffins, Petticoat and Highland watershed plans where required.
- **To work** in partnership with the Toronto and Region Conservation Authority, York Region and other partners in the preparation of a framework for the implementation of the Don, Rouge, Duffins, Petticoat and Highland watershed plans that may include the preparation of detailed implementation plans and the consideration of appropriate best

management practices and sustainable technologies in development of the 'Future Urban Area' lands shown on Figure 2.1.

- **To work** in cooperation with the Toronto and Region Conservation Authority, Ministry of Natural Resources and other partners, in the preparation of subwatershed plans for smaller drainage areas within Markham's watershed area boundaries.
- **To require** the preparation of subwatershed plans prior to development in the 'Future Urban Area' as shown on Figure 2.1 to guide land use options and identify mitigation and restoration strategies required to protect and enhance natural heritage and hydrologic features and their ecological functions and hydrologic functions.
- **To implement** *watershed* and *subwatershed plans* in the preparation of Master Environmental Servicing Plans (MESPs) and all other required studies prepared in support of development, *redevelopment* and *site alteration,* where applicable.

Additional detail on these various stages of planning is offered in Section 3.

Planning, design and revi*ew of Mast*er E*nvironmental Servi*cing Plans (MESPs), Functional Service Reports (FSRs) and Stormwater Management Reports within Markham should be based on the ecosystem *approach and* must *consider the ne*ed of not only protecting, but whenever possible enhancing the natural environment. The following objectives are to be considered:

i) Consider the protection of sensitive natural resources and propose appropriate restoration/naturalization measures for areas where these resources have been previously impacted;

ii) Provide peak flow control, and water quality protection, habitat enhancement, water balance and erosion control;

iii) Avoid negative impacts on wetlands, Areas of Natural and Scientific Interests (ANSI), Environmentally Sensitive Areas (ESA);

iv) Maintain groundwater recharge through infiltration practices in areas confirmed as significant recharge areas or supporting key hydrologic and natural features;

v) Protect, Rehabilitate and Enhance ecological linkages which secure wildlife movement and the biodiversity of plants and animals, such as valley buffers, ;

vi) Promote visual and passive recreational use of natural features and corridors;

vii) Restore eroded stream banks and vegetation to natural conditions;

viii) Protect and Enhance Fish and other aquatic habitats; and

ix) Ensure public input opportunities are provided at multiple points in the process.

These objectives are consistent with The Greenprint, Markham's Sustainability Plan (2011) whose guiding framework states that in a sustainable Markham "we value and restore the natural environment, and protect biodiversity, natural capital and ecosystem services."

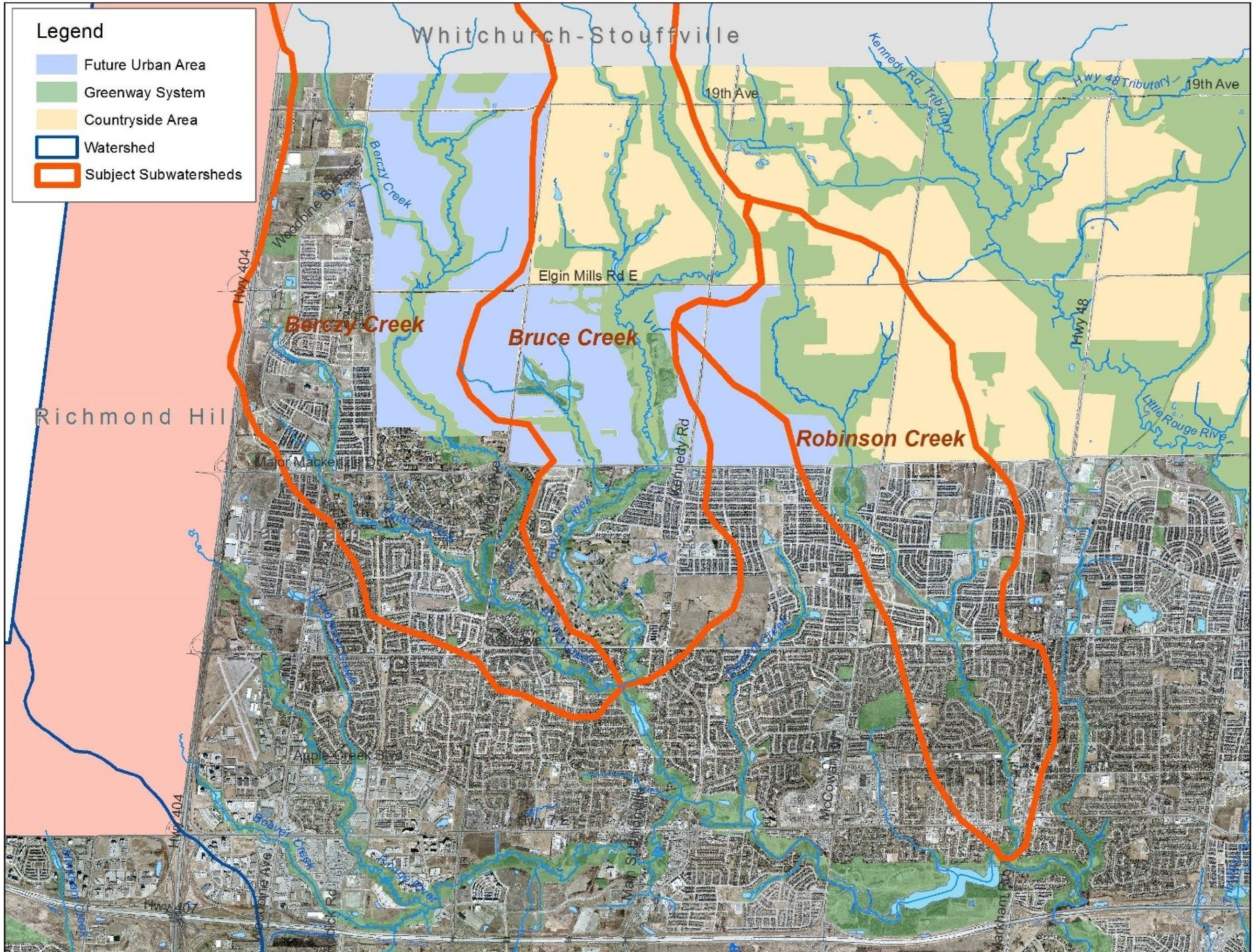

Figure 2.1: North Markham Future Urban Area

3.0 PLANNING AND APPROVAL PROCESS FOR URBAN DEVELOPMENT

3.1 General

This chapter describes the multi-phased stormwater and environmental management planning and design process for new urban development and its relationship to the concurrent land use planning process.

Stormwater management planning and design generally occurs through a multi-phase process which is completed in conjunction with the land use planning process. Figure 3.1 illustrates the relationship between environmental planning studies and the municipal planning process, together with the corresponding approval agencies. Environmental planning studies such as Watershed/Subwatershed Studies, Master Environmental Servicing Plans (MESPs), Functional Servicing Reports (FSRs) and Stormwater Management Reports are prepared in support of municipal land-use studies and plans at various stages of the development process, to help guide land use decisions and ensure that practical and effective plans are prepared which manage impacts to natural resources. Depending on the stage of development, the study and documentation process will effectively need to address the needs of the respective study.

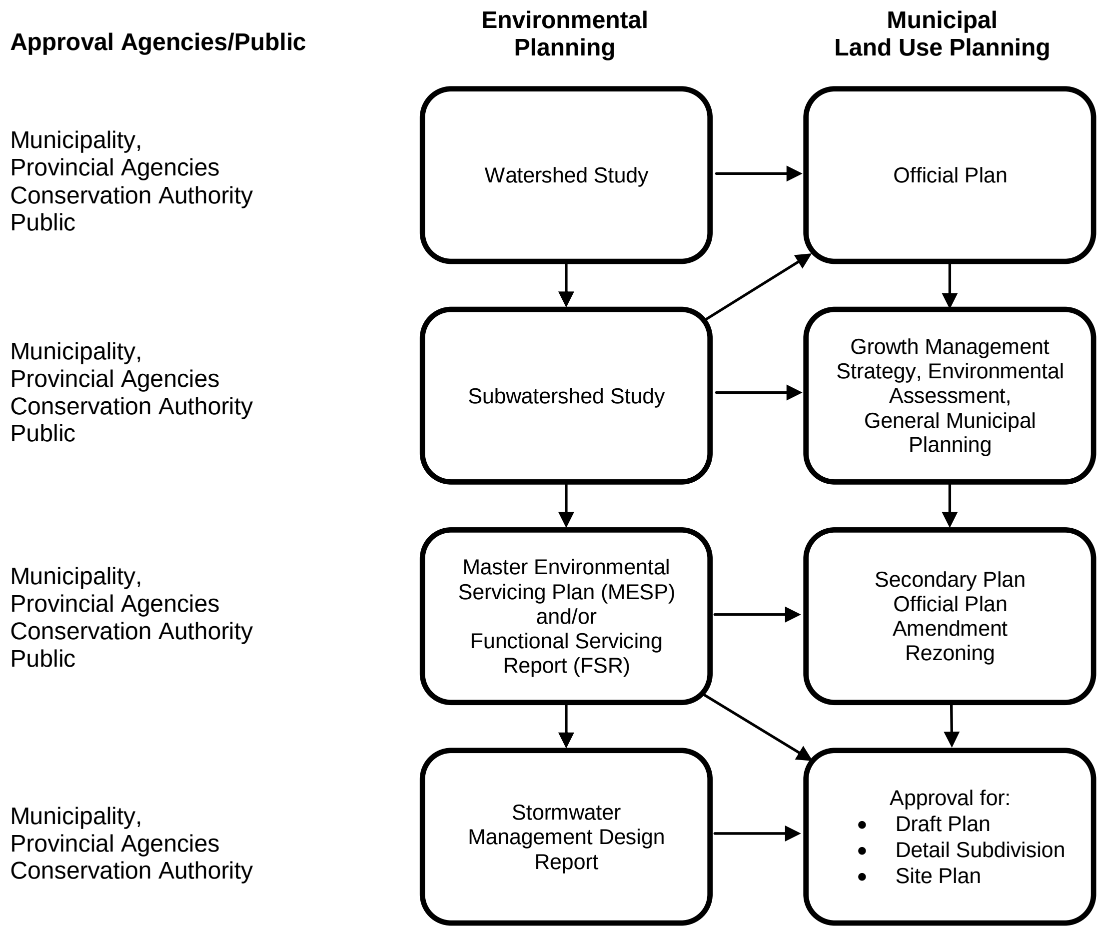

Figure 3.1 Relationship between Municipal Land Use Planning and Environmental (Watershed) Planning Processes
(Source: Adapted from MOE Stormwater Planning and Design Manual, 2003)

The basic objectives and deliverables for each of these various studies are discussed in the following sections.

Table 3.1 Stormwater Management Considerations at Various Stages of Land Use Planning

Planning Stage	Description
Official Plan (OP)	OP identifies land use type, density, and mitigation requirements to meet watershed objectives, including protection of sensitive features through land use designations. Applicable Watershed Plans represent resource documents for development of Official Plans and completion of Subwatershed Studies.
Secondary Plan/ Official Plan Amendment (OPA)	Full range of opportunities to achieve stormwater management objectives are identified, establishing a template for the more detailed resolution of the site specific design of stormwater management facilities at subsequent stages in the planning and design process. It is at this stage that the protection of natural features are identified. The reader is directed to Markham Natural Heritage Network which incorporates all regional and local features based on federal, provincial and local requirements. Resources to be consulted include but are not limited to: - Markham's OP - The Markham Natural Heritage Network - TRCA Headwater Drainage Features Guidelines - Rouge River and Don River Watershed Plans
Draft Plan of Subdivision	The location of lots, roads, parks and open space blocks, natural heritage features and buffers and stormwater management facilities are defined. Thought must be given to how stormwater management objectives can be achieved and how these objectives influence the location and configuration of each of the components listed above.
Site Plan	Opportunities are presented to integrate stormwater management facilities into all of the components of a development including landscaped areas, parking lots, roof tops and subsurface infrastructure. Solutions must be considered in the context of the overall stormwater management strategy for the block or secondary plan area to ensure that functional requirements are achieved.

3.2 Watershed Plans

Watershed studies or plans are higher level documents prepared for major river systems. Markham lies primarily within the Rouge River Watershed and the Don River Watershed. Smaller areas of Markham lie within the Highland, Petticoat and Duffins watersheds (Figure 3.2)

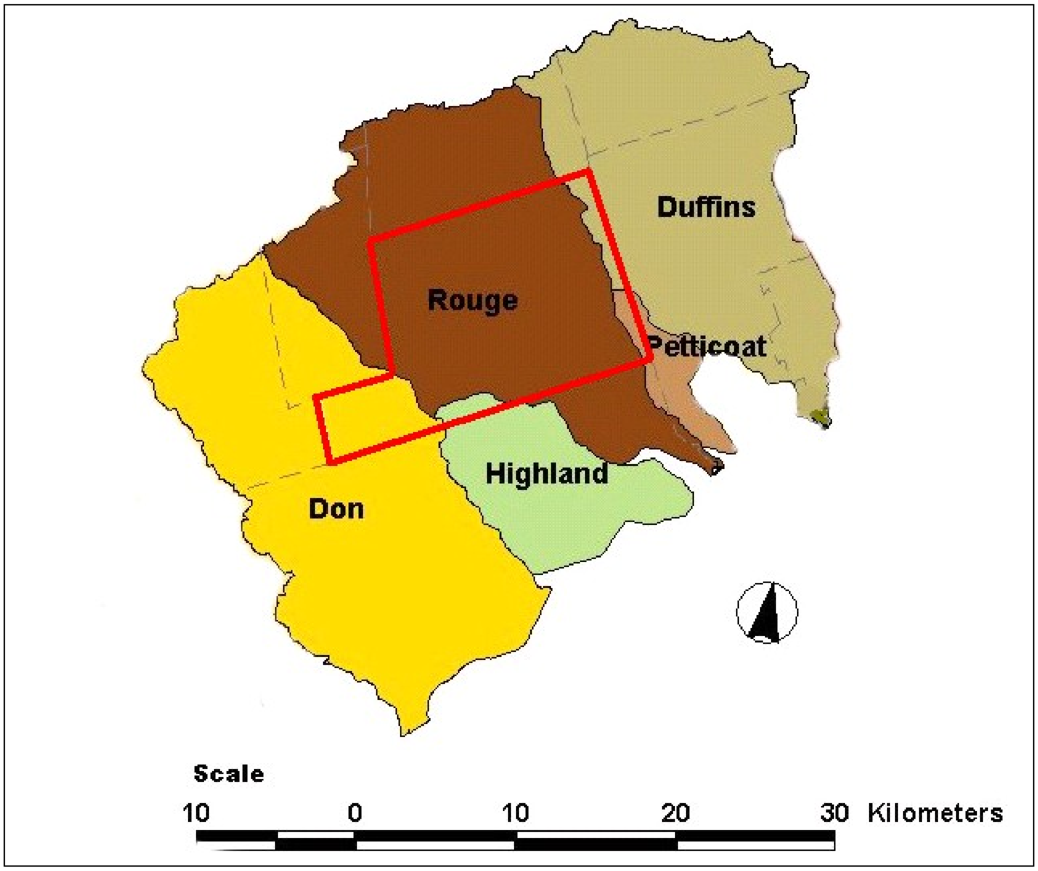

Figure 3.2 Watersheds Encompassing Portions of Markham

A watershed study area consists of the natural drainage boundary of the river and all of its tributaries. A watershed plan typically addresses environmental issues at an Official Plan scale and is used as a guide for managing human activities that affect water, land/water interactions, and terrestrial and aquatic resources. The watershed plan outlines areas for protection, enhancement, and rehabilitation and high level direction and policy such that the health of the watershed's ecosystem is protected as land uses and management practices change.

The Watershed Plan acts as an umbrella document that provides direction for subsequent more detailed and localized subwatershed studies. It establishes high-level environmental goals and objectives and identifies the actions required to meet these goals. A Watershed Plan is typically developed co-operatively between government agencies, conservation authorities and stakeholders.

3.3 Subwatershed Studies

Subwatershed studies are conducted to implement the recommendations from watershed plans and related policies which would ultimately provide environmental and water resources input into the Secondary Planning process for local development communities. Subwatershed studies are typically driven by urban development and led by the municipality with direct involvement from the Conservation Authority and proponent landowners. The Subwatershed study process consists of the four phases as shown in Figure 3.3.

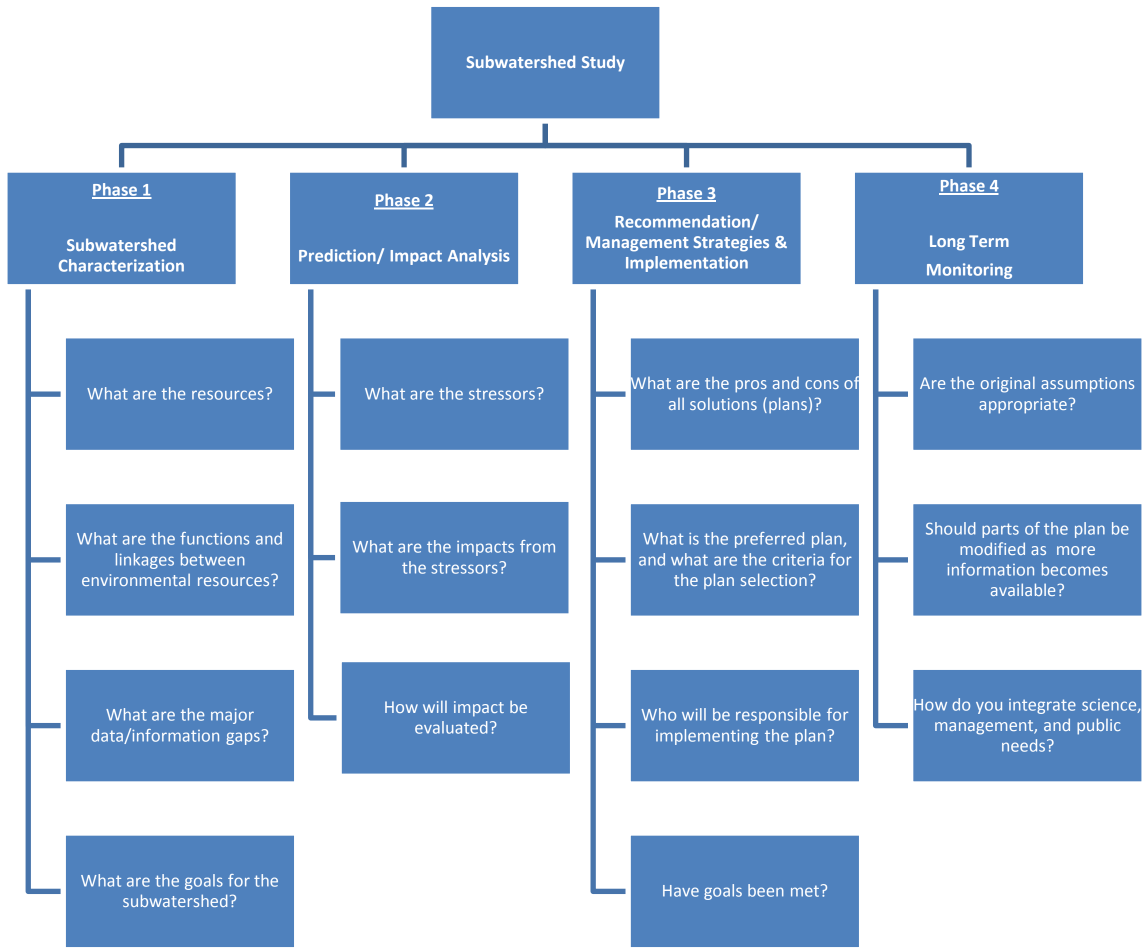

Figure 3.3 Subwatershed Study Process

Phase 1 "Subwatershed Characterization." This phase determines and assesses the resources of the subwatershed by various study disciplines including hydrology and hydraulics, hydrogeology, water quality, stream morphology, aquatic and terrestrial ecology. Background and supplemental field data are collected for each discipline and then considered across disciplines to establish an understanding of the form, function, and linkages of the environmental resources. Background must include relevant information pertaining to Species at Risk legislation (i.e. Natural Heritage Information Center – NHIC), and existing resources in regards to the Clean Water Act. During this phase, goals and objectives are developed to guide future management in the subwatershed.

Phase 2 "Prediction/Impact Analysis." In this phase, the future impacts of a variety of possible future land use scenarios are assessed related to multiple subwatershed scale parameters. It is during this phase that the assessment, considers impacts and mitigation strategies are to meet the targets and objectives established during Phase 1.

Phase 3 "Recommendation/Management Strategies & Implementation". This phase includes finalizing the alternative solutions and the selection of the preferred management strategy. This is done by taking direction from Phase 2, in terms of impacts and potential effectiveness of various management strategies and based on a finalized form of land use and establishing a set of management strategies to achieve the identified goals and objectives. The implementation plan for the subwatershed study and its associated recommendations provides input on:

- priorities;
- staging/phasing;
- monitoring; and
- future study requirements.

Phase 4 "Long Term Monitoring". This phase of the Subwatershed Study is long term monitoring which would follow implementation of the development and associated management; this phase is traditionally executed by the Municipality funded by development. The purpose of the monitoring is to evaluate the success of the Proposed Management Practices over time and adjust the plan as possible and as required.

3.4 Master Environmental Servicing Plans

Master Environmental Servicing Plans (MESPs) are to be completed prior to the consideration of Draft Plan Approval. The MESP would include supporting technical analyses including hydrology, hydraulics, hydrogeology, geotechnical investigations, and fluvial geomorphology. The MESP is conducted at a higher level of resolution and typically would involve a neighbourhood or block plan scale, not necessarily co-incident with the subwatershed(s). MESPs would integrate the evaluation of aquatic habitat and terrestrial features as part of an Environmental Impact Study (EIS). The purpose of the MESP is to provide an integrated and more detailed analysis of management requirements with the backdrop of more detailed and refined land use information. The MESP highlights the key recommendations and requirements to be addressed through the future draft plans of subdivision and/or site plans.

In general, the MESP is required to address the following:

Review Existing Information
The proponent should review Subwatershed Study data, analyses and recommendations, where applicable and appropriate, in conjunction with other companion studies to identify any information gaps relating to the conservation of natural heritage areas, features and functions.

Refine data for Existing Environmental Conditions
Based on the review of the existing information, the proponent should carry out the necessary studies to fill local scale data gaps with respect to natural features and systems.

Update Constraint/Opportunity Mapping
Based on the refined land use plan, and using existing information as a base ('starting point') the proponent should conduct a functional analysis of the ecologically sensitive lands constituting the natural heritage system and thereby prepare an updated detailed constraint and opportunity map.

Assess Detailed Land Use Impact to Establish Preferred Environmental and Stormwater Management Strategy
The proponent should refine a land use plan so that it best addresses the environmental and stormwater management requirements and practices identified by the higher level studies as appropriate, reflecting the detailed constraint and opportunity map. The impact assessment of the proposed land use would be updated and refined to determine if alternative environmental and stormwater management strategies may be necessary, considering other economic and social issues such as interim servicing, cost sharing, development timing etc.

Submission requirements for MESPs are provided in Annex 2 of the City's Engineering Standards. The proponent is required to contact Markham to determine the appropriate submission requirements for individual developments. *All MESP Reports must be signed and stamped by a professional engineer in good standing.*

3.5 Functional Servicing Reports

A Functional Servicing Report (FSR) provides details specific to the functional serviceability for a proposed development related to the water, sanitary, and storm sewer network ensuring that it can function to Municipal and Provincial criteria. The FSR describes the location and nature of existing municipal water, sanitary, and storm infrastructure that may be available to provide servicing for the proposed development. It should outline in detail the proposed servicing requirements for the development and indicate, where possible, the capacity of the existing infrastructure to support the development.

An FSR is prepared in support of development/re-zoning and intensification projects to identify how servicing will be provided while meeting approved environmental targets from preceding studies. For large developments with significant environmental considerations, a three-step process may be appropriate, requiring an MESP followed by underlying FSRs and Stormwater Management Report for individual subdivisions and servicing facilities, respectively. In some instances, it may be appropriate to complete only an FSR and single Stormwater Management Report. If the proposed development does not include a stormwater management facility, then a separate Stormwater Management Report is not required, although the FSR will be required to document the stormwater management strategy for the site (e.g. stormwater management within an off-site facility). However, if a stormwater management facility is proposed for the development, then a separate Stormwater Management Report shall be submitted.

Submission requirements for FSR's are provided in Annex 2 of Markham's Engineering Standards. The proponent is required to contact Markham staff to determine the appropriate submission requirements for individual developments. *All FSR Reports must be signed and stamped by a professional engineer in good standing.*

3.6 Stormwater Management Report (SWM Report)

A Stormwater Management (SWM) Report is prepared in order to meet the conditions set at the Draft Plan, Site Plan. The preparation, review and approval of the SWM Report should be the final step in the approval of the proposed SWM plan. The SWM Report must provide the required design and detailed supporting calculations for all component elements of the proposed stormwater management system. The SWM Report should contain the detailed design of stormwater controls, delineation/confirmation of constraint boundaries, and hydraulic and hydrologic analyses. The report should include and/or reference supporting geotechnical/ hydrogeological studies, environmental restoration reports, preservation and restoration/ remediation plans and, sediment/erosion control plans. Copies of all referenced reports should be included with the submission of the SWM Report.

The components of the SWM Report may vary depending upon whether an MESP and/or Subwatershed Study have been completed. Submission requirements for SWM Reports are provided in Annex 2 of Markham's Engineering Standards and are included in Appendix A of this document. The proponent is required to contact Markham to determine the appropriate submission requirements for individual developments. *All SWM Reports must be signed and stamped by a professional engineer in good standing.*

3.7 Submission Checklists

In order to ensure that required information is submitted with development applications, Markham has developed a series of checklists, forms and accompanying documents which outline the requirements of a complete submission.

These checklists, forms and accompanying documents are a mandatory submission requirement. Submissions failing to provide completed checklists will not be reviewed by Markham until such time as all submission requirements are provided. A*ll reports must be signed and stamped by a professional engineer or qualified person in good standing.*

Submission checklists are provided in the City's Engineering Standards for the following submissions:

1. Master Environmental Servicing Plan (MESP) requirements
2. Functional Servicing Plan (FSR) requirements
3. Stormwater Management Report requirements
4. Sample model parameter table
5. Storm sewer design summary table
6. Detailed landscape design drawings requirements

Checklists for stormwater management reports are provided in Appendix A of this document.

All models submitted to Markham for review must include a summary table within the supporting document presenting all relevant assumptions, input and output files in addition to the following:

1. A schematic flow diagram of the model must be included. The schematic and information must be consistent with other minor and major system diagrams/drawings provided in the report.
2. Parameter Table (Appendix A).

3.8 Legislative Authority and Approvals

Key to the use of the Markham Stormwater Management Guidelines is the understanding of the authority which Markham and its various regulatory stakeholders have over stormwater and environmental management within its jurisdiction. The level of authority influences the various solutions and their implementation. The following is intended to provide practitioners with guidance as to the various approval authorities and the related legislation and guidelines.

Within Markham, a number of policies, programs and guidelines provide guidance to direct the design and implementation of stormwater management practices and the protection of natural features. These policies and guidelines can be administered by Markham, the Toronto and Region Conservation Authority (TRCA), the Ontario Ministries of Natural Resources and Forestry (MNRF), the Ministry of the Environment and Climate Change (MOECC), Agriculture and Agri-Food Canada, and the Department of Fisheries and Oceans Canada (DFO). A summary of the existing guidelines, policies and legislation relevant to this document are provided in Section 1.3.

The proponent is responsible for obtaining all other necessary permits and approvals from some or all of the following agencies:

- Conservation Authorities (Toronto and Region Conservation Authority)
- Ontario Ministry of Transportation
- Ontario Ministry of the Environment and Climate Change
- Ontario Ministry of Natural Resources and Forestry
- Federal Department of Fisheries and Oceans
- Environment Canada

4.0 ANALYTICAL METHODS

4.1 General

This chapter provides an overview of the rainfall datasets and analytical methods which are currently accepted by Markham for hydrologic and hydraulic analyses and design of stormwater management infrastructure. The analytical method and/or model should be selected based upon:

- **The type of project -** urban development proposals, stream rehabilitation/erosion works, and retrofit designs will all have different objectives and modeling requirements.
- **The associated planning stage -** the level of detail required at the Subwatershed Plan stage and Draft Plan of Subdivision Site Plan stage would be different given the various spatial scales.
- **The complexity of the analysis -** design of storm sewer systems is typically undertaken using standardized desktop methods (e.g., Rational Method peak flow analysis for single design events, and Manning Equation uniform flow hydraulics), whereas analysis of stream erosion or groundwater recharge conditions requires more complex techniques (e.g., continuous period hydrologic modeling, and three-dimensional groundwater system modeling).

Additional details and guidance to aid in the selection of an appropriate computer models for hydrologic and hydraulic analysis are provided in the Floodplain Management in Ontario Technical Guidelines (MNR, 2001) and the Ontario Ministry of Transportation Drainage Manual (MTO, 1997), and outlined in Sections 4.2 and 4.3 of this document. While some of the more commonly applied analytical methods are discussed in this Chapter, it is recognized that other techniques and models are available and, further, that the analytical methods will continue to evolve over time. Therefore, discussions with Markham and other review agencies are recommended to confirm the appropriateness of applying alternative analytical methods or models, and to ensure compatibility with broader scale analyses where appropriate (e.g., watershed studies, MESPs).

4.2 Hydrologic Analysis

4.2.1 Intensity/Duration/Frequency (IDF) Relationships

Markham IDF curves were originally derived from the Atmospheric Environment Service (AES) rainfall gauge at Yonge and Bloor Street data. The average intensity of rainfall shall be determined using the following equation:

$$I\ (\text{mm/hr}) = A / (T+B)^{C}$$

where T is Time of Concentration in minutes

Intensity Duration Curves (IDF)

The values of A, B, and C for various return period storms are provided in Table 4.1.

Table 4.1 IDF Statistics for the City of Markham

Return Period	A	B	C
2-year	651.63	3.75	0.80
5-year	1045.41	4.90	0.83
10-year	1331.42	5.26	0.84
25-year	1817.88	6.22	0.87
50-year	1918.97	6.00	0.86
100-year	2167.43	6.03	0.86
The minimum initial time of concentration is to be 10 minutes			

In response to an Application for Review to the Ministry of the Environment (MOE) under the Environmental Bill of Rights, to review policies and regulations for municipal stormwater management systems in Ontario in light of climate change, the Ministry concluded that, in relation to stormwater management, "*Climate change science and modeling currently is not at a level of detail suitable for stormwater management where knowledge of the intensity, duration , frequency of storms and their locations and timing is required* (ref. Policy Review of Municipal Stormwater Management in the Light of Climate Change – Summary Report, MOE, PIBS: 8175e, February 2014)". Notwithstanding this uncertainty in predicting climate change impacts on IDF values, researchers have estimated increases in future intensities using various methods and climate change scenarios.

In order to evaluate potential influence of Climate Change on Markham's design standards, the City commissioned a comparison of the IDF relationships generated from the data collected at the Bloor Street gauge with those generated from the data collected at the more proximate Buttonville Airport gauge. The results of this assessment have indicated that the City's short duration design intensities based upon the Bloor Street gauge are up to 30% above existing Buttonville intensities, and that the City's daily average design intensity is 15% above existing intensities. Therefore, the City's current IDF standards maintain a 'buffer' above current climate intensities that are in line with predicted impacts in several Ontario studies, and hence will continue to maintain the use of the Bloor Street gauge to reflect and consider Climate Change requirements in the short-term.

The City will continue to monitor developments in climate change science and local IDF updates to ensure that City standards remain up to date and consider predicted impacts to future climate changes that should be considered in stormwater design.

4.2.2 Rational Method

Markham approves the use of Rational Method based upon the Markham IDF relationships (Section 4.2.1) generated from the Bloor Street gauge to determine design flows for storm sewer systems design. The Rational Method is not supported for use in establishing other stormwater management criteria (i.e. sizing stormwater management facilities for flood control or erosion control). However; the proponent should consult with City staff to confirm the acceptance of the Rational Method for sizing SWM facilities (e.g. on-site detention) for small sites (less than 5 ha).

Additional information and detail with respect to storm sewer design can be found in Section E – Storm Sewers within the City of Markham Engineering Design Criteria and Standard Drawings.

Storm sewers shall be designed to a 5-year design standard and must be accompanied by the appropriate design spreadsheets and checklists provided in Appendix B. Design flows shall be established using the following equation:

$$Q = KRCiA$$

Where:

- Q = Design flow (m^3/s)
- K = Conversion factor (0.00278)
- C = Runoff coefficient (Table 4.2)
- R = Return period factor (Table 4.3)
- i = Rainfall intensity (mm/hr)
- A = Contributing drainage area (ha)

The currently approved runoff coefficients for use in the design of storm sewers are presented in Table 4.2.

Table 4.2 Runoff Coefficients (C) for various surfaces

Area Type	Runoff Coefficient (C)
Asphalt, concrete, Roof Areas and Parking Lots	0.90
Grassed area	0.25
Parkland	0.40
Water Surfaces (eg. Ponds, Creeks, etc.)	1.00[1.]
Pond Block	0.60
Commercial	0.90
Industrial	0.90
Institutional (Schools and Churches)	0.75
Residential:	
Single family	0.65
Semi-detached	0.70
Row Housing, Town Houses	0.75
Apartments	0.85

NOTE: [1] Where water surfaces are deemed to be a significant portion of the contributing drainage area, the proponent has the opportunity to conduct a storage analysis to refine the runoff coefficient and the influence of the water surfaces on the capacity of the receiving system.

To calculate the corresponding run-off coefficient for existing development or where coefficients may be lower than standard values, the following formula may be used:

$C = 0.25\ (1 - i) + 0.9\ i$ or $i = (C-0.25)/0.65$

Where,

C = Runoff Coefficient

i = Imperviousness Ratio

Supporting calculations demonstrating the calculated imperviousness ratio must be provided. Lower coefficients values may be considered where lot-level best management practices detain 50% or more of the runoff from the City's 5-year design event. Values must be approved by the City.

The runoff coefficients provided in Table 4.2 shall be modified based upon the return period factor (R) in order to account for higher antecedent moisture conditions during more intense storm events, however runoff coefficients shall not exceed 1.0. The applicable adjustment factor for the given return period storm events are summarized in Table 4.3.

Table 4.3 Return Period Factor (R)

Return Period (years)	Return Period Factor (R)
Up to 10	1.0
25	1.1
50	1.2
100	1.25

4.2.3 Event-Based Modelling

Hydrologic analysis for sizing stormwater management infrastructure for flood control, erosion control, and water balance shall be completed using computer modelling. Rainfall data for event-based hydrologic modelling shall apply the 3 hour Markham modified AES design storm distribution.

A mass curve for the 3-hour Markham Design Storm is presented in Figure 4.1. The City's Engineering Standards provide a tabular summary of the 3-hour Markham Design Storm for the 2-year to 100-year return periods; this information is included in Table 4.4 of this document for ease of reference.

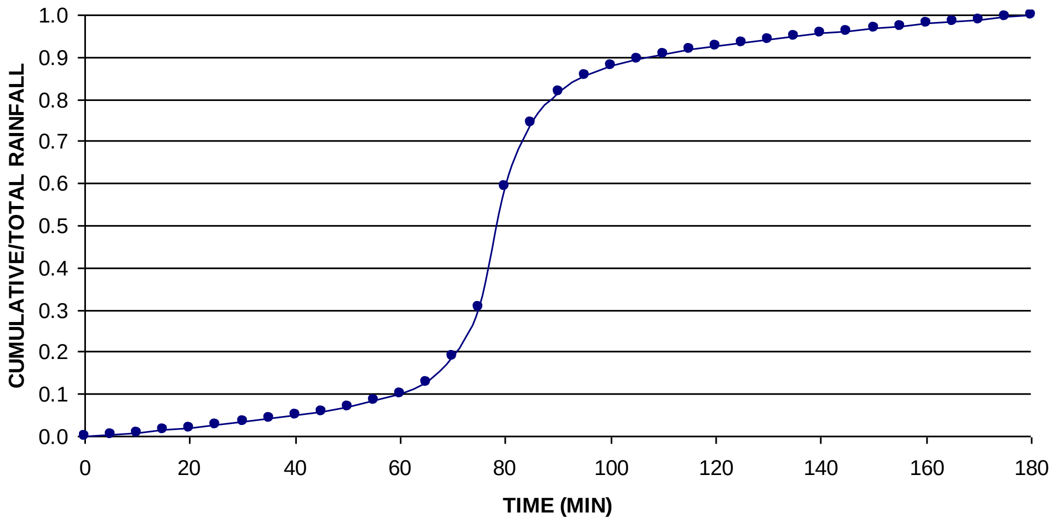

Figure 4.1 Mass –Curve for 3 Hour Markham Design Storm

Table 4.4 Rainfall Intensities for the 3-hour Markham Design Storm

Time (min)	Modified AES Storm for Markham Criteria						
	Mass Curve Mod. AES	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
0	0.0000	0.00	0.00	0.00	0.00	0	0.00
5	0.0045	1.58	2.28	2.69	3.31	3.82	4.34
10	0.0096	1.77	2.55	3.00	3.70	4.32	4.85
15	0.0149	1.86	2.68	3.16	3.89	4.49	5.11
20	0.0205	1.95	2.82	3.32	4.09	4.75	5.36
25	0.0266	2.14	3.08	3.63	4.48	5.17	5.87
30	0.0335	2.42	3.49	4.11	5.06	5.85	6.64
35	0.041	2.61	3.75	4.42	5.45	6.36	7.15
40	0.0495	2.98	4.29	5.06	6.23	7.21	8.17
45	0.0591	3.35	4.83	5.69	7.01	8.14	9.19
50	0.0702	3.91	5.63	6.64	8.18	9.41	10.73
55	0.0838	4.75	6.84	8.06	9.93	11.53	13.02
60	0.1011	6.05	8.71	10.27	12.66	14.67	16.60
65	0.1278	9.35	13.47	15.87	19.56	22.64	25.65
70	0.1901	21.79	31.39	37.00	45.59	52.82	59.79
75	0.3079	41.22	59.37	69.97	86.23	99.87	113.08
80	0.5939	100.07	144.13	169.87	209.33	242.47	274.54
85	0.7458	53.18	76.60	90.28	111.25	128.78	145.90
90	0.8174	25.03	36.05	42.48	52.35	60.70	68.66
95	0.8555	13.35	19.23	22.66	27.93	32.30	36.63
100	0.8788	8.15	11.74	13.84	17.05	19.75	22.37
105	0.8950	5.67	8.16	9.62	11.86	13.73	15.55
110	0.9075	4.38	6.32	7.44	9.17	10.60	12.03
115	0.9179	3.61	5.19	6.12	7.54	8.82	9.89
120	0.9268	3.15	4.53	5.34	6.58	7.55	8.63
125	0.9346	2.70	3.89	4.58	5.65	6.61	7.41
130	0.942	2.61	3.75	4.42	5.45	6.27	7.15
135	0.9489	2.42	3.49	4.11	5.06	5.85	6.64
140	0.9556	2.33	3.35	3.95	4.87	5.68	6.38
145	0.9620	2.23	3.22	3.79	4.67	5.43	6.13
150	0.9681	2.14	3.08	3.63	4.48	5.17	5.87
155	0.9739	2.05	2.95	3.48	4.28	4.92	5.62
160	0.9795	1.95	2.82	3.32	4.09	4.75	5.36
165	0.9848	1.86	2.68	3.16	3.89	4.49	5.11
170	0.9902	1.86	2.68	3.16	3.89	4.58	5.11
175	0.9952	1.77	2.55	3.00	3.70	4.24	4.85
180	1.0000	1.68	2.41	2.84	3.51	4.07	4.60
Total Rainfall (mm)		29.16	42.00	49.50	61.00	70.65	80.00

The 3-hour Markham Design Storm is the preferred standard rainfall distribution for use in studies which use single event modeling. Other distributions may be justified in special situations depending on the type of project, drainage area, and other characteristics of the drainage area.

Other agencies may require the use of an alternative rainfall distribution (e.g., used in watershed-scale hydrology planning). It is the responsibility of the proponent to contact the appropriate agency to determine the appropriate/preferred rainfall distribution(s). In some instances, different hyetographs may be used to identify the governing requirements for different design (e.g., 12 hour post to 12 hour pre watershed hydrology storm may govern storage design, while 3 hour post to 3 hour pre Markham Design Storm may govern peak-flow dependent conveyance design).

4.2.4 Continuous Simulation

Continuous modelling applies a long term time series of historical meteorological data instead of a single synthetic design storm. Continuous models are typically more complex than event based models, as they generally consider more processes of the hydrologic cycle including soil water movement (infiltration), snowpack accumulation and melt, evapotranspiration, groundwater recharge and groundwater discharge to local watercourses. Continuous models are typically utilized during higher level studies/modeling exercises of a watershed and subwatershed studies in determining annual and/or seasonal water balances and related infiltration targets and in watercourse erosion analyses which evaluate cumulative hydraulic stresses on the receiving watercourse system. The use of continuous models may be appropriate for the analysis and design of Low Impact Development Best Management Practices (LID BMP's) in order to more accurately account for the performance of these systems during more frequent less formative storm events, as well as to account for the physical processes of infiltration and/or evaporation within these systems.

As noted in the 2001 MNR Technical Guidelines Continuous modeling is generally conducted with a time series of hourly precipitation, or finer, available from AES for a nearby representative gauging station with at least 30 years of continuous meteorological data.

4.2.5 Hydrologic Models

Some hydrologic models which are currently accepted by Markham for event-based and/or continuous modeling are listed in Table 4.5. Where feasible and appropriate, the hydrologic analyses should apply the currently approved hydrologic model for the study area, as developed from higher level studies (i.e. watershed studies, subwatershed studies, MESP's), refined as required to reflect the subject study area. Discussions with Markham and other review agencies are recommended to confirm the appropriateness of applying alternative models.

Table 4.5 Commonly Used Hydrologic Models for Event-Based Modelling

Model	Application(s)
SWMHYMO	single event
VISUAL OTTHYMO	single event
QUALYMO[1.]	single event or continuous
InfoWorks	single event or continuous
SWMM	single event or continuous
XP-SWMM	single event
PC-SWMM	single event or continuous

NOTE: [1.] QUALHYMO is less preferred as the model is dated and less formally supported/maintained.

Sound modeling standards of practice should be followed in developing an event based model. The following standards of practice are recommended for Markham:

1. All assumptions should be provided with rationale for their selection;
2. Provide the purpose for developing the hydrologic model, such as determining flow rates, runoff volumes, flow routing effects for proposed development, and existing land use conditions;
3. Provide the study objectives and how they relate to the hydrologic modeling;
4. Provide the model selection criteria and how the model matches the criteria;
5. Provide the basis for the storm design information, outlining how the design storm has been selected;
6. Provide drainage area plans outlining both internal and external catchments, modeling schematics, and tables providing drainage area parameters;
7. Background information on the selection of the drainage area parameters should be provided to assist the review in understanding on the assumptions leading to the drainage area parameters;
8. Background data on overland (major) and minor storm systems should be provided with plans clearly presenting and labeling both systems;
9. Data should be provided on routing through natural and manmade storage systems, with detailed plans and calculations outlining how the stage/discharge relationship has been developed;
10. For complex models (i.e. models with several subcatchment parameters, integrated models, complex routing routines) and major studies, sensitivity analysis should be conducted on a number of key parameters;
11. For complex models and major studies, verification or validation of results should be provided through various methods such as calibration to recorded stream flow, observed water level, unit flow rates and runoff volume comparison using a technique such as the

MTO index method or equivalent. The application of the validation technique (number and type) will depend on the availability of data and the sensitivity of the analysis;

12. All input and output details should be provided in a logical manner, with an explanation for potential errors;
13. A schematic flow diagram of the model must be included. The schematic and information must be consistent with other minor and major system diagrams/drawings provided in the report;

Low impact development measures require special consideration in selection of analytical methods. In early planning stages, criteria for these measures (e.g., infiltration, erosion, etc.) may be based on continuous period hydrologic analysis considering cumulative hydraulic stresses on the receiving watercourse system. At the functional servicing and design stage, the design and placement of necessary stormwater management measures may consider single event hydrologic analysis for stormwater management measures where continuous period benefits can be achieved if performance for a particular design event is adequate. The simplification from continuous to single event analysis is warranted only for storage measures that have a high probability of draining between typical consecutive rainfall events (typically 48 hours or less). Where target draw down times are not met, continuous modeling methods may be required to ensure that the original long-term performance benefits are achieved.

4.3 Hydraulic Analysis

4.3.1 Manning's Equation

Markham approves the use of Manning's Equation for Rational Method to determine design capacity for storm sewers. The capacity calculations shall be based upon the 5-year design flow determined from the hydrologic analysis using Markham IDF relationships, and applying the applicable roughness coefficient as provided in Table 4.6.

Table 4.6 Roughness Coefficient 'n' to be used in the Manning's Formula for Storm Sewers and Pipes

Pipe Material Type	Manning's 'n'
Concrete Pipe	0.013
Corrugated Metal	0.024
PVC Pipe	0.013

The design capacity of surface drainage systems (i.e. ditches, watercourses, road rights-of-way) may be calculated using Manning's Equation or computer models. Where computer models are to be used, roughness coefficients for surface drainage systems shall be selected based upon the guidance provided in the User's Manual for the corresponding design conditions. Markham approves the use of Manning's Equation to determine the capacity of surface systems conveying runoff with low flow depths at the design condition (i.e. depths of flow less than 0.5 m). Acceptable roughness coefficients to be used for the hydraulic analysis of surface drainage systems using Manning's Equation are summarized in Table 4.7. Further guidance may be found in the MTO Drainage Manual (MTO, 1997) and the Highway Drainage Design Standards (MTO, January 2008).

Table 4.7 Roughness Coefficient 'n' to be used in the Manning's Equation for Surface Drainage Systems

Surface Type	Manning's 'n'
Roads and Gutters (concrete or asphalt)	0.015
Concrete Channel	0.017
Earth Channel with Maintained Grass	0.035
Rock Lined Channel	0.040
Unmaintained Channel with Dense Weeds	0.100
Unmaintained Channel with Dense Brush	0.120

4.3.2 Hydraulic Models

Computer modeling is required by Markham to determine the design capacity of major drainage systems (i.e. watercourses and corridors, and roadway drainage, culverts and bridges). Some of the hydraulic models which are currently accepted by Markham, and their associated applications, are listed in Table 4.8. Where feasible and appropriate, the hydraulic analyses for the major systems should apply the currently approved hydraulic model for the major system, as developed from higher level studies (i.e. watershed studies, subwatershed studies, MESP's), refined as required to reflect the subject study area. Discussions with Markham and other review agencies are recommended to confirm the appropriateness of applying alternative models.

Table 4.8 Commonly Used Hydraulic Models

Model	Application(s)
HEC-RAS	open channel, culvert / bridge structures
CULVERT MASTER	culvert structures
FLOWMASTER	open channel culvert, pipe
SWMM	urban storm drainage system analysis
OTTSWMM	urban storm drainage system analysis
XP-SWMM	urban storm drainage system analysis
PC-SWMM	urban storm drainage system analysis
InfoWorks	urban storm drainage system analysis,

While Markham accepts the use of one-dimensional modelling for hydraulic analysis, certain circumstances may require the use of more sophisticated (i.e. two-dimensional) modelling for hydraulic analysis. The proponent should consult with Markham and TRCA to confirm the appropriate modelling platform and methodology for conducting hydraulic analyses.

Sound hydraulic modeling standards of practice should be followed in developing a model. The following standards of practice are recommended:

1. Clearly identify the study purpose, objectives and how they relate to the hydraulic modeling;
2. Provide the model selection criteria and how the model matches the criteria. This should also include a summary of any and all model limitations;
3. Provide all assumptions with rationale for their selection.
4. Provide plans clearly presenting the closed and/or open hydraulic system;
5. For open systems – clearly present the cross sections, study limits, land use, crossing details, spill areas, ineffective flow areas, and flooding limits and elevations for the appropriate design event(s). Preparation of the model should be such that it fully contains the modeled flows without exceeding the hydraulic cross-section. Should it not be possible to contain the flows within the defined geometry of the open storm system, the proponent should provide details on the spill characteristics. In the event of a spill, rationale should be provided on whether or not to include a flow loss in the calculation;
6. For closed system (i.e., storm sewers) - clearly present the storm sewer network details including manhole numbers, storm sewer size, length, study limits, land use, slope, and sewer and ground elevations;
7. For combined hydrologic/hydraulic models such as InfoWorks or SWMM - provide plans that not only describe the closed system but also the contributing drainage areas and overland flow system;
8. For all hydraulic models - provide the downstream and, if applicable, the upstream boundary conditions for each storm modeled and the assumptions used to define the boundary conditions. Document the parameters established for hydraulic losses such as Manning's 'n', inlet and outlet losses and other appropriate losses;
9. Summarize the selection of procedures for determining the computed energy grade line and water surface elevations;
10. Document the hydraulic results in summary form for the relevant storm events;
11. Document potential impacts on existing infrastructure and possible mitigation measures;
12. For complex models and major studies, sensitivity analysis should be conducted on a number of parameters;
13. If possible, verify hydraulic results for an existing closed/open storm system by documenting historical flood elevations for specific storm events and comparing the hydraulic modeling results to the historic data; calibration of losses should be included, if sufficient data exists;
14. Provide the input and output data in a logical manner with an explanation of the potential error; and
15. A schematic flow diagram of the model must be included. The schematic and information must be consistent with other minor and major system diagrams/drawings provided in the report.

5.0 GOVERNING ENVIRONMENTAL DESIGN CRITERIA

5.1 Introduction

The governing environmental design criteria for stormwater management are specified in the 2003 Ministry of the Environment Stormwater Management Planning and Design Manual (MOE SWMPD Manual). These represent the general criteria as currently provided by the Province of Ontario, and include:

- Preservation of groundwater and baseflow characteristics;
- Prevention of undesirable geomorphic changes in the watercourse;
- Prevention of any increase in flood risk potential;
- Protection of water quality;
- Maintenance of an appropriate diversity of aquatic life and opportunities for human uses.

In addition to the Provincial criteria as prescribed by the Ministry of the Environment and Climate Change (MOECC), more specific criteria are provided within other documents, including Watershed Plans, Subwatershed Studies, and Master Environmental Servicing Plans. In certain areas, stormwater management may be required to address other environmental design criteria (i.e. Species At Risk).

This chapter summarizes the applicable design criteria for new greenfield and infill/intensification type developments within Markham urban boundaries. General environmental criteria to be used in the absence of higher level planning studies (i.e. Watershed Plans, Subwatershed Studies, MESPs, etc.) is provided and area-specific criteria developed as part of relevant watershed/subwatershed studies, Master Environmental Servicing Plans (MESPs) etc. are referenced where applicable. It is the responsibility of the designer to consult with Markham, TRCA, and other agencies as appropriate in order to confirm the governing and applicable criteria for stormwater management system design. It is the objective of this chapter to provide stormwater practitioners with the appropriate design criteria originating from the MOE SWMPD Manual (2003) and the TRCA Criteria Document in addition to Markham specific design criteria that reflect the results of local studies and associated requirements.

Although this section distinguishes between the requirements to provide for flood protection, water quality, erosion control, infiltration and natural features it should be recognized that achieving the required design criteria will be dependent upon minimizing the impact that urbanization has on the overall hydrologic cycle (i.e. water budget). Designing a stormwater management system that controls the volume of runoff by encouraging water to infiltrate into the ground, evapotranspirate, and/or be re-used, is important to sustaining groundwater resources, and in turn, maintaining the baseflow to creeks and other natural features that rely on surface and groundwater resources.

5.2 General

Stormwater management is required to satisfy flood control criteria, erosion control criteria, water quality criteria, infiltration criteria and criteria for the protection of natural heritage features. The specific applicable criteria for a given site are recognized to be dependent upon many factors including:

- Location of proposed site within the relevant watersheds;
- Location within Markham;
- The type of development (Greenfield or redevelopment/intensification); and
- The presence of identified local constraints.

A summary of the environmental design criteria is provided in Table 5.1

Table 5.1 Summary of Environmental Design Criteria

ENVIRONMENTAL DESIGN CRITERIA	ADDITIONAL INFORMATION / COMMENTS
FLOOD CONTROL CRITERIA (Section 5.3) Control Peak Flows to the governing criteria of: i. appropriate Watershed/ Subwatershed Flood Control Criteria to manage riverine flooding as described in Section 5.3.1. and ii. appropriate Local Storm Drainage Control Criteria to manage drainage infrastructure capacity as described in Section 5.3.2	1. Development defined by latest approved watershed hydrology model 2. Hydrologic study may be required to update approved watershed hydrology for lands beyond current Official Plans 3. Hydraulic analysis of downstream infrastructure may be required to identify minor and major systems criteria.
WATER QUALITY CRITERIA (Section 5.4) Enhanced Level of Protection for long term TSS removal is required as per 2003 MOE Manual Temperature impacts of development must be mitigated through use of appropriate BMPs in accordance with governing Provincial legislation.	1. Recommended approach is similar to that described in 2003 MOE Manual 2. Infiltration/filtration is encouraged in all soil types; other LID practices are encouraged where soil types provide limited infiltration. 3. Downstream monitoring required to demonstrate compliance with water quality criteria (see Section 13) 4. Approvals of mitigative measures to protect endangered species may be required from the MNRF as per the Endangered Species Act (see Section 1.3).
EROSION CONTROL CRITERIA (Section 5.5)	1. Simplified approach is similar to methodology outlined in 2003 MOE Manual.

ENVIRONMENTAL DESIGN CRITERIA	ADDITIONAL INFORMATION / COMMENTS
Simplified Approach: For developments or sites lacking erosion control criteria determined through large-scale studies; and for infill developments, redevelopments, and intensifications in excess of 5 ha erosion requirements based on mitigating increased erosion potential from runoff from a 25 mm event For infill developments, redevelopments, and intensifications less than 5 ha, erosion control can be addressed using runoff volume reduction measures. As a minimum, developments which meet the above criteria, must capture and retain, infiltrate, or re-use an equivalent of the first 5 mm of runoff from all impervious surfaces. Detailed Approach: For MESPs and Subwatershed Studies, erosion requirements based on a number of factors including channel assessment (existing type and condition of receiving streams) and channel erosion targets	2. Detailed approach requires geomorphic field assessment work, consultation with TRCA and continuous modeling. Standard erosion thresholds for different stream types can be obtained from the TRCA. 3. Local Municipal Erosion Criteria as defined in completed studies such as Pomona Mills Creek and Eckhardt Creek Erosion Optimization study provide recommendations for local erosion control requirements.
INFILTRATION AND WATER BUDGET CRITERIA (Section 5.6) Maintain pre-development water balance using on-site infiltration to the maximum extent feasible to the governing criteria of: • All areas confirmed as having significant recharge within the Rouge River Watershed as per the RRWP and the City of Markham Official Plan; • Maintain pre-development water balance for Redside Dace Streams per the MNRF Draft Guidance for Development Activities in Redside Dace Protected Habitat • Maintain post-development recharge at pre-development levels for areas identified as Ecologically Significant Groundwater Recharge Areas (EGRA) • Maintain function of hydrologically sensitive features as defined in the Oak Ridges Moraine Conservation Plan, and key	1. In general, for Highly Vulnerable Areas (HVAs), infiltration from surfaces that increase water quality risks (i.e. roads, parking lots, storage areas on industrial lands, etc.) should be avoided. 2. Restrictions exist in areas of seasonally high water table, bedrock outcrops, floodplains and wetlands and associated hydric soils. For infiltration practices in soils less than 15 mm/hr, use of an alternative methods such as underdrain system is required. (See 2010 TRCA/CVC LID guide for additional guidance.) 3. Infiltration within HVAs only permitted from roof and landscaped areas without completion of an appropriate risk assessment in consultation with Markham, Region of York and TRCA staff.

ENVIRONMENTAL DESIGN CRITERIA	ADDITIONAL INFORMATION / COMMENTS
hydrologic features identified in the Greenbelt Plan, including permanent and intermittent streams, seepage areas and springs. • Maintain water budget to natural features (wetlands, woodlots, streams)	4. Process for maintaining water budget to natural features required definition of natural features and baseline characterization of the water budget to the feature under existing conditions. Per the TRCA/CVC Headwater Drainage Features Guidelines (July 2013 Revised), watercourse features providing recharge functions require that overall water balance be maintained by providing mitigation measures to infiltrate clean stormwater unless the area qualifies as an Area of High Aquifer Vulnerability under the Oak Ridges Moraine Conservation Plan or Significant Recharge Areas under the Source Water Protection Act; these areas will be subject to specific policies under their respective legislation.

5.3 Flood Control Criteria

Stormwater quantity controls to provide flood control are required based upon Watershed/ Subwatershed-scale criteria and local storm drainage criteria.

The Watershed/Subwatershed scale control criteria are intended to manage riverine-based flood risks related to flood hazards along watercourses and at watercourse crossings. These are derived from the TRCA's Stormwater Management Criteria (August 2012) document and included in Markham Engineering Design Criteria document.

Local storm drainage control criteria are intended to manage flood hazards and address capacity constraints related to receiving drainage infrastructure, including storm sewers and overland flow routes. Local criteria may represent the governing or constraining criteria (i.e., quantity control requirements to manage sewer surcharge, basement flooding or roadway flooding; these may be more stringent than those required to manage watercourse flooding risks). Nevertheless, in all cases, stormwater quantity controls shall be applied to satisfy both the watershed/subwatershed scale criteria and the local criteria.

Criteria:

- Control peak flows to the most stringent criteria as they relate to Watershed/Subwatershed Flood Control Criteria (Section 5.3.1) or Local Storm Drainage Control Criteria (Section 5.3.2).

5.3.1 Watershed/Subwatershed Flood Control

Markham has portions of the Rouge River Watershed, the Don River Watershed, the Highland Creek Watershed, the Duffins Creek Watershed, and the Petticoat Creek Watershed within its limits (Figure 3.2). Stormwater management criteria related to flood control at the watershed-scale vary among the different watersheds, due to the characteristics and constraints which are unique to each system. In addition, the flood control criteria may vary within a given watershed (i.e. at the subwatershed scale) due to similar variations in physical characteristics and constraints.

Watershed/subwatershed flood control criteria are provided within the respective Watershed Plans, Subwatershed Studies, and governing Master Environmental Servicing Plans. It is recommended that the designer pre-consult with Markham and the TRCA in order to confirm the applicable approved watershed/subwatershed scale criteria for stormwater quantity control for flood control. Proponents are required to comply with the most conservative approach if two or more studies provide different flood control recommendations and targets.

As noted, the watershed/subwatershed flood criteria may be superseded by:

- Local constraints such as:
  - Flood vulnerable areas (Special Policy Areas and designated Flood Damage Centres)
  - Active valley land uses; and
  - River or creek crossings
- Results of local studies that may have identified flood vulnerable areas (e.g., Don Mills Ditch Capacity Remediation Class EA Study)

For relevant Local Storm Drainage Criteria see Section 5.3.2

In all cases the proponents should consult with Markham and TRCA staff to confirm the criteria to be utilized. Where feasible and appropriate, the analytical methodology and approved models applied for the higher level studies should be applied for the more site specific analyses to avoid modeling bias. Any alternative approaches must first be reviewed with Markham and TRCA to confirm acceptance for use. In some instances both the watershed and Markham distributions may be required for use in the analysis.

5.3.1.1 Special Policy Areas (SPA)

Special Policy Areas (SPAs) are historic communities that exist within the regulated flood plain and are expected to provide continued viability of existing uses, and provide compliance with site-specific flood hazard management policies. Site–specific policies associated with SPAs include flood proofing, flood remediation and risk reduction measures. A number of areas adjacent to the Main Rouge River between Warden Ave. and McCowan Rd, as well as connecting areas adjacent to Bruce and Fonthill Creeks (including the historical Unionville Village) are designated as SPAs by the Province. Figure 5.2 depicts the currently designated Special Policy Areas within Markham.

These historic areas of Markham were developed prior to the implementation of Provincial flood plain planning policy. These areas are subject to flooding from the Regional Storm (and in some cases more frequent events) and therefore require careful management of development within those areas, as well as in upstream locations. The SPA policies provide for new development and redevelopment opportunity within the SPA, subject to planning considerations and structural flood protection.

The SPA policies prohibit development where flood risks would create an unacceptable hazard, could result in structural damage and/or the required flood proofing would have a negative effect on adjoining properties. The SPA polices include prohibited property uses for those land units designated within SPAs. The flood protection criteria for new development and redevelopment areas designated within the SPA may supersede watershed-scale flood control criteria. The increased flood risk to properties within the SPA, including increased flood risk during the Regional Storm event, may require additional upstream control for new development and/or redevelopments to ensure flood risks do not increase. Proponents are directed to confirm requirement with Markham and TRCA.

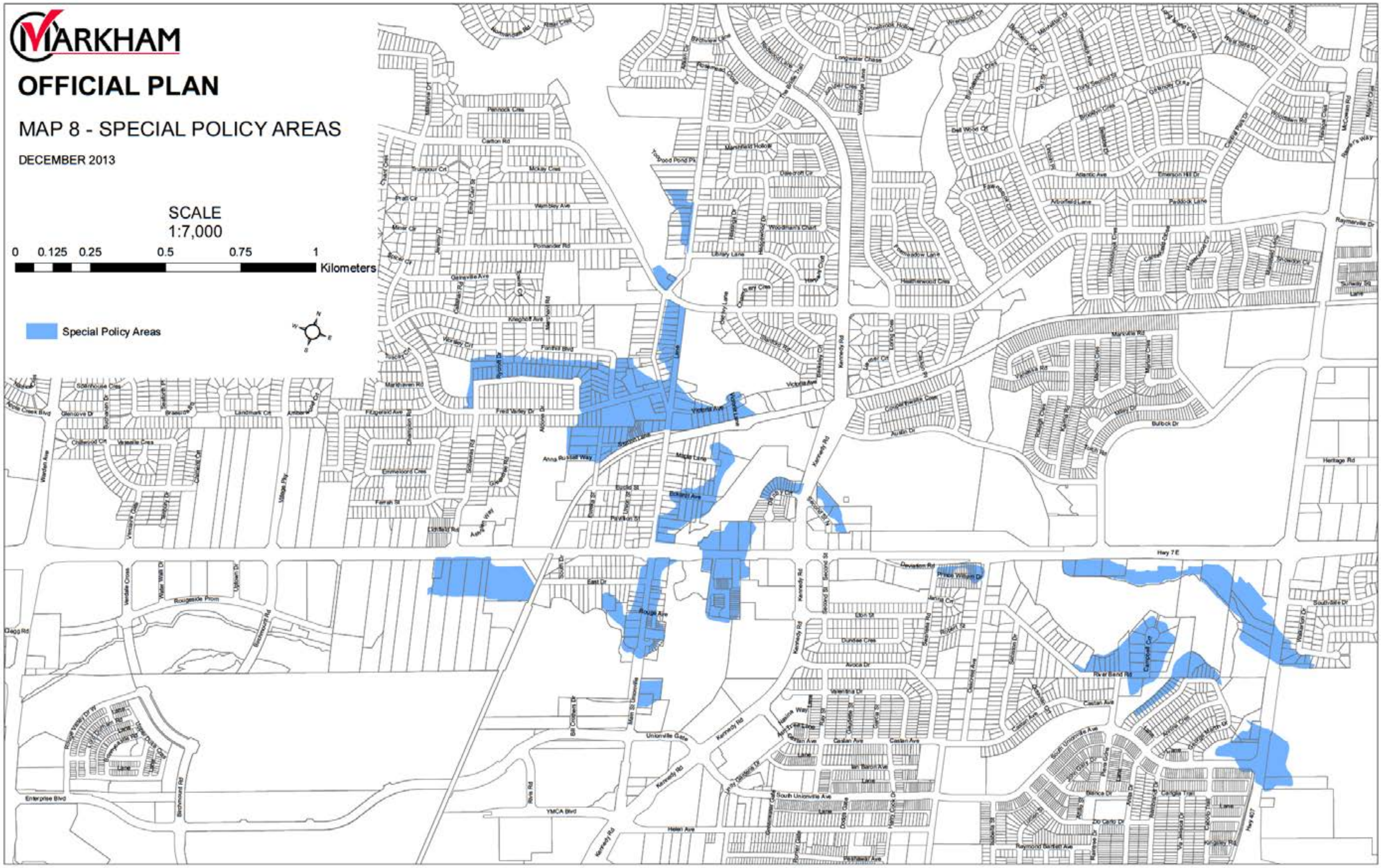

Figure 5.2 Special Policy Areas (SPAs) within the City of Markham (Source: Markham OP)

5.3.2 Local Storm Drainage Control Criteria

Local storm drainage control criteria are intended to manage flood hazards related to constraints imposed by existing municipal drainage infrastructure, including storm sewers, overland flow routes and other hydraulic structures. As a significant portion of Markham has previously been developed, the existing drainage system and infrastructure constraints require specific local flood control criteria. These local storm drainage control criteria are intended to mitigate potential local flooding impacts (i.e. sewer surcharging, basement flooding and/or overland flooding etc.). While local constraints related to hydraulic capacity of receiving systems and associated potential for flooding should be evaluated as part of any development application, this is recognized to be of particular significance for infill development, redevelopment, and intensification within the existing urban areas of Markham especially upstream of the flood prone areas. Analyses for local storm drainage control criteria should consider both interim and ultimate conditions, if proposed changes to the receiving system and/or stormwater management system are proposed following development.

5.3.2.1 Redevelopment, Infill and Intensification within Markham

Redevelopment and Infill/Intensification projects generally consist of development projects for relatively small sites (i.e. generally 5 ha or less) which are located within currently urbanized areas. For redevelopment projects, the property of interest is either currently developed and proposed to undergo some alteration to provide a new use; for infill development projects, the property is undeveloped but surrounded by existing developed which impose unique servicing and grading constraints. Redevelopment and Infill/Intensification projects present the following challenges related to stormwater management for flood control:

- opportunities to provide stormwater management within centralized multi-party facilities are typically difficult due to the presence of historic development and infrastructure which separate the development area from the potential centralized facility;
- sites are typically constrained with respect to the extent of potential open space available to provide on-site stormwater management;
- there is typically limited flexibility to manipulate topography since grades around the perimeter of the site are fixed;
- servicing infrastructure around and downstream of the site, including stormwater conveyance systems are typically fixed in terms of location, depth and capacity; and
- the presence of other servicing infrastructure beneath and around the site may limit potential excavation depths and opportunities for infiltration.

Redevelopment, infill and intensification projects can range in size from a single lot to the complete redevelopment of significantly larger areas. Many forms of these types of development can be more intensive than previous uses and have higher levels of imperviousness (e.g. more pavement, roads, roof area, etc.) and corresponding higher runoff rates. Existing infrastructure that receives this runoff may have capacity limitations associated with the design standards in place at the time of construction. Stormwater conveyance standards in various areas are shown on Figure 5.3 and must be considered to identify local storm drainage control requirements. Historical drainage system design standards in Markham are generally summarized by era as follows:

- Pre 1978: Minor system designed to 2-year event with no major system design criteria
- 1978-1983: Minor system designed to 2-year event and major system designed to 100-year
- 1983-1995: Minor system designed to 2 and 5-year event and major system designed to 100-year
- 1995-Current: Minor system designed to 5-year event and major system designed to 100-year

The hydraulic constraints of the receiving system must be identified in order to establish local capacity constraints and associated local storm drainage control requirements.

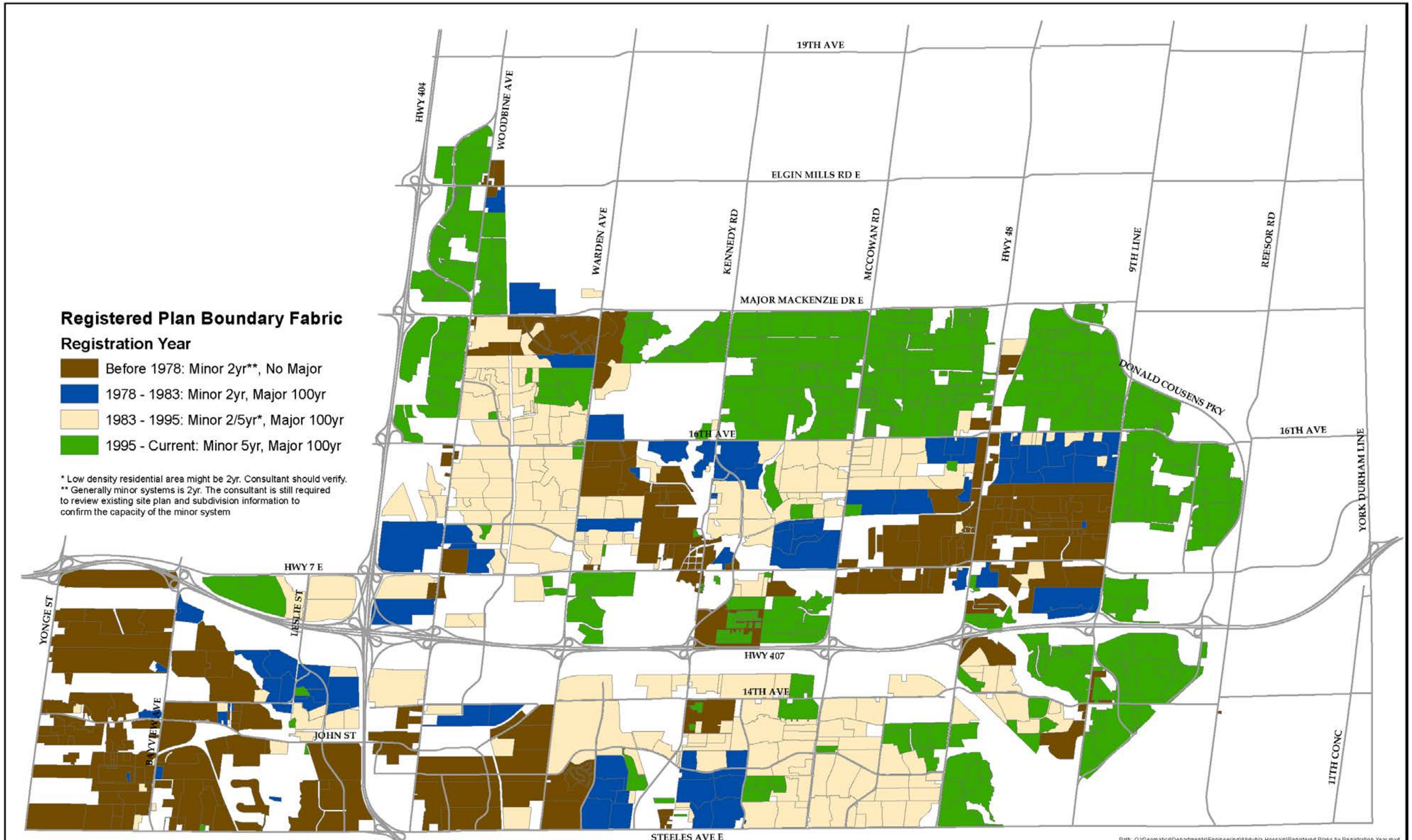

Figure 5.3: Development Areas within Markham with construction era and stormwater conveyance standards

For infill development the target release rates shall be established based upon the undeveloped land use condition for the subject development area. For redevelopment/intensification, the target release rates shall be established based upon the existing developed condition for the site. For single lot developments (generally measuring less than 0.3 ha), Low Impact Development Best Management Practices (LID BMP's) shall be implemented at-source to compensate for the additional impervious coverage, and shall be sized assuming a 50% loss of efficiency over time.

Where the receiving system has been designed with a minor system but no major system, all infill, redevelopment, and intensification shall provide appropriate stormwater quantity control to manage the 100-year peak flow under post-developed conditions to the target release rate corresponding to the design capacity of the receiving minor system. Where the receiving system has been designed with both major and minor conveyance systems, all infill, redevelopment, and intensification shall provide appropriate stormwater quantity controls to control the minor system discharge to the capacity of the receiving minor system, as well as control the total post-developed 100-year discharge rate to the target 100-year discharge rate. Given that the receiving system can often extend large distances downstream, it will be a requirement for the proponent to discuss the extent of the minor and major system capacity assessment with Markham staff in advance in order to establish appropriate assessment limits.

In all cases, Markham will not allow worsening of the performance of the existing downstream minor and/or major systems caused by infill, redevelopment, and intensification.

5.4 Water Quality Criteria

Stormwater quality control requirements for Markham are established in the respective Watershed Plans, Subwatershed Studies, MESPs and MOECC documents. In addition, Markham has completed a Stormwater Quality Retrofit Plan, which has identified strategic locations for retrofit opportunities to improve stormwater quality and quantity controls.

The stormwater quality control requirements for new development and infill/redevelopment within Markham are as follows:

- Criteria established in the higher level studies e.g. respective watershed, subwatershed studies and MESPs.
- In absence of the above studies, Enhance level (80% TSS removal) quality control as per MOECC guidelines.
- Any industrial, institutional and commercial site plan development (greater than or equal to 0.3 ha) needs on-site spill control, regardless if there is a downstream SWM facility or not. Spill Control Criteria:
  - 50% TSS removal if there is a downstream SWM wet pond
  - 80% TSS removal, if there is no downstream SWM wet pond.

The above application of TSS sizing for spill control represents one approach acceptable to the City. Alternative approaches may be considered, provided that sufficient technical justification is provided. City requirements to provide spill protection may be addressed through the completion of spill prevention and contingency plans as required through Environmental

Protection Act (Ontario Regulation 224/07). Proponents are also required to comply with the requirements of the Source Water Protection Plan under the Clean Water Act.

In addition to the above requirements, all stormwater that may impact species at risk is subject to provisions of the Endangered Species Act. As such, all developments within the Rouge River Watershed are required to provide specific stormwater quality controls to address requirements associated with Species At Risk Act (i.e. Redside Dace). Proponents should consult with Markham, TRCA, and MNRF to confirm the governing stormwater quality control criteria for the subject development area and for details regarding retrofit opportunities within Markham.

5.5 Erosion Control Criteria

The following section is intended to provide the practitioners with design guidance, as it relates to erosion control criteria. It describes the approach used to identify erosion control targets to mitigate the impact of stormwater discharge into the drainage network from a proposed development or redevelopment area.

Stormwater management requirements for erosion protection for greenfield developments are required to comply with the governing Watershed or Subwatershed study and/or MESP where applicable. As part of a Subwatershed Study or MESP, an erosion analysis is conducted to assess the impact of development on in-stream erosion potential in the downstream receiving drainage network. The results of those analyses are used to establish extended detention criteria (volumes and release rates), and in some cases runoff volume control criteria, for the overall stormwater management strategy. The approach consists of three components:

1. Selection of an appropriate study area, field survey of watercourse reaches within the study area, and calculation of reach-based erosion thresholds.
2. Assessment of changes to flow regime and in-stream erosion potential resulting from proposed development, using continuous simulation hydrologic modelling.
3. Determination of stormwater management facility extended detention and runoff volume control criteria to maintain existing in-stream erosion potential under post-development conditions throughout the study area.

The field characterization results and documentation must be completed under the seal and signature of a professional geoscientist or professional engineer qualified to practice in the field fluvial geomorphology. The continuous modelling and selection of stormwater criteria must similarly be completed under the seal and signature of a qualified professional water resources engineer.

It is recommended that the proponent consult with Markham and TRCA to confirm the applicable erosion control criteria for the development area prior to undertaking any erosion assessments.

In the absence of guidance from higher level studies a simplified approach may be applied for infill and redevelopment/intensification developments for which erosion control criteria are not provided by through higher-level studies or Municipal erosion control studies. For infill developments, redevelopments, and intensifications in excess of 5 ha, erosion control may be provided within end-of-pipe stormwater management facilities, provided that the stormwater management facility for the development provides extended detention of runoff from a 25 mm event for a minimum of 24 hours (48 hours where possible).

For infill developments, redevelopments, and intensifications less than 5 ha, erosion control can be addressed using runoff volume reduction measures, since end-of-pipe extended detention storage facilities are often impractical for such small drainage areas. As a minimum, developments which meet the above criteria, must capture and retain, infiltrate, or re-use an equivalent of the first 5 mm of runoff from all impervious surfaces. This approach can only be applied for isolated developments, and as such is inappropriate for multiple developments that comprise a part of a larger intensification and re-developments.

5.6 Infiltration and Water Budget Criteria

Stormwater management practices are encouraged to also preserve groundwater quantity and baseflow characteristics by ensuring that sufficient water is infiltrated, or recharged, into the ground under post development conditions as compared to existing conditions. The pre-development water budget is to be maintained on an average annual basis using on-site infiltration to the maximum extent feasible to the governing criteria of:

- All areas confirmed as having significant recharge within the Rouge River Watershed as per the RRWP and the City of Markham OP;
- Maintain pre-development water balance for Redside Dace Streams per the MNRF Draft Guidance for Development Activities in Redside Dace Protected Habitat;
- Maintain post-development recharge at pre-development levels for areas identified as Ecologically Significant Groundwater Recharge Areas (EGRA);
- Maintain, improve or restore those elements that contribute to the ecological and hydrologic functions of the Oak Ridges Moraine Area, including the quality and quantity of its water and its other resources as per the Oak Ridges Moraine Conservation Plan;
- Protect, improve or restore the quality and quantity of ground and surface water and the hydrologic integrity of water as per the Greenbelt Plan (ref. Ministry of Municipal Affairs and Housing, 2005)

Natural features, such as wetlands, woodlands, and streams are integral components of the natural landscape that can be impacted following urban development. Impacts are often linked to changes in hydrology, including changes in water quantity (rate and volume), quality, duration, frequency of flow, and spatial distribution of flow (locations of discharge). Water budget measures are typically required in order to demonstrate that flow regimes will be maintained to the extent feasible in the post-development scenario. Guidelines to specifically address impacts at the feature-scale are critical to the maintenance of natural heritage features and functions. The 2012 TRCA SWM Criteria Document provides separate approaches for each feature type.

In all cases, proponents should consult with Markham and TRCA to confirm the targets to be used. Proponents may have to additionally contact MNRF where species at risk or features of provincial interest are potentially impacted. Stormwater management practices which are located on private properties and which promote infiltration and maintaining the water budget present a challenge with respect to required operation and maintenance activities necessary to preserve the long-term reliability of these systems. Consequently, proponents should consult with Markham to determine the City's requirements to maintain the long-term effectiveness of LID BMPs on private property, in order to obtain any credits toward the sizing of end-of-pipe facilities for erosion and stormwater quality control. Notwithstanding, the application of stormwater management practices on private properties to promote infiltration and maintain water budgets shall not be considered in the sizing of end-of-pipe facilities to provide flood control.

The recommended steps for determining existing recharge rates and post-development targets at the site scale and selection of appropriate mitigation strategies are in consultation with by TRCA, the Ministry of Natural Resources and Forestry, and the Ministry of the Environment and Climate Change. Proponents are encouraged to pre-consult with the foregoing agencies to determine requirements for managing groundwater recharge.

6.0 STORMWATER MANAGEMENT INFRASTRUCTURE DESIGN CRITERIA

6.1 General Introduction

This section outlines the criteria for the design of Storm Sewers and related appurtenances in Markham.

6.2 Dual Drainage Concept: Design of Minor and Major Systems

Storm drainage system design is comprised of a *minor* system and a *major* system. The minor system consists of sewers and ditches designed to convey runoff from more frequent storms, thereby conveying the runoff from frequently used or travelled surfaces. The major system represents the overland route where the excess runoff will follow when the minor system capacity is exceeded. The major system includes such features as natural and constructed open channels, streets and roadways, and overland drainage easements.

Various methodologies may be applied for the analysis of the dual drainage system. The following methodologies are commonly applied, and may be acceptable for application subject to approval from Markham:

- Spreadsheet methodologies (i.e. Manning's Equation/Bernoulli's Equation for minor system capacity analysis and Manning's Equation for major system analysis)
- Separate computer models for major and minor system (i.e. minor system capacity analysis using a closed conduit model, major system capacity analysis using an open channel model)
- Integrated major and minor system models (i.e. SWMM-based model, infoWorks, others)

Hydrologic analyses for major and minor system designs shall account for the presence/absence of direct rooftop and foundation drain connections. The proponent is encouraged to pre-consult with Markham staff to establish the most appropriate methodology and model platform to be applied for the given assessment.

The hydrologic analyses for the minor system may be completed using the Rational Method or computer modelling described in Section 4.2. Hydrologic analyses for the major system shall be completed using appropriate computer modelling methodologies. Computer modelling using design events shall apply Markham's modified AES distribution, and the current IDF relationships for Markham based upon the Bloor Street rainfall gauge. As discussed in Section 4.2, Markham's short duration design intensities based upon the Bloor Street gauge are up to 30% above existing Buttonville intensities, and that Markham's daily average design intensity is 15% above existing intensities. Markham's current IDF standards maintain a 'buffer' above current climate intensities that is in line with predicted impacts in several Ontario studies.

6.2.1 Minor System Design Criteria

The minor systems shall be designed in accordance with the current Engineering Design Standards of Markham . The proponent is encouraged to pre-consult with City staff to confirm the most current design standards to be applied.

Storm Sewers

Storm sewers shall be designed to accommodate a 5-year design storm. Storm sewers shall be sized using the Rational Method and Manning's Equation as outlined in Sections 4.2 and 4.3, such that the 5 year event design peak flow represents no more than 85% of the total capacity of the pipe. Storm sewers shall be designed in accordance with the criteria provided in the City of Markham's Engineering Standards.

Hydraulic analysis of the proposed and existing storm sewer system shall be completed for the 5-year and 100-year storm events. The 5 year hydraulic grade line (HGL) analysis is required to confirm that no surcharge would occur during a 5year storm event. The 100 year HGL analysis shall demonstrate that the basement slab elevations are a minimum of 0.5 m above the 100-year HGL. Where storm sewers discharge to stormwater management facilities, the extended detention water surface elevation within the stormwater management facility shall be applied as the boundary condition for the HGL analysis of the 5-year event, and the 100-year water surface elevation shall be applied as the boundary condition for the HGL analysis of the unobstructed inlet capacity condition. The 100-year HGL should be clearly indicated on all plans and profiles where relevant. HGL calculations are to be incorporated into the 5-year and 100-year Storm Sewer Design Sheets.

Sewers discharging directly to watercourses shall be designed such that the invert is at a minimum above the 5 year water surface elevation within the receiving watercourse. Where conditions and constraints preclude the possibility of designing the sewer outlet above the 5 year water surface elevation, hydraulic analyses shall be completed to demonstrate that the sewer would adequately convey the 5 year flow without surcharging or flooding under the submerged or partially submerged conditions at the outfall. A 100 year HGL analysis shall also be completed for storm sewers discharging to open watercourses. The boundary condition for the 100-year HGL analysis shall be established in consultation with City staff, with consideration for the size of the drainage area upstream of the sewer outfall and the potential difference (i.e. lag) in peak flow timing between the sewershed and the upstream drainage area.

Where the storm sewers are proposed to connect to existing sewer networks, hydraulic analyses shall be completed to demonstrate the proposed storm system would not increase the incidence or extent of surcharge within the existing sewers. The extent of the analysis within the existing sewers shall be established in consultation with City staff.

All Storm sewers calculations shall be completed on the 5-year and 100-year Storm Sewer Design Sheets and included in all design submissions to Markham. Designs submitted without completing the appropriate Stormwater Design Sheets in full will not be reviewed until such time as the City receives the completed Design Sheets.

Foundation Drains and Clean Water Collectors

Storm sewers with foundation drain and clean water collector connections shall be designed in accordance with Markham's Engineering Standards. Hydraulic grade line analyses shall be completed as required for foundation drains connected by gravity to the storm sewer system to demonstrate that the elevation of the basement floor is at least 1.0 m above the elevation of the storm sewer obvert or at least 0.5 m above the 100-year HGL at that point.

6.2.2 Major System Design Criteria

The major stormwater system within the Municipal right-of-way shall be designed to safely convey the 100-year storm minus minor system (5-year) flows and contained within the road allowance and walkways. Overland flow routes must be continuous either within the road right-of-way or by walkways to the nearest outlet, such as a river or stormwater management facility. Maximum depth of flow shall be 250 mm (typically associated with gutter flow). The major system shall be designed in accordance with the criteria outlined in the City of Markham Engineering Standards. Under no circumstances shall the existing overland flow system in Markham be negatively impacted by proposed development or redevelopment projects. Redevelopment projects, including roadway improvement or expansion projects, that are in areas that do not comply with current guidelines shall investigate opportunities to address existing deficiencies, consistent with the Markham Flood Control Program goals (i.e., 100-year storm sewer systems including major and minor system components).

6.3 Stormwater Management Facilities

Stormwater management facilities should be designed in accordance with municipal policies (including landscaping and land use) so as to support stormwater management function, maintain soil stability and provide appropriate safety strategies. The location of SWM facilities shall be based on site specific conditions and on appropriate analysis of environmental, technical (safety, maintenance and operations), economic and social considerations and shall be subject to relevant governing policies.. Additional safety provisions may be required in areas where an increased level of public access may be anticipated (i.e. SWM facilities integrated with adjacent parks and pathways). The City discourages wet SWM facilities adjacent to elementary schools, walkway routes leading to elementary schools or other active recreation areas frequented by young children. The design of stormwater management facilities shall to facilitate ease of maintenance. No SWM facilities will be allowed within the Regional flood limits.

Stormwater management facilities may be designed as dry ponds (provided water quality controls are included), wet ponds, wetlands, or hybrid facilities as described in the MOE 2003 guidelines, or as underground storage systems within permitted areas as per Section 6.5.1. The design of stormwater management facilities shall fulfill Markham's criteria for safety and maintenance as per Markham's Engineering Standards, and as summarized in Tables 6.1 and 6.2.

All stormwater management facilities within Markham shall be designed to include the following appurtenances:

- Sediment forebay.
- Wet cell/aftbay.
- Outlet control manhole with outlet structure.
- Maintenance access road.
- Sediment decanting zone.
- Emergency spillway.
- Thermal cooling system.

Table 6.1: City of Markham Safety Criteria for Stormwater Management Facility Design

DESIGN FEATURE	OBJECTIVE	CRITERIA
Pond Depth (Difference between top of bank elevation and permanent pool elevation)	Provide barriers to prevent access to the permanent pool	Provide enhanced vegetative barriers and 3.0 m wide flat terraces at approximately mid-depth for ponds with total depths of 4.0 – 5.0 m, depending upon facility type. Terraces may be integrated with maintenance access roads.
Slope Grades	Reduce risk of uncontrolled fall	Slopes to be varied between 3:1 to 7:1, however 3:1 slopes shall be avoided in areas expected to have greater exposure to the public, otherwise consideration of enhanced vegetative barriers and/or terracing shall be required.
Setbacks	Provide barrier to uncontrolled falls	Minimum 3.0 m wide setback between top of the slope and the stormwater management facility property limit.
Water Edge Treatment	Provide ease of egress from water	7:1 terrace at permanent pool edge, 3.0 m wide either side of permanent pool.
Vegetative Barriers	Prevent falls	Ponds within residential areas shall be provided with enhanced vegetative barriers
Signage	Warn the public of potential hazards	All facilities with active (permanent) wet areas must have the information/warning signage shown in the Standard Drawings (MP1A)
Safety Equipment	Facilitate rescues	Provide, in areas with greater exposure to public and, as required by the Director of Engineering

DESIGN FEATURE	OBJECTIVE	CRITERIA
Clay Liner	Prevent interaction between the stormwater and the groundwater and to maintain the permanent pool level	Provide a compacted clay liner extended to the permanent pool or the seasonal high groundwater lever (whichever is higher) + 0.5 m. Liner thickness to be prescribed by qualified Geotechnical Engineer. The bottom inverts of the facilities are to be constructed to the design level, and may not to be over excavated to provide additional sediment capture during construction. Other liner materials may be used subject to Markham approval and specification verified by a Geotechnical Engineer.
Chain Link Fence	Provides public safety	Provide a 1.5 m high chain link perimeter fencing along the property lines of residential, commercial, industrial or institutional lands where they abut a stormwater management facility block. Gates along fences shall not be allowed

Table 6.2: City of Markham Maintenance Criteria for Stormwater Management Facility Design

DESIGN FEATURE	OBJECTIVE	CRITERIA
Maintenance Roads	Facilitate access for maintenance vehicles to critical pond features	Roads shall be constructed on a granular base, covered with grass and minimum topsoil, 4.0 m wide within a 5.0 m easement, 2% cross fall, maximum 10% gradient. Refer to Standard Drawing MP 4.
Access to Pond Inlet/Outlet	Facilitate maintenance of pond inlets/outlets	Create routes, accessible by personnel and maintenance vehicles, to top and bottom of inlet and outlet structures. Where an access to the outlet to the receiving watercourse is proposed, soft material shall be used and approved by TRCA, MNRF, and Markham.
Access to Sediment Forebay	Facilitate removal of sediments	Grade of ramp shall be maximum 10% gradient maintenance access.
Sediment Forebay Bottom Treatment	Provide adequate bearing capacity for maintenance vehicles removing sediment	4.0 m wide ramp of adequate bearing capacity shall continue to the bottom of the permanent pool.
Vegetation	Stabilize ground surface, enhance stormwater control effectiveness, safety and aesthetics	Vegetation shall be native species requiring minimal maintenance and suited to variations in water levels experienced in ponds (i.e. see MOECC guidelines). For pond depths < 6.0 m, basic slope landscaping shall contain grasses and shrubs of adequate density to discourage public access and geese.
Sediment Dewatering Area	Dewater sediment	Temporary dewatering areas for sediment shall be provided within the SWM block if there is no adjacent park.

Additional details regarding the design of wet ponds, wetlands, and hybrid facilities for stormwater management are provided in the following subsections.

6.3.1 Stormwater Management Facility Storage Requirements

The storage volume requirements within the end-of-pipe facility are comprised of the permanent pool volume, extended detention volume for stormwater quality and/or erosion control, and flood control volume above the extended detention volume.

The permanent pool volume for wet ponds, wetlands, and hybrid facilities shall be established in accordance with the criteria provided in the Stormwater Management Planning and Design Manual (MOE 2003) to achieve an Enhanced standard of stormwater quality treatment.

The extended detention storage volume for stormwater quality and/or erosion control shall be established in accordance with the criteria provided in the governing Subwatershed Study, Master Environmental Servicing Plan, Master Drainage Plan, or Master Stormwater Management Plans as applicable. Where no direction is available from higher level studies, the extended detention storage volume for stormwater quality control shall be established in accordance with the criteria provided in the Stormwater Management Planning and Design Manual (MOE 2003), and requirements for erosion control shall be established in consultation with Markham and TRCA. Further discussion surrounding criteria for erosion control is provided in Section 5.5 of these guidelines.

The flood control volume above the extended detention storage volume shall be established in accordance with the criteria provided in the governing Subwatershed Study, Master Environmental Servicing Plan, Master Drainage Plan, or Master Stormwater Management Plans as applicable. Where no direction is available from higher level studies, the flood control volume above the extended detention storage volume shall be established in consultation with Markham and TRCA.

6.3.2 Forebay

All wet ponds, wetlands, and hybrid stormwater management facilities are to be constructed with a forebay. The forebay is to be separated from the wet cell (aftbay) by a berm. The crest of the forebay berm (spillway) is to be at the permanent pool elevation with appropriate erosion protection measures. The berm is to have a 2.0 m top width with 3:1 maximum side slopes, and shall be designed to withstand the velocities for the inflow condition accounting for the corresponding tailwater within the wet cell for the return period of the inflow. The forebay length to width ratio shall be a minimum 2:1, with length designed in accordance with the MOE 2003 Design Manual.

The forebay bottom shall be designed in order to provide an impermeable base to retain water and prevent the inflow of groundwater or interflow into the stormwater management facility. Any proposed forebay liners shall be designed to maintain the impermeable base following sediment removal with equipment, without requiring reinstatement, repair, or replacement of the liner. Any proposed forebay liners shall be certified by a qualified geotechnical engineer.

6.3.3 Length to Width Ratio

All wet ponds, wetlands, and hybrid facilities shall be designed to provide a minimum 4:1 length to width ratio. Berming within the stormwater management facility may be used to increase the flow path to meet this criterion, and should only be considered where the physical constraints of the stormwater management facility footprint preclude the possibility of establishing the facility footprint to provide the requisite length to width ratio. Berms designed to increase length to width ratio shall provide a 3:1 side slope and minimum 1 m top width, with berm height extending to the extended detention water level for stormwater quality control. The berms shall be designed by a qualified geotechnical engineer and constructed to geotechnical specifications.

6.3.4 Standard Water Depths

The permanent pool water elevation/level within the facility represents the normal facility operational water level. The standard water depths within the stormwater management facility shall be designed in accordance with the criteria provided in Table 6.3.

Table 6.3. Depth Requirements by Stormwater Management Facility Type

Facility Component	Wet Pond	Wetland	Hybrid
Permanent Pool	1.0 to 2.0 m	0.15 to 0.30 m (75 % of surface area) 0.90 m max. for deep pools	0.15 to 0.30 m (40 % of surface area) 1.5 m max for deep pools
Permanent Pool at Outlet	2.5 m max.	2.0 m max.	2.5 m max
Extended Detention Storage	1.5 m max.	1.0 m max.	1.5 m max.
Quantity Control Storage	2.5 m max.	2.0 m max.	2.0 m max.
Overall Max. Depth	5.0 m	3.0 m	4.5 m

Deeper permanent pool areas at outlet structures will be considered by Markham where site specific conditions have identified the requirements for this design consideration, or where requirements to achieve thermal mitigation necessitate this design consideration. For wetlands, a localized deep pool shall be designed at the outlet structure. Markham permits the use of extended detention storage for erosion control to satisfy extended detention storage for stormwater quality control where it is demonstrated that the volume and drawdown criteria for erosion control satisfy or exceed MOECC requirements for water quality control.

6.3.5 Side Slopes

Side slopes centred on the edge of the permanent pool shall extend a minimum of 3 m above the permanent pool and 3 m below the permanent pool, and shall provide a 7:1 side slope for safety. Beyond the 3 m shelf above and below the permanent pool, side slopes shall be minimum 3:1.

6.3.6 Berming

Berming around the perimeter of a facility shall be permitted at the discretion of Markham, to construct stormwater management facilities where the operating water surface elevations are proposed to be above the existing grade of the site. Where berming is permitted, the berm shall be designed with a minimum top width of 3.0 m (where trail or maintenance access is not located on the berm). The top of the berm elevation shall be established at a minimum of 0.3 m above the greater of the 100-year or Regional Storm water surface elevation within the stormwater management facility. Geotechnical considerations should be discussed in the design of the facility berming. Constructed berms shall be certified by a qualified geotechnical engineer to confirm that the berm has been constructed to the approved specifications and material.

6.3.7 Inlet Structures

Storm sewer system inlets into the stormwater management facility shall be designed so that the pipe invert is at, or above the permanent pool water surface elevation, and the pipe sized to account for the tailwater condition generated by the greater of the extended detention water surface elevation or the operating water surface elevation within the facility corresponding to the design criteria of the pipe (i.e. 5-year or higher). The storm sewers within the Municipal road right-of-way shall be designed to provide inverts above the extended detention water surface elevation within the facility so as to achieve a free flowing condition within the storm sewers within the right-of-way. The connecting pipe between the right-of-way and the stormwater management facility may be constructed below the extended detention water level provided that a hydraulic grade line analysis be completed confirming that:

- the connecting pipe has sufficient capacity to convey the required flows under a submerged outlet condition, and
- no surcharge within the right-of-way.

Headwalls and grating shall conform to OPSD. A geodetic monument shall be established on the top of the inlet concrete headwall to assist in monitoring future water levels. The monument shall have horizontal and vertical controls in accordance with municipal standards.

Erosion protection shall be provided between the inlet headwall and forebay bottom as needed to prevent localize scouring. Erosion protection shall match the headwall width at the inlet and shall extend a minimum 1.5 m on either side of the headwall at the forebay bottom. Protection material shall be appropriately selected and sized, and underlain with geotextile. The protection, size, and depth shall be based on engineering consultant recommendations and subject to review and acceptance by Markham.

6.3.8 Outlet Structures

Reverse slope pipe and perforated riser pipe outlet structures shall be used to provide extended detention discharge for stormwater management facilities unless otherwise demonstrated to the satisfaction of Markham and the applicable approval agencies. Maintenance pipes shall be installed to allow the facility to drain by gravity flow wherever possible. Maintenance access roadways shall be implemented to facilitate access to the outlet structure. Outlet structures for extended detention discharge shall include thermal cooling systems and measures to provide thermal mitigation of storm discharge to receiving watercourses if the receiving system is a cool water system and/or considered as Redside Dace habitats or contributing Redside Dace habitats by MNRF.

The outlet structures shall be designed such that the control structure for the extended detention component of the facility is at, or above the 2 year water surface elevation within the receiving watercourse, and the control structure for events up to and including the 100 year condition is above the 25 year water surface elevation as a minimum. The control structure for the Regional Storm conditions shall be above the Regional Storm (Regulatory) water surface elevation within the receiving watercourse. Where submerged conditions are anticipated during the operation of the stormwater management facility, supporting hydraulic and hydrologic analyses shall be completed to demonstrate facility performance under both submerged and free flowing conditions.

A weir outfall/spillway shall be considered for discharge of less frequent events, if designed in combination with a ditch inlet type of structure. Erosion protection shall be provided on the spillway, as per the criteria provided in Section 6.3.9. The erosion protection shall be designed by a qualified engineer. Outlets to environmentally significant areas may require site-specific treatment as determined by Markham and/or TRCA, or as stipulated in Subwatershed Studies, MESPs, Master Drainage Plans, or associated Environmental Reports. The design of outlets may be subject to approval by MNRF where discharging to Redside Dace habitat or where approvals under ESA are required.

6.3.9 Major System Overland Flow Routes

The major system overland flow route to a SWM facility shall be designed to safely convey the greater of the 100 year or Regional Storm peak overland flow. Where possible, the overland flow shall not be directed into the forebay to avoid the re-suspension of settled sediments and erosion. Overland flow routes other than the Rights of way shall be flat bottomed channels with minimum 3:1 side slopes, maximum flow depth 0.25 m and minimum freeboard of 0.15m. Overland flow route erosion protection shall include soil reinforcement systems with a natural vegetated surface treatment, based on the engineering consultant's recommendation and subject to City and TRCA approval.

6.3.10 Emergency Overflow Spillways

An emergency overflow spillway shall be included in the design of each stormwater management facility to allow for the safe and controlled conveyance of storm discharge in the event that the outfall structure fails to function or the storm event exceeds the design capacity of the stormwater management facility. The overflow spillway shall convey the greater of the uncontrolled peak flow from the 100 year event or the difference between uncontrolled peak flow from the Regional Storm event and the controlled 100 year discharge.

Erosion protection shall be provided along the entirety of the emergency spillway. Erosion protection may consist of a soil reinforcement system with a natural vegetated surface treatment or alternative protection measure as specified by the designing engineer. Wherever access roads cross the top of the spillway, the surface treatment and base material of the access road design shall be provided at the point of intersection/overlap. Side slopes at the top of the spillway shall be 3:1 maximum and shall be a maximum 10 % if used as a roadway.

6.3.11 Maintenance Access Roadways

Maintenance access roadways shall be located to allow access from the Markham's road allowances to the inlet and outlet structures and to the base of the sediment forebay for maintenance and cleanout purposes. Where feasible, two access points shall be provided from the Markham's road allowance such that the access road is looped to the key components of the SWM facility. In situations where this is not practical, dead end access roads shall be designed with a hammerhead turning area consisting of a minimum centerline turning radius of 16.0 m as per the City's Engineering Standards. A curb cut to Markham's Standards shall be provided at the road allowance and removable, lockable, bollards shall be installed at the right-of-way limit to prohibit public vehicular access.

Maintenance access roadways shall be constructed on a granular base, covered with grass, and shall provide a 2% crossfall and maximum 10% longitudinal gradient. Stormwater blocks between residential/commercial/industrial lots for the sole purpose of maintenance access shall have a minimum easement width of 5.0 m with a 4.0 m wide road surface. In the case of access only for pedestrians, the walkway shall not exceed a maximum longitudinal slope of 6:1.

6.3.12 Setbacks

A minimum setback of 3.0 m from the stormwater management facility property line to the commencement of the facility grading shall be established. Maximum side slopes within the setback areas will be 10:1. Any SWM facilities adjacent to an open space block with no structures may not be required to meet the above setback requirements.

Where a walkway is proposed adjacent to the stormwater management facility, the walkway shall be integrated into the design of the maintenance access roadway as noted in Section 6.3.10 above, and shall be situated at the outside limit, furthest from the stormwater management facility.

6.3.13 Sediment Dewatering Areas

Sediment dewatering areas adjacent to stormwater management facilities are permitted in commercial and industrial settings, and may be permitted in residential areas subject to approval by the City. Where sediment dewatering areas are not proposed, the proponent is required to address requirements for the removal of wet sediment from the stormwater management facility within the operation and maintenance manual, including an assessment of additional costs associated with the removal and disposal of wet sediment compared to costs associated with the removal of dewatered sediment.

Where sediment dewatering areas are proposed, the sediment dewatering area shall be provided immediately adjacent to the maintenance access road and to the sediment forebay to facilitate ease of access for sediment removal from the forebay and storage. The drying area shall be graded at a minimum slope of 2.0 % to allow partial drainage to the forebay. The footprint of the sediment dewatering area shall be determined based upon the spatial requirements to facilitate excavation of a sediment volume equivalent to 50 % of the forebay volume, and placement at a 1.0 m maximum storage depth and 4:1 angle of repose. The dewatering area shall be surface treated with a granular design as per the maintenance access roads to allow for vehicular use.

6.4 Interim Stormwater Management Facilities

Markham will consider the use of interim stormwater management facilities to accommodate development phasing, and provide the requisite level of stormwater quantity and quality control, as well as addressing interim requirements for erosion protection as appropriate (not sediment and erosion protection during construction). Interim stormwater management facilities are considered separate and distinct from temporary facilities to provide erosion and sediment control during construction; as such, interim stormwater management facilities are not intended to provide temporary erosion and sediment control during construction.

Markham will consider the use of interim stormwater management facilities, provided the following requirements, but not limited to, are met.

1. Interim SWM facilities are to be located on lands that are dedicated to the City as an easement by the proponent.
2. All interim SWM facilities that become permanent SWM facilities based on the master plan/ MESP recommendations will be required to be located on lands that the proponents shall dedicate to the City.
3. The proposed interim facility addresses the requirements for stormwater quality and quantity control for the proposed phase of development.
4. The interim facility remains in-place and operational until the ultimate facility or sewer connection are constructed to the satisfaction of the City.
5. The land owner/developer is solely responsible for the operation, maintenance, demolition, removals and/or restoration associated with the decommissioning of the interim stormwater management facility, including the disposal of any contaminated sediments in accordance with applicable Provincial guidelines and regulations. Site plans or development agreements must be structured to reflect all such requirements.
6. The interim stormwater management facility is designed in accordance with the following criteria;
    a. 3:1 maximum side slopes from facility bottom to top of berm

b. Facilities requiring perimeter fencing shall be vinyl chain link fence with access gate in accordance with applicable standards. All gate(s) must remain locked at all times.
c. No maintenance pipe or valve required as part of outfall structure
d. Gravel Access Roads must be provided for emergency vehicles

6.5 Subsurface Stormwater Management Facilities

Subsurface storage facilities may be used to address design criteria for flooding when only a detention function is provided (i.e. no retention). Erosion and water budget design criteria can also be satisfied when underground storage facilities are designed with infiltration capabilities. Subsurface systems for stormwater management may be implemented on private properties, subject to the approval of Markham, and shall be designed and constructed in accordance with the manufacturer's specifications and with recognition of the specific conditions on the site, and shall be operated and maintained by the owner according to manufacturer and/or designer specifications / requirements.

6.5.1 Subsurface Stormwater Quantity Control Facilities

Subsurface stormwater quantity control facilities, consisting of pre-manufactured units, can reduce peak flow rates by providing storage of stormwater underground. Generally, underground storage facilities are used for smaller development sites or areas of intensified urban development which lack sufficient space to construct typical surface-based stormwater detention facilities. Acceptable locations for using subsurface stormwater storage facilities are to be established in consultation with City staff and justified to the satisfaction of the City. Subsurface stormwater quantity control facilities shall be designed in accordance with manufacturer's specifications, and supporting documentation from the manufacturer shall be included within the stormwater management design brief. The stormwater management design brief for subsurface stormwater quantity control facilities shall also include a section outlining the operation and maintenance requirements for the facility, which clearly describes the following, but not limited to:

- components to be inspected,
- frequency of inspection,
- approach for sediment removal,
- frequency of sediment removal,
- monitoring requirements to verify structural integrity,
- training requirements for inspection and maintenance (e.g. confined space entry)
- cost estimates for maintenance and inspection

Underground storage systems shall include an emergency overflow system consisting of a surface overflow path sited and sized to convey the uncontrolled flow for the 100-year storm in the event that the subsurface storage facility becomes clogged or inoperable.

6.5.2 Oil/Grit Separators (OGS)

Oil/Grit Separators (OGS) may be implemented for stormwater quality control in urban area where land use constraints prohibit the use of other BMPs. They are typically used for small sites or infill development (typically 5 ha or less) where a water quality control pond/wetland is not feasible. OGS can be used for spill control or as a pre-treatment device as part of a multi-component system (treatment train) to achieve enhances level water quality control. They can be used as a standalone water quality device in situation where a lower level of water quality protection is needed.

Based on current studies, OGS have minimal effects on nutrients and organic matters and do not effectively remove dissolved or emulsified oils and pollutants like a SWM pond. OGS designed as per manufacturer specifications to achieve 80% TSS removal shall be considered by the City to provide 50% TSS removal, considering anticipated loss of efficiency over time unless otherwise demonstrated to the satisfaction of the City.

In accordance with the most current MOECC SWM manual (2003), for enhance level water quality protection (80% TSS removal), OGS shall be sized to capture and treat a minimum of 90% of the runoff volume that occurs for a site on a long-term average basis.

6.5.3 Adoption of New Technologies

To foster innovation in stormwater management, Markham has adopted a policy for the adoption of, and use of, new-technologies. Markham requires that all oil/grit separators for stormwater quality control technologies are approved under the Canadian Environmental Technology Verification (CETV) Program. If the new product receives CETV certification no additional monitoring will be required to demonstrate performance and the product will be included on the City's list of approved products. The proponent is directed to contact Markham staff for an approved list of devices/techniques. Markham approved list will be updated regularly.

If the new product has not received CETV certification, or if the certification is pending, new technologies will be assessed based on the following process and requirements:

1. A thorough review of existing background information by a third party reviewer, selected by Markham and paid for by the land owner/developer or technology manufacturer/ provider.
2. A pilot study to test the technology under laboratory conditions performed by, or at a minimum verified by a third party. Current existing pilot studies deemed acceptable by Markham may eliminate this requirement. Pilot studies are to be paid for by the land owner/developer or technology manufacturer/provider.
3. A full-scale field demonstration test to obtain performance data. This requirement is to be performed by, or at a minimum verified by a third party. The results of any and all field tests are to be reviewed by Markham as per requirement 1. Field demonstration tests are to be paid for by the land owner/developer or technology manufacturer/provider.

4. Performance verification tests of the technology's ability to meet performance standards at the site where it will be deployed. Only existing start-up/compliance tests that are within a reasonable proximity to the eventual site where it will ultimately be deployed will be accepted. 'Reasonable proximity' is at the discretion of Markham. Start-up/compliance tests are to be paid for by the land owner/developer or technology manufacturer/provider.

   Note: Process steps 3 and 4 can be combined based on the location selected.

The results from all four process requirements above will be examined by a peer-review committee selected by Markham and based on recommendations from the peer-review, Markham may add the product to the list of approved SWM products and practices. Costs associated with the peer-review process are to be paid by the land owner/developer or technology manufacturer/provider.

6.6 Stormwater Management Facility Planting Guidelines

The landscape design and planting requirements for stormwater management facilities shall be consistent with the current TRCA Stormwater Management Pond Planting Guideline (TRCA, September 2007) and the City of Markham Urban Design and Sustainable Development Guidelines (City of Markham, June 2014) and the City of Markham Stormwater Management Pond and Planting Design Guidance (January 2014). Stormwater management facility landscaping and design shall also be reviewed and approved by MNRF, as appropriate and required based upon applicable Provincial legislation.

7.0 EROSION AND SEDIMENT CONTROL (ESC) DURING CONSTRUCTION

7.1 Introduction and Background

The Municipal Act authorizes municipalities to pass “Sediment and Erosion Control” Bylaws (S.142) that regulate activities and undertakings that disturb the natural ground conditions and alter soil sediment distribution. Erosion and sediment control requirements established by the Greater Golden Horseshoe Area Conservation Authorities, TRCA and MNRF (where applicable) are intended to manage the washoff and movement of sediment to the receiving watercourses during storm events while sites are under construction. By comparison, the erosion and sediment control requirements established by Markham are intended to manage the washoff and movement of sediment to adjacent properties during storm events.

The information provided in this section pertains specifically to the requirements for erosion and sediment control in accordance with Markham’s requirements and objectives. This does not alleviate the proponent from addressing the requirements to provide erosion and sediment control to address the requirements of other agencies (i.e. TRCA, MNRF).

7.2 General

Erosion and sediment controls are required by Markham for any proposed site alterations. Acceptable erosion and sediment control practices and requirements for submission are provided in Markham’s Engineering Standards.

Prior to the commencement of any on site work, the proponent must implement a Site Alteration Plan that include ESC plan, approved by Markham’s Engineering Department, to effectively reduce on-site erosion and minimize off-site transport, either through overland flows or through municipal sewer systems. The approved ESC plan must include provisions to minimize wind transport off-site in accordance with the City’s adopted “Dust Control Measures and Construction Practices Guidelines” found in the current Markham, Engineering Design Criteria and Standard Drawings.

Details of the ESC plan/drawings shall be prepared by a licensed professional engineer and be included with the appropriate submission(s) for approval by Markham, TRCA, MNRF and DFO, as may be required.

7.3 Erosion and Sediment Control Requirements

All stormwater management plans submitted to Markham must include an erosion and sediment control plan. This plan should conform to the erosion and sediment control methods as outlined in the Greater Golden Horseshoe Area Conservation Authorities Erosion and Sediment Control Guidelines for Urban Construction (2006) in addition to Markham erosion and sediment control requirements.

ESC plans for areas within Markham must address specific requirements for each stage of the construction as follows:

- Clearing and grubbing;
- Rough grading and servicing;
- Street building and Construction;

Additional information may be required where:

- Sewers and/or watermains cross creeks;
- Bridges or culverts are constructed across active streams;
- Channels diverted;
- Active streams are encountered.

Plans must outline measures to reduce the impact on the streams including the timing of construction activities to minimize disruption as required by the TRCA, MNRF, and DFO.

All disturbed ground left inactive for greater than 30 days, must be stabilized by seeding, sodding, mulching or covering, or by other equivalent measures, unless otherwise authorized by the City.

All ESC measures are to be inspected by the Design Engineer or a CISEC (Certified Inspector of Sediment and Erosion Controls) Certified Inspector a minimum of twice per week and after rainfall events to ensure ESC measures remain in good working condition. Independent inspections may be completed by Markham staff in order to verify that the erosion and sediment controls implemented on the site are in compliance with the approved plan; written notice will be provided as required, outlining the deficiencies noted and providing a timeline to address. The proponent is responsible for addressing any deficiencies noted in the erosion and sediment controls implemented on the site. If the deficiencies are not addressed within the specified timeframe, Markham may use the Letter of Credit to finance any required remedial works.

7.4 Permissible Sediment Controls

Permissible sediment controls for site alterations include but are not limited to the following practices.

7.4.1 Vehicle Tracking Control

Vehicle tracking control is used for sites typically 1 ha in area or larger where vehicles access and leave a site via a municipal road. Markham requires that granular material designed as per the vehicular traffic requirements be placed for a minimum length of 15 m prior to the municipal road pavement. Should sediment be conveyed to the road, the proponent will clean the road at its expense. Should Markham inspect the road and determine that maintenance is not adequate; the proponent will be charged accordingly.

7.4.2 Vegetative Buffer Strip

Sediment control can be provided through the use of existing or proposed vegetation. TRCA has minimum vegetation buffer strip widths which are to be incorporated into the site design. Buffer strips are generally located adjacent to creeks, swales and stormwater inlets.

7.4.3 Temporary Grading Diversion

Diversion of drainage from steep slopes and disturbed areas through the use of diversion swales should be considered as per TRCA's guidelines. Drainage should be directed to appropriate sediment control measures.

7.4.4 Temporary Slope Drain

To prevent slope erosion, concentrated drainage may be conveyed down a slope via a temporary slope drain comprising a flexible conduit or ditch liner. Slope drains should employ adequate inlet and outlet protection and should not discharge directly to creeks.

7.4.5 Sediment Control Fence

TRCA's design considerations for sediment control fence should be adopted. This measure acts as a barrier to drainage creating ponding and therefore settling of sediment, rather than filtering the drainage. Markham Standard Sediment control fence should be properly installed and maintained to ensure it functions as intended.

7.4.6 Sediment Trap

The design and construction of sediment traps should incorporate TRCA's guidelines as a minimum. Typically, drainage areas to sediment traps are less than 2 ha. The location of the sediment trap should be out of the floodplain whenever possible to avoid being washed out.

7.4.7 Sediment Control Basin

Similar to sediment traps, sediment control basins should incorporate TRCA's guidelines as a minimum. Typically, drainage areas to sediment control basins are over 2 ha. Sediment control basins should be located out of the floodplain.

7.4.8 Compost Berm

A compost berm may be used instead of sediment control fence. The compost berm should be designed according to manufacturer's guidelines. Unlike sediment control fence, compost berms are able to filter sediment from drainage and do not obstruct flow paths. Compost berms are easily spread out on-site after construction completion instead of being required to be removed as per sediment control fence.

7.4.9 Compost Socks

Compost socks provide the function of compost berms, but on steep or paved surfaces, manufacturer's guidelines should be used in both design and placement of the compost sock.

7.5 Permissible Erosion Controls

Permissible erosion controls for site alterations include but are not limited to the following practices.

7.5.1 Surface Roughening (Scarification)

Scarification is a process of roughing the slopes of a site prior to vegetative cover. Typically scarification is for sites with steep slopes up to 2:1. Scarification reduces drainage velocity, quantity and erosion potential.

7.5.2 Seeding

Vegetative cover is established by seeding a disturbed area. Typically, seeding of disturbed areas is conducted following final grading or for site areas where no further construction is scheduled for 45 days. Seed application typically occurs with straw mulching, hydraulic mulching and erosion control blankets. Sodding may occur in site areas where instant ground cover is required.

7.5.3 Mulching

Freshly seeded soils can be protected by spraying on manmade or natural materials. Mulching reduces drainage velocity and therefore the erosion potential of seeded soils. Manufacturer's specifications should be followed in implementing mulch.

7.5.4 Erosion Control Blankets, Netting and Matting

Erosion control blankets, netting and matting are typically biodegradable materials which are placed on relatively steep surfaces to prevent erosion and promote seed growth. Manufacturer's guidelines should be followed in the use of erosion control blankets.

7.6 Drainage Protection

Permissible drainage protection for site alterations include but are not limited to the following practices.

7.6.1 Temporary Creek Crossings

Temporary creek crossings consist of a span for the purpose of construction access. For regulated watercourses, TRCA, MNRF, and possibly Federal Department of Fisheries and Oceans (DFO) will have individual requirements that should be fulfilled.

Where watercourses are not regulated by other agencies, concrete or corrugated metal pipes may be used to provide temporary crossings during construction. Notionally, the crossings would be required to convey between the 2 year and 5 year design flow, depending upon the duration of crossing, time of year, and any site-specific constraints, and is to be established in consultation with Markham.

7.6.2 Cofferdams

Temporary cofferdams are used to allow dewatering of a construction area to permit work in dry conditions. Design considerations and installation and maintenance considerations are provided within the TRCA guidelines. Design of cofferdams will require TRCA approval, and in some cases MNRF and possibly DFO approval.

7.6.3 Stream Diversions

Watercourse diversions should be conducted only when necessary to reduce impacts on the social or natural environment. Stream diversions should be designed according to stream function and form and may require natural channel design principles. TRCA, MNRF, and potentially DFO will typically review an application for stream diversion.

7.6.4 Rock Check Dams

Granular material is temporarily placed either in a swale, ditch or watercourse to facilitate settling of sediment. Design of rock check dams will require TRCA approval, and in some cases MNRF and possibly DFO approval.

7.6.5 Storm Drain Inlet Protection

Storm drain inlet protection may consist of a sediment control barrier, granular material, geotextile and/or ponding area. Specific applications will require different inlet protection designs. Typically, only Markham and possibly the TRCA will comment on inlet protection design.

7.6.6 Storm Drain Outfall Protection

Outfall protection should be designed according to both the outfall flow velocities and the receiving watercourse flow dynamics. Markham, TRCA, and possibly the MNRF will review an application for a storm drain outfall.

8.0 OPERATIONS AND MAINTENANCE

The ongoing operations and maintenance of all stormwater management and drainage infrastructure is important toward ensuring the long-term performance. General guidance regarding operations and maintenance requirements for commonly used stormwater management facilities and systems is provided in the Stormwater Management Planning and Design Manual, MOECC (2003), and guidance regarding the operations and maintenance requirements for LID BMP's is provided in the Low Impact Development Stormwater Management Planning and Design Guide, Version 1.0, (TRCA/CVC, 2010).

As part of engineering submissions for the detailed design of stormwater management facilities, proponents are required to include an operations and maintenance program for proposed stormwater management facilities and LID BMP's. The following information shall be specified related to the required maintenance activities:

- frequency of the various activities,
- estimated cost of the maintenance activity, including equipment and human resource needs.

This information shall be established with particular consideration for the stormwater management practice proposed, as well as the conditions of the contributing drainage area and the receiving system. The maintenance activities are to be identified as either "Routine Maintenance Activities" (which may be completed on an annual/semi-annual basis) or "Capital Works Projects" (which would be completed less frequently and require separate funding, financing, and approval, as well as relevant investigations to support the proposed works and develop more refined and detailed cost estimates for implementation). The operations and maintenance requirements shall include supporting calculations for forebay and facility cleanout frequency, and verify that the forebay has been designed to a minimum of 10-year cleanout frequency as per current MOECC standards. Larger forebay that requires less frequent cleanout (more than 10 years) is recommended.

The operations and maintenance program shall include any supplemental investigations which may be required to better refine the maintenance requirements. This may include any requirements for sediment sampling and analysis for sediment quality, in order to determine opportunities and requirements for disposal. The cost estimates shall include allowance items for these activities, and shall specify any assumptions made in developing the cost estimates.

The Operations and Maintenance report shall be a standalone report signed and stamped by a P.Eng. and submitted with the SWM report.

9.0 STORMWATER MANAGEMENT FACILITY ASSUMPTION REQUIREMENTS

Prior to transferring ownership of stormwater management facilities to Markham, the requirements for assumption shall be addressed in accordance with Markham's Stormwater Management Facility Assumption Requirements, provided in Appendix C.

Prior to assumption the stormwater management facility, accumulated sediment within the facility shall be removed and appropriately disposed of. A geodetic survey of the as-built condition of the facility shall be completed, and an Engineering Certification provided to confirm that the facility and all appurtenances have been constructed and installed in accordance with the approved design. The Environmental Compliance Approval (ECA) from the MOECC shall be amended as appropriate and required.

The above information must be submitted to Markham under the seal and signature of a Professional Engineer licensed in Ontario.

10.0 VALLEY SYSTEMS AND WATERCOURSE DESIGNS

The design of valley systems and/or watercourses applying natural channel design principles shall be completed in accordance with the requirements and standards established by the City, TRCA, the MNRF, and DFO as necessary. Prior to undertaking the design of any works within valley systems, proponents should pre-consult with MNRF (for areas where Provincial legislation apply), TRCA, and Markham.

When subsurface infrastructure that service urban areas, such as sanitary sewers, watermains, utilities (gas, oil, hydro), storm sewers and associated surface features (e.g., manholes) are located across, or within valleys, they are at potential risk from exposure due to channel processes. Design criteria pertaining to placement and/or replacement of subsurface infrastructure in valley systems include:

- At the planning stage, every effort should be made to keep subsurface infrastructure out of the valley.
- When stream/valley crossings cannot be avoided, attempts should be made to minimize the number of subsurface crossings and manholes.
- Where feasible, infrastructure should cross under roads (i.e., between the road deck and culvert).

When subsurface infrastructure is to be placed within the valley, then the following criteria are recommended:

- Subsurface infrastructure and associated manholes routed within the valley should remain outside of the meander belt.
- Infrastructure crossings should, to the extent possible, be placed at a minimum of 2 m below the existing channel bed (i.e., if under pool, then 2 m below pool invert, if below a riffle, then 2 m below the minimum invert of the upstream/downstream pool).

The proponent should consult Markham and the TRCA on all projects where subsurface infrastructure is proposed under, or in proximity to, the watercourse before proceeding with detailed design. In areas with Redside Dace habitat, the MNRF should be consulted to determine if there are any additional requirements under the Ministry's legislation.

11.0 MONITORING

Watercourse and SWM facility monitoring are required by Markham for all new development. Under the City's Stormwater Management Facility Assumption Requirements, all proponents are required to submit a detailed monitoring and evaluation program, demonstrating that the facility is functioning as designed to the satisfaction of the Director of Engineering. The following sections provide additional details regarding the watercourse and stormwater management monitoring programs. Monitoring programs for other purposes (i.e. verifying performance of new technologies, assessing stormwater quality retrofits, etc.) are to be established in consultation with the City, as well as other regulators and agencies as appropriate.

11.1 Watercourse Monitoring Program

Monitoring of the watercourses is required as a condition of approval for new development, at the discretion of Markham. While the scope, methodology, frequency, and duration of the monitoring program are to be established based upon recommendations provided in higher level studies, the following general guidance is provided for conducting monitoring programs of the City's watercourses in the absence of direction from higher level studies.

The locations for conducting the watercourse monitoring program should be established in order to provide an assessment of instream water quality at the upstream and downstream limits of the proposed development. The sites for collecting water quality samples should be established to allow safe access to the watercourse to collect water quality samples during wet weather and dry weather conditions, as well as during and outside of business hours.

All water quality samples should be obtained in accordance with the Protocols Manual for Water Quality Sampling in Canada (CCME, 2011). The method for collecting the samples (i.e. grab sampling, composite sampling, continuous monitoring) should be established based upon the contaminants to be monitored, and required analyses. The monitoring program is required to be implemented for a minimum of 3 years and may be extended depending upon the conclusions and recommendations advanced in the final report as well as additional monitoring requirements advanced in applicable higher level studies. The water quality monitoring should distinguish between wet weather and dry weather conditions, and should provide a characterization of the seasonal variations and trends in surface water quality (i.e. spring, summer and fall); consequently, a minimum of six (6) wet weather and six (6) dry weather samples should be obtained each year of the monitoring program.

The water quality parameters to be monitored are to be established in consultation with Markham, TRCA, MNR, and MOE, and may include the following general parameters:

- Oil and Grease
- Total Phosphorus
- Anions (Nitrate, Nitrite, Phosphate, Chloride)
- Ammonia
- Total Kjeldahl Nitrogen (TKN)

- Conductivity
- Total Solids (TS)
- Total Suspended Solids (TSS)
- BOD5
- Dissolved Oxygen
- pH/alkalinity
- Salinity
- Total Coliforms/Fecal Coliforms/E. Coli
- PAH
- Metals (Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Si, Ag, Na, Sr, Tl, Sn, Ti, W, U, V, Zn, Zr)
- Hardness as CaCO3
- Turbidity
- Temperature

The approved monitoring program is to be implemented and reports prepared and submitted to Markham.

11.2 Stormwater Management Facility Monitoring

Markham's Stormwater Management Facility Assumption Requirements include monitoring stormwater management facilities to demonstrate that the facility is functioning as designed. The scope, methodology, frequency, and duration of the monitoring program for stormwater management facility performance should be established based upon the following general guidance provided below, as well as any requirements provided by approval agencies (i.e. MOECC, MNR, TRCA) as conditions of approval. The duration of the monitoring program to verify stormwater management facility performance is to be established in consultation with Markham staff and based upon the conditions of approval from other agencies. In the absence of this direction, the monitoring program to verify stormwater management facility performance is required to be implemented for a minimum of 3 years and may be extended depending upon the conclusions and recommendations advanced in the final report as well as additional monitoring requirements advanced in applicable higher level studies.

11.2.1 Stormwater Quantity Control

Stormwater quantity monitoring to verify stormwater management facility performance shall be completed as required by Markham. Depth probes shall be installed at the inlet and outlet of the stormwater management facility to determine the operating water surface elevations within the facility during storm events. The water surface elevations shall be correlated to storage and discharge rates based upon the stormwater management facility rating curve as determined by the as-built survey of the facility after cleanout and prior to assumption by Markham.

Available rainfall data shall be used to determine the corresponding return period of the storm event, for comparison and verification of the operating water levels within the facility. Where required by Markham, the approved hydrologic models shall be updated to represent the as-built condition of the stormwater management facility and contributing drainage area, and hydrologic analyses completed to verify the stormwater management facility performance.

Where feasible and appropriate, the monitoring for stormwater quantity control performance shall be coordinated with holistic monitoring programs to collect flow data along the receiving watercourses. Opportunities to integrate the stormwater quantity control requirements for stormwater management facilities within holistic monitoring programs shall be at the discretion of Markham.

11.2.2 Stormwater Quality Control

Water quality monitoring to verify stormwater management facility performance should verify that the stormwater management facility is providing the requisite stormwater quality treatment as per the applicable standards, and should afford a characterization of the treated effluent from the stormwater management facility compared to the water quality within the receiving watercourse. As such, water quality monitoring to verify stormwater management facility performance should be completed at the inlet to the stormwater management facility, at the outlet of the stormwater management facility downstream of the control structure (i.e. not within the water column of the stormwater management facility), as well as instream along the receiving watercourse upstream and downstream of the stormwater management facility. The locations for obtaining water quality samples within the receiving watercourse should be established to allow safe access to the watercourse to collect water quality samples during wet weather and dry weather conditions, as well as during and outside of business hours.

All water quality samples should be obtained in accordance with the Protocols Manual for Water Quality Sampling in Canada (CCME, 2011). The method for collecting the samples (i.e. grab sampling, composite sampling, continuous monitoring) should be established based upon the contaminants to be monitored, and required analyses.

Water quality monitoring to verify stormwater management facility performance is to be completed for three (3) storm events per year, and should attempt to capture one event for each season monitored (i.e. spring, summer, and fall).

The water quality parameters to be monitored are to be established in consultation with Markham, TRCA, MNRF, and MOECC, and may include the following general parameters:

- Oil and Grease
- Total Phosphorus
- Anions (Nitrate, Nitrite, Phosphate, Chloride)
- Ammonia
- Total Kjeldahl Nitrogen (TKN)
- Conductivity
- Total Solids (TS)
- Total Suspended Solids (TSS)

- BOD5
- Dissolved Oxygen
- pH/alkalinity
- Salinity
- Total Coliforms/Fecal Coliforms/E. Coli
- PAH
- Metals (Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Si, Ag, Na, Sr, Tl, Sn, Ti, W, U, V, Zn, Zr)
- Hardness as CaCO3
- Turbidity
- Temperature

The approved monitoring program is to be implemented and reports prepared and submitted to Markham. If the results of the monitoring program are deemed unsatisfactory by Markham and regulating agencies, additional investigation shall be completed to identify opportunities to address any deficiencies in the performance of the stormwater management system. The preferred approach to address any deficiencies shall be established in consultation with Markham and regulating agencies.

APPENDIX A: SUBMISSION REQUIREMENTS AND CHECKLISTS FOR STORMWATER MANAGEMENT DESIGN REPORTS

Stormwater Management (SWM) Report
(including major and minor system design)

A SWM report is prepared in order to meet conditions set at the Draft Plan, Site Plan, or MESP stage. The SWM report must provide the required design and supporting calculations for all areas of the proposed stormwater management system. The SWM report shall contain detailed design of stormwater controls and environmental restoration works, delineation/ confirmation of constraint boundaries, sediment/erosion control plans, hydraulic and hydrologic analyses, and preservation and restoration/remediation plans.

The submission outlines for SWM Report includes, but not limited to, the following:

Outlines for SWM Report

Section	Description	Page No.
1.0	**Introduction** • Objectives • Description and location of site • Description of proposed development • Referenced background studies/reports; watershed, sub-watershed, MESP, FSR, SWM reports and identify any deviations from the latest Markham's guidelines the MOE's Stormwater Management	
2.0	**Existing/Pre-development Stormwater Drainage** • A map of existing contours and pre-development catchment areas, including runoff coefficients and external contributing areas • Existing storm drainage plan and areas including existing sewers and overland flow drainage systems and direction(s), current capacities, and possible connections • Characterization and classification of soils on the site. • Characterization of existing land use and surface cover. • Existing SWM facilities and location, including low impact development measures • Detail calculations and input parameters to the hydrologic and hydraulic models • Model schematic and subcatchment boundary plan • Electronic data files of input and output for pre-development conditions • Complete computer output/input printouts and summaries • A schematic flow diagram of the computer model. • Parameter table. • Identification of flood plain limits of all watercourses • Identification of existing watercourse crossings	

Section	Description	Page No.
3.0	**SWM Design Criteria** • Summary of the applicable municipal and Provincial guidelines and legislation • Stormwater quantity control criteria including allowable/pre-development discharge rate, erosion control criteria, and Regional Storm control requirements • Stormwater quality control criteria • Thermal mitigation requirements • Low impact development criteria	
4.0	**Proposed Post-development SWM** • Description of proposed development and change in land use or surface cover. • Proposed Storm Drainage Plan showing the post-development drainage areas and runoff coefficients, existing/proposed SWM facilities/LID location(s) and external areas • Proposed Storm Servicing Plan showing the proposed minor/sewer and major/overland flow routes systems and directions, and existing/proposed SWM facilities/LID location(s) • Proposed Grading Plan showing the existing and proposed grades of the proposed development • Proposed water quantity control including discharge rates and on-site storage • Stage-storage-discharge relationships for proposed stormwater management facilities • Verification that operating water surface elevations within the stormwater management facility and the outlet structure design comply with Markham and MOECC criteria relative to storm sewer inverts and water surface elevations within the receiving systems. • Proposed water quality control • Detailed design of proposed SWM facilities (e.g. Wet Pond) including low impact development measures, their location and design drawings • Outline of the maintenance and monitoring program for the proposed SWM facilities • Detail design calculations and input parameters for hydrologic and hydraulic models • Proposed catchbasin inlet control devices and orifice pipe controls • Proposed minor system capacities and proposed connections • Proposed major system capacities, full capture locations, and flow depth • Hydraulic verification that major overland flow routes do not impact properties and that road gutter flows are within municipal parameters	

Section	Description	Page No.
	• Electronic data files of input and output for post-development conditions • Model schematic and subcatchment boundary plan • Complete computer input/output printouts and summaries • A schematic flow diagram of the computer model • Parameter table • Summary of how all municipal and Watershed SWM criteria has been satisfied • Expansion and upgrades requirements to existing infrastructure, if required, to support the proposed development • Erosion and sediment control measures to be implemented including design plans	
5.0	**Hydraulic Gradeline Analysis** • 100-year hydraulic grade lines to be calculated for all pipes • Basement elevations to be evaluated for surcharge/flooding potential • Plan depicting street names associated with each pipe segment • Tabular summary of pipe upstream and downstream inverts, sizes, length, slopes, and manning n values • Tabular summary of pipe flows and flow velocities • Tabular summary of pipe friction losses, manhole losses and velocity head • Tabular summary of pipe surcharge conditions, and upstream and downstream HGL • Tabular summary of the freeboard between the upstream HGL and the basement elevation	
6.0	**Channel Design or Alteration (if required)** • Location • Sizing calculations (flow, velocity, etc.) • Vertical and lateral erosion rates • Detailed design plans (plan/profile) • Fluvial geomorphology components (low flow/bankfull/floodplain width, inverts and slope, tractive force/erosion analysis, etc.) • Tabular summary of water surface elevations at stormwater management facility outlet for 2 – 100 year flow frequencies/return periods and Regional Storm event • Hydraulic analysis for freeboard and overtopping for hydraulic structures.	
7.0	**Summary & Conclusions**	

Stormwater Management (SWM) Brief

A Stormwater Management Brief is a technical document to summarize how the proposed design shall meet the stormwater management targets for water quality, quantity, erosion, water balance (infiltration) and the protection of natural features for the proposed development/project as required. A SWM Brief is prepared to provide greater detail, at a much smaller scale, as compared to a Stormwater Management Report.

Typically SWM Briefs are used for small developments (single lot, small commercial sites) to detail stormwater management source control, conveyance and end-of-pipe facilities. To determine if a project scale and complexity is appropriate for a SWM Brief, the proponent is required to contact the Markham staff.

The submission outlines for a SWM Brief includes, but not limited to, the following:

Outlines for SWM Brief

Section	Description	Page No.
1.0	**Introduction** • Objectives • Description and location of site • Existing and proposed catchment area plan including delineation of internal and external drainage areas • Description of proposed development • Referenced Background studies/reports; MESP, FSR, SWM reports (for peak flow analysis), and Identify any deviations from latest Markham's guidelines and the previous accepted reports • Significant features, such as species at risk habitat, provincially significant wetlands, etc	
2.0	**Existing/Pre-development Stormwater Drainage** • Existing storm drainage plan and areas including existing sewer and overland flow drainage systems and direction(s), runoff coefficients, external contributing areas, current capacities, and possible connections • Detail calculations and input parameters • Electronic data files of input and output for pre-development conditions • Existing receiving SWM facilities and location including low impact development measures, if applicable • Identification of flood plain limits of all watercourses, if applicable • Identification of existing watercourse crossings, if applicable	
3.0	**SWM Design Criteria** • Summary of the Markham's applicable criteria to be met • Stormwater quantity control criteria including allowable/pre-development discharge rate • Identify on-site detention requirements • Stormwater quality control criteria	

Section	Description	Page No.
	• Low impact development criteria	
4.0	**Proposed Post-development SWM** • Proposed Storm Drainage Plan showing post-development drainage areas and runoff coefficients, SWM facilities/LID and external areas • Proposed Storm Servicing Plan showing the proposed minor/sewer and major/overland flow routes systems and directions, and SWM facilities/LID • Proposed Grading Plan showing the existing and proposed grades of the proposed development • Proposed water quantity control including discharge rates and on-site storage • Proposed water quality control • Detail design calculations including input data • Proposed orifice pipe controls • Proposed minor system capacities and proposed connections • Proposed major system capacities, full capture locations, and flow depth • Verification that major overland flow routes do not impact properties and that road gutter flows are within municipal parameters • Electronic data files of input and output for post-development conditions • Complete computer input/output printouts and summaries • Summary of how all municipal SWM criteria has been satisfied • Expansion and upgrades requirements, if required, to support the proposed development • Erosion and sediment control measures to be implemented including design plans	
5.0	**Hydraulic Grade-line (HGL) Analysis** • 100-year hydraulic grade lines to be calculated for all pipes • Basement elevations to be evaluated for surcharge/flooding potential • Show street names associated with each pipe segment • Show pipe upstream and downstream inverts, sizes, length, slopes, and manning n values • Show pipe flows and flow velocities • Show pipe friction losses, manhole losses and velocity head • Show pipe surcharge conditions, and upstream and downstream HGL • Show the freeboard between the upstream HGL and the basement elevation	
6.0	**Conclusions & Recommendations**	

CHECKLIST – Stormwater Management Design Report Requirements

MARKHAM

**Stromwater Management
Design Report Requirements**

		Yes	No	Notes
1.	Site Location Plan	☐	☐	--------------------------------
2.	Referenced Drainage Studies			
	• Watershed, subwatershed or Master Drainage Studies	☐	☐	--------------------------------
	• Approved MESP and FSR Requirements for Water Quality, Quantity & Facility Design	☐	☐	--------------------------------
	• Approved Stormwater Management Reports (nearby)	☐	☐	--------------------------------
	• Identify Deviations from Latest Markham SWM Guideline and MOE Stormwater Manual	☐	☐	--------------------------------
3.	Site Hydrology and Hydraulics (Pre and Post)			
	• Assumptions and Site Parameters	☐	☐	--------------------------------
	• Sub-basin within or Flowing through site	☐	☐	--------------------------------
	• Land-use, Acreage, Hydrologic soils group & Land-use	☐	☐	--------------------------------
	• Input/output Summary (hydrologic/hydraulic analysis)	☐	☐	--------------------------------
	• Tabular summary of model parameters (see attached table)	☐	☐	--------------------------------
	• Detailed Hydraulic Analysis and Hydrologic Calculations	☐	☐	--------------------------------
	• Topographic Map of Pre and Post-Development	☐	☐	--------------------------------
4.	Stormwater Management Design			
	• Proposed Methods	☐	☐	--------------------------------
	• Alternative Methods	☐	☐	--------------------------------
	• Justification for Proposed Methods	☐	☐	--------------------------------
	• Detailed Calculations	☐	☐	--------------------------------
	• Calculations/ Methods to Meet Water Quality Criteria	☐	☐	--------------------------------
	• Topsoil requirements	☐	☐	--------------------------------
	• Detailed Design Plans	☐	☐	--------------------------------
	• Stormwater Pond Requirements (if applicable)	☐	☐	--------------------------------
	• Receiving Stream Water Elevation 5-100yr and Regional Storm)	☐	☐	--------------------------------
	• Mitigation of Thermal Impacts	☐	☐	--------------------------------
	• Headwall Safety Barriers	☐	☐	--------------------------------
	• Operation and Maintenance Plan/Report	☐	☐	--------------------------------
	• Monitoring Program	☐	☐	--------------------------------
5.	Hydrogeologic			
	• Final Design of Infiltration Facilities to Maintain Pre-development Water Balance	☐	☐	--------------------------------
	• Confirmation that Infiltration Facility Design is Appropriate for Hydrologic Soil Conditions	☐	☐	--------------------------------
6.	Channel Design or Alteration (if required)			
	• Requirements	☐	☐	--------------------------------
	• Location	☐	☐	--------------------------------
	• Justification for Crossing	☐	☐	--------------------------------
	• Geomorphic Analysis of channels (Setting, meander/amplitudes, alignment & slopes)	☐	☐	--------------------------------
	• Hydrologic and Hydraulic Calculations	☐	☐	--------------------------------
	• Details Drawings (Plan, Profile, x-sections)	☐	☐	--------------------------------

7. Erosion and Sediment Control Plan			
• Details	☐	☐	----
• Location Plan	☐	☐	----
• Calculations	☐	☐	----
• Outfall Locations	☐	☐	----
• Monitoring Location	☐	☐	----
• Contingency Plan	☐	☐	----
• Construction Sequencing	☐	☐	----
• Maintenance Requirements	☐	☐	----
8. Re-vegetation/ Landscape Plan			
• Requirements	☐	☐	----
• Locations	☐	☐	----
• Species List and Quantity Calculations	☐	☐	----
9. Channel Crossing Plans (if required)			
• Requirements	☐	☐	----
• Location	☐	☐	----
• Justification	☐	☐	----
• Geomorphic Analysis of channels (Setting, meander/amplitudes, alignment & slopes)	☐	☐	----
• Hydrologic and Hydraulic Calculations	☐	☐	----
• Details Drawings (Plan, Profile, x-sections)	☐	☐	----
• Fisheries Timing Window	☐	☐	----
• Services and Utilities Allowances	☐	☐	----
10. Monitoring Plan			
• Requirements Based on MESP or Draft Plan	☐	☐	----
• Monitoring Requirements	☐	☐	----
11. Operations and Maintenance Plan			
• Maintenance Methods and Procedures	☐	☐	----
• Sediment Removal Techniques	☐	☐	----
• Annual Loading Rates	☐	☐	----
• Estimates of Sediment Accumulation Rate	☐	☐	----
• Estimate of Maintenance/cleaning Frequency	☐	☐	----
• Inspection Procedures and Frequency	☐	☐	----
12. Performance Monitoring	☐	☐	----
13. Summary and Conclusions	☐	☐	----

Additional Notes

CHECKLIST- Sample Model Parameter Table

The following tables are intended to outline the general requirements for Engineering submissions to the City of Markham. These requirements, however are general and do not relieve the Design Engineer of the responsibility for submitting a finished product of competent Engineering design and construction.

Model Parameter Input Table					
Model	**Sub Basin Number**				
Description	**Notation**	**1**	**2**	**3**	**4…**
Basin Discretization					
Basin Area	AREA				
Unit Hydrograph Type					
Pervious Area Component (Rural Area)					
No of Reservoirs	N				
Time to Peak (hrs)	TP				
Simulation Time Increment (min)	DT				
Dry Weather Flow (cms)	DWF				
Runoff Curve Number	CN				
Impervious Area Component (Urban Area)					
Initial Abstractions IA (mm)	IA				
Simulation Time Increment (min)	DT				
Dry Weather Flow (cms)	DWF				
Runoff Curve Number	CN				
Ratio of Total Impervious Area Directly Connected	XIMP				
Ratio of Total Impervious Area	TIMP				
Infiltration Loss Method: 1- Horton 2- SCS 3- Green and Ampt	LOSS				
Overland Flow Length of Pervious Area (m)	LGP				
Manning of Pervious Area	MNP				
Manning of Impervious Area	MNI				
Storm Data					
Total Storm Duration (hrs)	TD				
Ratio of the Time to the Peak Intensity of the Storm to the Total Duration of the Storm	R				
Storm's time increment (min)	SDT				
Storm type i.e. 3hr AES / 12/24 SCS	ST TYP				
Rainfall Data Input: 1- Values of the IDF Curve A = B = C = 2- Time, Intensity of the IDF Curve	ICASE				
Notes:					

APPENDIX B: 5-YEAR & 100-YEAR STORMSEWER DESIGN SHEETS AND SUMMARY TABLES

MINOR SYSTEM STORM SEWER DESIGN (5-YR)

PROJECT NAME ________________________________

SHEET NO: ______________________

JOB NO: ________________________

DATE: _________________________

CONSULTANT: ___________________

SUBDIVISION NUMBER:_____________

Design Return Period = 5 Yrs, n =

Rainfall Intensity 'I' = $A/(t + B)^c$

A =

B =

C =

Starting 't' = 10 min

Location			Runoff					Rainfall Intensity	Cumm Flow	Pipe Data			Full Capacity	Full Velocity	Qact/Qcap	Time (Entry 10 min.)	
Street Name	Manhole No.		Area(A) (ha)	(C_R)	(C)	i	Cumm (m^3/s) ($Q_5=0.00278C_RCiA$)	I (mm/hr)	(m^3/s)	Length (m)	Diameter (mm)	Slope (%)	(m^3/s)	(m/s)		Sect. (min)	Accum. (min)
	From	To															

Notes	Prepared By:	

MAJOR SYSTEM - STORM SEWER DESIG MARKHAM AULIC GRADE LINE (HGL) ANALYSIS (100-YR)

PROJECT NAME ________________________________

SHEET NO: ______________________
JOB NO: ______________________
DATE: ______________________
CONSULTANT: ___________________
SUBDIVISION NUMBER:_____________

Design Return Period = 100 Yrs, n =

Rainfall Intensity 'I' = $A/(t + B)^c$
A =
B =
C =
Starting 't' = 10 min

Location			Runoff					Rainfall Intensity	Cumm Flow	Pipe Data			Full Capacity	Full Velocity	Time (Entry 10 Min.)		Flow	Hydraulic Grade Line Analysis					
	Manhole No.		Area(A)	(C_R)	(C)	i	Cumm (m^3/s)	I		Length	Diameter	Slope			Sect.	Accum.	(Act/Full)	U/S	D/S	Surcharging (m)	Basement	U/S HGL less	Verification
Street Name	From	To	(ha)				(Q_S=0.00278C_RCiA)	(mm/hr)	(m^3/s)	(m)	(mm)	(%)	(m^3/s)	(m/s)	(min)	(min)		HGL (m)	HGL (m)	Above U/S Obv.	Elevation (m)	Basement Ele(m)	

Notes:

Prepared By:

Note: The designer should use appropraite Routing Coefficient (CR) and Runoff Coefficient based on Table 4.3-4.4 (section 4.3)

APPENDIX C: STORMWATER MANAGEMENT FACILITY ACCEPTANCE FOR MAINTENANCE AND/OR ASSUMPTION REQUIREMENTS

SWM Facility Acceptance for Maintenance and/or Assumption Requirements:

1. Prior to initiating the Stormwater management facility acceptance for maintenance and final assumption process, the following information shall be submitted to the City:
    a. SWM facility cleaning: prior to acceptance for maintenance or as directed by the City, sediment shall be completely removed from the SWM facility. Prior to commencement of the SWM facility cleaning, the owner will conduct bathymetric survey of the entire facility and provide the City with the following:
        i. Plan and profile (pond cross-section) drawings for the SWM facility showing design and existing sediment level including sediment volume calculation.
        ii. Estimate of cost for sediment cleanout and disposal.
        iii. Sediment cleanout methodology and work plan along with dewatering plan, pumping rate, discharge location, erosion & sediment control plan, sediment disposal location, temporary haul route, etc.
        iv. Necessary permits/approvals from applicable agencies (e.g. TRCA, MNRF, Region of York).
    b. Prior to disposal of sediment, the owner shall sample the sediment following acceptable methods and using applicable criteria and guidelines and provide the City with a sediment sampling report, including lab results for peer review and concurrence. The report shall be prepared and signed by a Qualified Person.
    c. After cleanout, the owner shall re-survey the SWM facility and submit to the City an as-built drawing (AutoCAD and PDF format) demonstrating that:
        i. All accumulated sediment has been removed.
        ii. Plan and profile (pond x-sections) drawings comparing the designed and post-cleaning elevations.
        iii. The permanent and active pond volumes are as designed.
        iv. As-built elevations of inlet(s), outlet(s), weirs, forbay, berm, emergency spillway and any other hydraulic structures within the pond.
        v. Plan & profile of the pond showing maintenance access and representative side slopes for the various pond sections.
    d. The owner shall provide the City with an Engineering Certification indicating that all components of the facility are in good repair and that they have been installed in accordance with the approved SWM report and detailed design. A comparison table shall be provided showing the design and as-recorded pond attributes (inlet/outlet pipe size and inverts, control structures, orifice size and invert, forebay berm elevation, side slopes, emergency spillway, and any other hydraulic structures in the SWM facility) including stage/storage/outflow characteristics. Any significant deviation between the design and as-built information shall be identified in the report along with its remedial measures.

e. The owner shall collect field data and develop a rating curve for the hydraulic outlet control structure(s) and submit to the City to demonstrate that the facility is functioning as designed to the satisfaction of the Director of Engineering.

f. A copy of the MOECC Environmental Compliance Authorization.

g. A copy of an acceptance letter from the City's Urban Design Group for the landscaping plan.

2. The proponent shall submit to the City a completed Pond General Information Form provided below, SWM Pond General Information Submission Form.
3. The above information must be stamped by a professional engineer licensed in Ontario.
4. Upon receipt of the above information, the City will perform verification checks to confirm sediment removal, facility permanent pool capacity, proper hydraulic and performance function, and satisfactory condition of facility, and will provide subsequent feedback if deficiencies are found.

CHECKLIST – SWM Pond General Information Submission Form

Pond General Information Sumission Form

General Information Form

Facility Name	
Type	
Function	
Pond Type	
General Description	
Location Description	
Nearest Major Intersection	
Municipal Address	
Easting	
Northing	
Access	
Driveway	
Driveway Material	
Vehicle Turnaround	
Gate Present	
Lock Present	
Adjacent Land Use	

Additional Notes

SWM Pond Block Area(ha) =

Benchmark Location and Elevation =

Permanent Pool Elevation =
Outlet control Orifice(s) size and invert=
Overflow Weir(s) size and invert=

Permanent Pool Volume
Required =
As-Built =

Extended Detention
Elevation =
Required Volume =
As-Built Volume =

100-year Elevation =
Flow =
Storage required =
As-built Volume =

Insert photo of the pond here	**Insert photo of the pond inlet structure here**	**Insert photo of the pond outlet structure here**