THE INFLUENCE OF EROSION CONTROL CRITERIA ON STORMWATER MANAGEMENT FACILITY DESIGN

5TH INTERNATIONAL CONFERENCE ON NATURAL CHANNEL SYSTEMS
SEPTEMBER 27, 2016

Aaron Farrell, M.Eng., P.Eng., Amec Foster Wheeler

John Parish, P.Geo., Parish Aquatic Services

PARISH
aquatic services
A Division of Matrix Solutions Inc.

amec
foster
wheeler

Presentation Outline

- Introduction
- Fluvial Characterization and Assessment Requirements
- Stormwater Management Design Considerations
- Case Study

Introduction

- Urbanization of rural lands reduces groundwater recharge and evapotranspiration, thereby increasing both the volume and rate of runoff to receiving watercourses.
- If unmitigated, the increased volume and rate of runoff generally results in increased downstream flood risk and increased watercourse erosion.
- Erosion impacts are typically associated with more frequent storm events which would generate relatively low or moderate runoff, but which would expose the open watercourse system to increased erosion potential due to the frequency of the events.

Introduction

- For several years, stormwater management plans for urban development have included requirements for erosion controls.
- Various of metrics and methodologies are available to characterize the erosion potential within the receiving watercourse and to assess the impacts from development.
- Little formal guidance and direction is available to practitioners regarding the appropriate methods for characterization and evaluating erosion impacts and potential.
- The metrics and methods can influence decisions regarding sizing and performance of stormwater management for erosion control.
- The practice of evaluating erosion impacts requires an integrated approach between fluvial geomorphology and water resources engineering.

Fluvial Characterization and Assessment Requirements

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Reach Delineation

- Reach of interest must be defined.
- Reach delineation using maps and aerial imagery

Characterize Reach

- Reach walks
- RGA/RSAT
- Identify susceptible areas within reach (weak link in the chain)

Fluvial Characterization and Assessment Requirements

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Data Collection

- Longitudinal profiles, cross-sections
- Identify sensitive areas of reach
- Bed and bank sediment composition
- Typically focus in on riffles – grade controls

Analyses

- D50, energy gradient, manning's n
- Critical shear/permissible velocity
- Recommended approaches
  - Dunn (1959), Chow (2001), Lane (1955)…

Fluvial Characterization and Assessment Requirements

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Determining Best Approach

- Look for convergence between approaches for similar soil types.
  - Test against field data
  - Bed vs bank thresholds

Reach Specific Erosion Thresholds

- Thresholds are expressed as critical flows. Both shear, stream power and velocity are used.
- Thresholds used in continuous simulations
  - Duration of hours
  - Index (magnitude)
  - Cumulative excess work

Stormwater Management Design Considerations

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Provincial Design Criteria

- Current Provincial standards for stormwater management formally require that all new development implement stormwater quality and quantity control practices, to provide flood protection for downstream properties, and to provide erosion control to protect sensitive downstream watercourses.
- These objectives are commonly achieved through the planning, construction, and design of end-of-pipe stormwater management facilities (i.e. wet pond, wetland, or hybrid facility).
- End-of-pipe facilities tend to be favoured by practitioners due to their proven effectiveness to satisfy current Provincial stormwater management criteria when designed in accordance with current standards, as well as their ability to serve larger drainage areas (i.e. 5 ha to 125 ha).

Stormwater Management Design Considerations

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Provincial Design Criteria

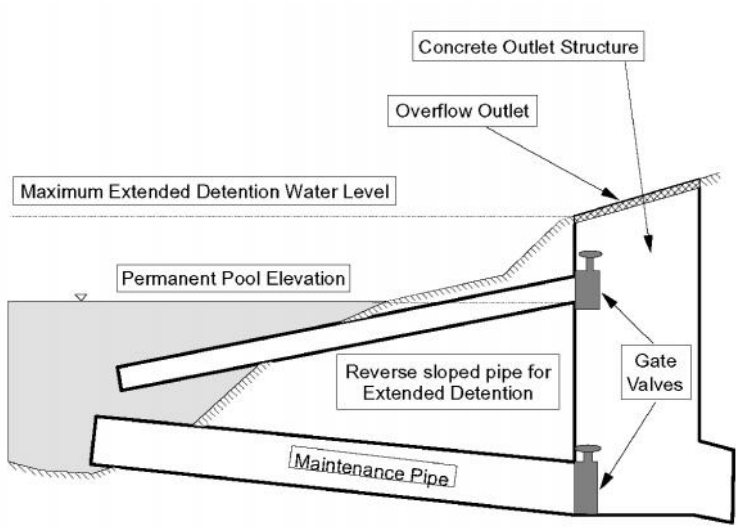
- Erosion control within the end-of-pipe facility is provided by the extended detention component of the facility above the permanent pool.
- The extended detention storage receives the first portion of runoff during storm events, and temporarily detains the stored runoff for a relatively prolonged period (i.e. 1 – 5 days).
- The discharge rate from the extended detention component of the facility is controlled by means of a designed outlet structure (typically an orifice), which is engineered to the specific hydraulic conditions within the stormwater management facility and the prescribed release rate.

Stormwater Management Design Considerations

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Provincial Design Criteria



The current design standards for that the extended detention storage volume require:

- The depth of the extended detention storage be no more than 1.0 m or 1.5 m above the permanent pool (depending upon facility type).
- The current design standards require that the control structure be no less than 75 mm in diameter, in order to prevent the outlet structure from becoming obstructed with debris.

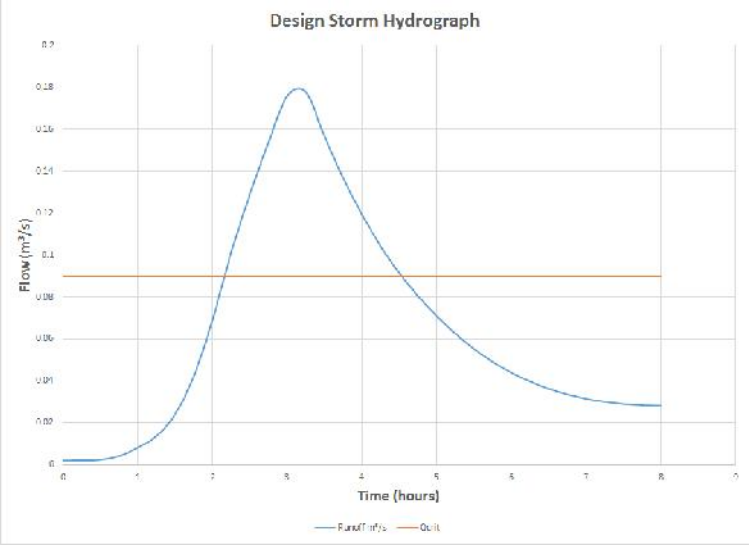
Stormwater Management Design Considerations

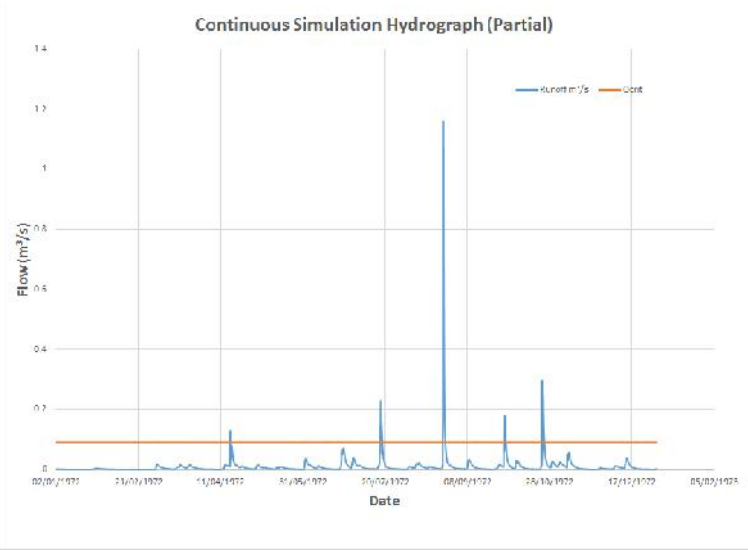
PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Analytical Methods for Hydrologic Impact Assessment

- The flow data and hydrographs generated by the hydrologic analysis represent a key input and component to the erosion assessment and evaluation of alternatives for mitigating impacts.
- The analyses may be completed using simplified approaches (i.e. “single event” synthetic design storms) or more robust techniques (i.e. “real world multiple event” continuous simulation).





Stormwater Management Design Considerations

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Integration Between Hydrology and Fluvial Geomorphology

- The ability of a facility design to satisfy both Provincial design standards and the erosion control criteria is not always achievable for all metrics.
- Consequently, sizing end-of-pipe facilities for erosion control often requires an iterative approach of “testing” the sizing requirements based upon one threshold, and refining the metrics and sizing criteria as appropriate based upon the findings of the assessment.
- Dialogue between fluvial geomorphologists and water resources engineers is integral to this process.

Case Study

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Boyne Survey Area within the Sixteen Mile Creek Watershed, Town of Milton

Case Study


CITY OF BRAMPTON
TOWN OF HALTON HILLS
SUBWATERSHED 1
TOTAL AREA 7870 ha
SUBWATERSHED 2A
TOTAL AREA 2890 ha
SUBWATERSHED 2B
TOTAL AREA 1855 ha
EROSION
MONITORING SITE
CITY OF MISSISSAUGA
TOWN OF MILTON
TOWN OF OAKVILLE
TOWNSHIP OF PUSLINCH
CITY OF BURLINGTON
CITY OF HAMILTON
LEGEND
WATERCOURSE
WATERSHED BOUNDARY
SUBWATERSHED BOUNDARY
SUBJECT REACH OF SIXTEEN MILE CREEK
Scale 1:50000

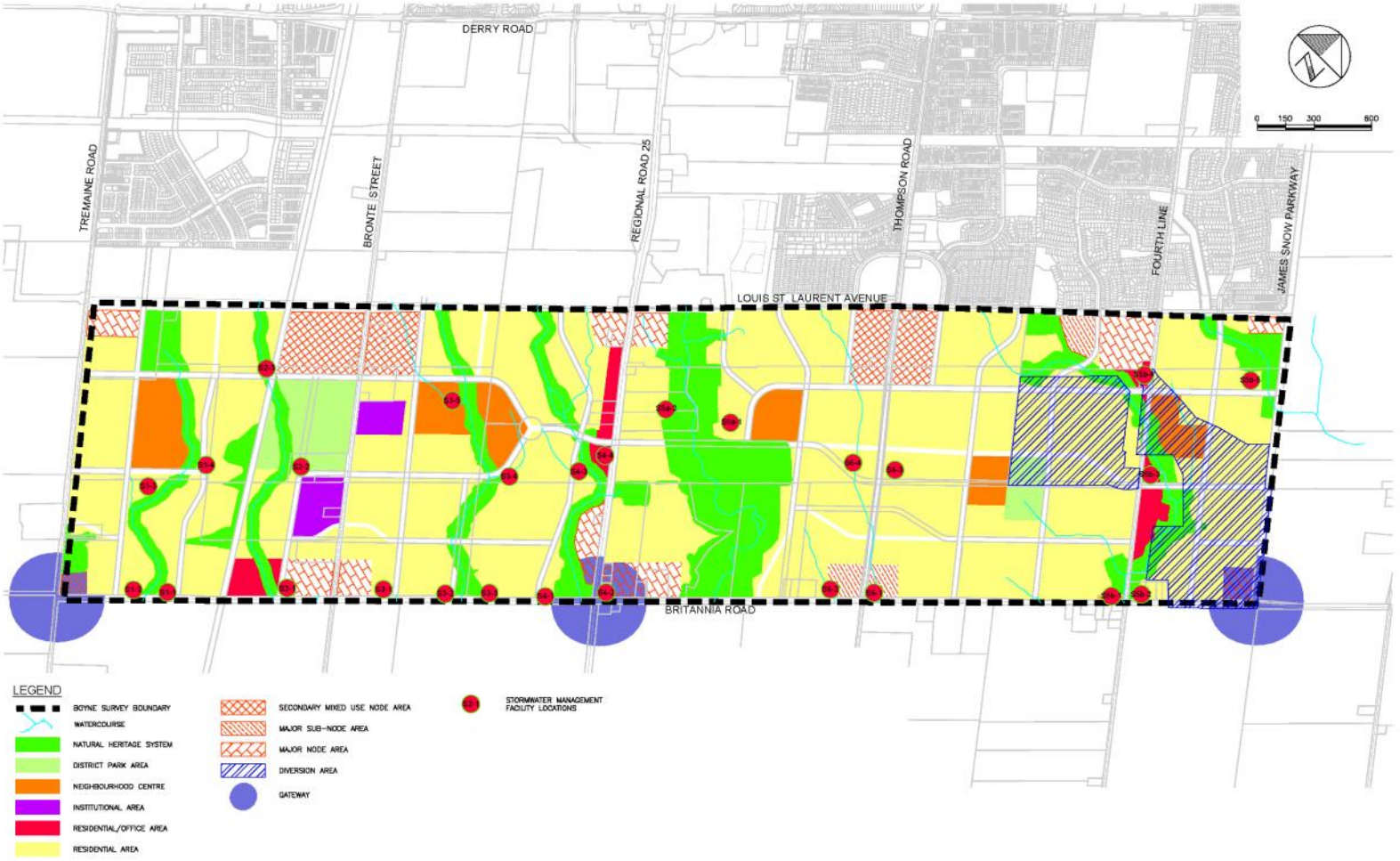
Case Study


DERRY ROAD
TREMAINE ROAD
BRONTE STREET
REGIONAL ROAD 25
THOMPSON ROAD
FOURTH LINE
JAMES SNOW PARKWAY
LOUIS ST. LAURENT AVENUE
BRITANNIA ROAD
0 150 300 600
LEGEND
BOYNE SURVEY BOUNDARY
WATERCOURSE
NATURAL HERITAGE SYSTEM
DISTRICT PARK AREA
NEIGHBOURHOOD CENTRE
INSTITUTIONAL AREA
RESIDENTIAL/OFFICE AREA
RESIDENTIAL AREA
SECONDARY MIXED USE NODE AREA
MAJOR SUB-NODE AREA
MAJOR NODE AREA
GATEWAY

Case Study

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler



Case Study

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Hydrologic Analysis Methodology

- Hydrologic analyses for the Sixteen Mile Creek Watershed have been completed using the HSP-F hydrologic model for a 42 year continuous simulation.
- Routing elements were added to the outlet of each subcatchment representing the future urban development within the Boyne Survey Area.
- The unitary storage and discharge criteria for erosion and flood control were iteratively adjusted until the requisite erosion and flood control has been achieved.

Case Study

Storm Servicing Plan – Hydrologic Assessment

Summary of Extended Detention Storage Requirements for Boyne Survey Area Facilities Discharging Toward Sixteen Mile Creek Main Branch					
Facility ID	**Drainage Area (ha)**	**Impervious Coverage (%)**	**Extended Detention Storage (m^3)**	**Extended Detention Discharge (m^3/s)**	**Estimated Draw Down Time (days)**
S5a-1	29.02	49	5712	0.058	2.5
S5a-2	11.42	32	1464	0.023	1.5
S5b-2	53.60	65	19140	0.027	16.0
S5b-3	34.50	65	12320	.0.017	16.5

Case Study

Erosion Assessment – Duration of Critical Flow Exceedance

- Erosion analyses for the Sixteen Mile Creek Main Branch have been completed initially based upon the change in duration in peak flow above the critical erosion threshold.

Duration Analysis for Erosive Flows Along Sixteen Mile Creek Main Branch (hours)		
Existing Conditions	Future Land Use and SWM	Percent Difference Compared to Existing Conditions
124379	132770	7

- The results indicate that the stormwater management plan would result in a 7 % increase to the duration of flows above the critical erosive flow for the Sixteen Mile Creek Main Branch, which was above the acceptable threshold.
- Additional analyses indicated that increasing the volume and/or drawdown time would not provide adequate erosion protection based upon the duration criteria.

Case Study

PARISH aquatic services
A Division of Matrix Solutions Inc.
amec foster wheeler

Erosion Assessment – Critical Shear Exceedance

- The critical shear exceedance has been evaluated based upon the methods developed by MacCrae and Rowney (ref. The role of Moderate Flow Events and Bank Structure in the Determination of Channel Response to Urbanization, 1992) and shear force relationships outlined by Lorant (ref. Vulnerability of Natural Watercourses to Erosion due to Different Flow Rates, 1982).
- The approach accounts for the shear force exceedance in addition to the duration of exceedance of the critical shear, and which further distinguishes between the shear exceedance applied to the channel bed and the exceedance applied to the channel bank.
- Hydraulic analyses were completed using the HEC-RAS model to determine channel velocities for use in this method.

Case Study

Erosion Assessment – Critical Shear Exceedance

Erosion Assessment Summary for Site R71X (			
Chanel Bed/Bank Station	Land Use Condition within Boyne Survey		Percent Difference Compared to Existing Conditions
	Existing	Future with SWM	
Channel Bed	2104	2148	2
Total Bank Shear	1091	1115	2
0.2 x bankfull depth	841	863	3
0.5 x bankfull depth	511	526	2
0.8 x bankfull depth	94	97	4
1.0 x bankfull depth	17	17	0

Case Study

PARISH aquatic services
A Division of Matrix Solutions Inc.

amec foster wheeler

Erosion Assessment – Critical Shear Exceedance

The results indicate that, based upon the more robust and refined methodology, the erosion control recommended for the Boyne Survey Areas discharging to the Sixteen Mile Creek Main Branch would mitigate the erosion impacts to less than 5 % above existing conditions.

Conclusions

- Different metrics and methods are available for characterizing watercourse erosion potential and quantifying impacts from proposed development.
- The conclusions regarding stormwater management performance and requirements may vary depending upon the metric and method applied to size stormwater management facilities.
- Careful consideration is required to establish the appropriate metric and methodology.
- This frequently requires an iterative and integrated approach, wherein dialogue between water resources engineers and fluvial geomorphologists is integral to select and apply the appropriate methodology.

PARISH
aquatic services
A Division of Matrix Solutions Inc.

amec
foster
wheeler

Thank You!