



Channel Design and Geofluvial Assessment

PURPOSE:

This document provides guidance for the completion of a Channel Design and Geofluvial Assessment which may be required for the submission of an application under the *Planning Act*. All Channel Design and Geofluvial Assessments shall follow the requirements referenced in this document.

A Channel Design and Geofluvial Assessment provides information required for a Planning Application to ensure that erosion hazards are identified and respected, that input is provided as part of stormwater management planning to mitigate costly geomorphic adjustments and to ensure infrastructure such as road crossings and underground linear infrastructure are protected from future lateral and vertical erosion risk. An erosion mitigation assessment may also be required if permanent dewatering discharge is directed to a watercourse to accommodate underground infrastructure such as parking, subject to confirmation by the City that the approach is acceptable.

Geomorphological input is typically required in support of several types of projects and at various stages in planning (e.g., expert plans, secondary plans, and tertiary plans) and design phases (e.g., conceptual, and detailed design). The following types of geomorphological studies can be initiated at various points in the planning and design process:

- Fluvial geomorphological characterization;
- Headwater drainage feature assessments (HDFAs);
- Erosion hazard assessments;
- Erosion threshold and mitigation assessments;
- Infrastructure crossing assessments (e.g., watermains, sanitary sewers, road crossings)
- Natural channel design;
- Stormwater/dewatering outfall siting and treatment design; and
- Baseline Instream monitoring.

Pre-development monitoring, characterization studies and HDFAs are often used to determine flow regimes and development management recommendations. Erosion hazard assessments delineate the natural hazard associated with a watercourse and define, in part, the overall limit of development. Results of erosion threshold and mitigation analyses inform overall stormwater management strategies, identify appropriate locations for infrastructure (e.g., outfalls) when they are proposed within the erosion hazard, as well as outlet-specific erosion mitigation treatments. Often, these types of studies provide baseline conditions that

Channel Design and Geofluvial Assessment – Development Application Guidelines

can be used as a reference during construction and post-construction project phases, and as such, it is critical to ensure that the appropriate study(s) is initiated early in a given project to avoid data gaps and project delays.

If channel realignments are required as part of a development, a technical report supporting the conceptual or detailed design should be provided as part of the submission.

In many cases, portions of geomorphological work would be completed in earlier phases of the planning process. In these instances, the geomorphological component of a given project would be to verify/update previously documented conditions and assessments to ensure consistency. Before proceeding with a geomorphological assessment, the extent and detail of work should be defined with the City of Hamilton and other review/approval bodies.

Where there is a watercourse(s) present within or adjacent to a site that poses a potential natural hazard to proposed development and associated infrastructure, and / or stormwater management/dewatering plans are proposed that include discharge to a watercourse(s), a geomorphological study is required. A geomorphological assessment is also required when watercourse relocation and/or restoration is proposed.

With consideration to the above, a fluvial geomorphology study may be required in support of the following planning processes/development application types:

- Master Plan / Subwatershed Study.
- Official Plan Amendment (OPA).
- Draft Plan of Subdivision Application.
- Site Plan Application.
- Land Severance Application.

PREPARED BY:

A Channel Design and Geofluvial Assessment must be prepared by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or Professional Engineer (P.Eng.) licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology.

CONTENTS:

The applicant is encouraged to discuss the study scope, any site-specific considerations and design assumptions with City staff prior to initiating work. In many cases a fluvial geomorphology study is completed in conjunction with stormwater management reports and delineation of limit of development linework.

A Channel Design and Geofluvial Assessment shall contain the following:

- Review any previously completed studies to ensure consistency and identify/address any data gaps;

- Characterize the watershed and existing drainage network;
- Characterize existing watercourse conditions;
- Characterize headwater drainage features (HDFs);
- Develop recommendations for appropriate watercourse and HDF management;
- Delineate constraints to development such as erosion hazards or setback limits for infrastructure crossings (e.g., meander belt widths / 100-year erosion limits);
- Support the design of stormwater management / dewatering strategies that mitigate the potential for erosion; and
- Provide baseline monitoring to determine pre-development watercourse conditions and characterize natural channel adjustment.

The Terms of Reference is organized based on typical project types specific to fluvial geomorphology. The overall project may involve one or more project types described below. Annotated Tables of Contents are also provided separately and align with each project type.

Fluvial Geomorphological Characterization

A fluvial geomorphological characterization study must contain sufficient information to understand existing drainage feature/watercourse conditions prior to development (e.g., areas of erosion concern or sensitivity, anthropogenic modification, locations of watercourses/drainage features that are high constraint). The following tasks should be included in the project scope:

1. Describe the proposed development and location;
2. Review available background reports and mapping (e.g., watershed/subwatershed studies, geology, topography, conceptual development plans) to inform watershed and drainage network characterization;
3. Describe historical changes in land use, channel planform and instream characteristics, if feasible, within and upstream of the development that may affect current and future channel form. This exercise is typically completed using historical and recent aerial photographs. Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used, including but not limited to LiDAR, false infrared, and satellite imagery;
4. Delineate watercourse reaches based on desktop review of channel and drainage area characteristics;
5. Conduct rapid geomorphic field assessments to confirm the desktop reach delineation and characterize existing conditions. Rapid assessments should include standardized techniques such as Rapid Geomorphic Assessments (RGA) (MOE, 2003) and Rapid Stream Assessment Techniques (RSAT) (Galli, 1996). Methods such as the Downs (1995) model, River Styles Framework (Brierley and Fryirs, 2005) and others may also be applied based on the opinion of the Practitioner;
6. At minimum, provide technical input to HDFAs specifically related to sediment supply/ transport and feature form / function following MNR/ TRCA/CVC criteria. HDFAs can be undertaken collaboratively with the project ecologist;
7. If applicable, develop HDF and watercourse management recommendations to inform development opportunities and constraints; and,

8. Prepare a report that documents the above activities, including dates of field work, extent of drainage features/watercourses assessed, any limitations to the assessment (e.g., site access), and all key findings that are relevant to the development.

Erosion Hazard Assessments

Erosion hazard assessments are typically completed for watercourses that are to be retained to inform, in part, the limit of development and/or the siting of infrastructure such as storm water/dewatering outfalls and road crossings. Meander belt widths should also be calculated for designed channels to ensure the proposed corridor is adequately sized to accommodate the bankfull channel and addresses the potential erosion hazard. The following tasks should be included in the project scope:

9. Complete items 1 to 5 above;
10. Review historical and recent aerial photographs and remote sensing data, as appropriate, to inform the meander belt width / 100-year erosion limit for all features to be retained on the landscape;
11. Erosion hazard delineation will be completed in accordance with the Provincial Planning Statement (PPS, 2024) on defining natural hazards and consider valley setting (i.e. unconfined, partially confined, confined), historical channel form and field-based reach observations;
12. Where the watercourse is confined by valley walls, the erosion hazard limit is defined by the 100-year erosion rate/toe erosion allowance and the long-term stable top of slope. When imagery and channel form allow for the accurate measurement of individual meanders, measurements should focus on lateral migration (i.e., not downstream migration). The long term stable top of slope should be delineated by a geotechnical engineer;
13. The assessment should also include consideration of any additional setbacks (e.g., erosion access allowance);
14. Map the extent of the erosion hazard to inform, in part, the limit of development; and,
15. Prepare a report that documents the above activities, including the date of field work, extent of drainage features/watercourses assessed, approach to delineation of the erosion hazard, any limitations to the assessment (e.g., site access, poor aerial photograph resolution, dense woody riparian vegetation in aerial imagery), and the extent of all erosion hazards.

Erosion Threshold and Mitigation Assessments in Support of Stormwater Management / Dewatering

An erosion threshold and mitigation assessment is typically required when stormwater or dewatering discharge is proposed to outlet to a watercourse. Erosion mitigation criteria may have been defined in previous planning stages. The approach taken should be consistent with requirements established for the watershed and address any local, site-specific concerns. The following tasks should be included in the project scope:

16. Complete items 1 to 5 above;
17. Consideration of the location of HDFs may also be required, subject to the

- proposed outlet location;
18. Complete a detailed geomorphic field assessment to support erosion threshold determination. The detailed assessment will include a longitudinal profile survey of the channel centreline and cross sections, and a detailed review of channel substrate grain size distribution and bank material composition and structure. The site will be downstream, where possible, of future outlets and be associated with the reach most sensitive to erosion;
 19. Erosion threshold calculations should consider both channel substrates and bank composition;
 20. Provide technical support for assessing erosion mitigation strategies as part of the proposed stormwater management plan (e.g., modelling of post- to pre-development hydrology scenarios). The assessment should follow accepted erosion mitigation practices outlined in stormwater management guidelines;
 21. If an erosion exceedance analysis is required, the study should document the type and source of the hydrological modelling used (e.g. synthetic storms or continuous modelling) and development of an erosion mitigation scenario based on post- to pre-development comparisons of erosion threshold exceedance duration, exceedance frequency, cumulative exceedance volume, and cumulative excess work; and,
 22. Prepare a report that documents the above activities, including the date of field work, extent of drainage features/watercourses assessed, approaches used to determine the erosion threshold and complete the erosion exceedance analysis and any limitations to the assessment (e.g., site access).

Infrastructure Crossing Assessments (Underground Services and Watercourse Crossings)

Crossing assessments are typically completed when road crossings and underground infrastructure are proposed to ensure that potential lateral and vertical erosion hazards are adequately mitigated. Fluvial geomorphologic recommendations should be considered with those of other disciplines (e.g., hydrology and hydraulics, wildlife passage). The following tasks should be included in the project scope:

23. Complete items 1 to 5 above;
24. Consideration of the location of HDFs may also be required, subject to the proposed crossing location;
25. If required based on the project scope and design stage, complete a detailed geomorphic field assessment. The detailed assessment will include a longitudinal profile survey of the channel centreline and cross sections, and a detailed review of channel substrate grain size distribution and bank material composition and structure;
26. Provide technical input and recommendations for any watercourse crossings including location, structure type, span, and skew, as well as any setbacks to address the erosion hazard;
27. When possible, structures should be sited along relatively straight sections of channel, cross perpendicular to the channel, and be of sufficient span to accommodate the potential erosion hazard;
28. A vertical scour assessment may be required where underground services are

- proposed to ensure adequate depth of cover over the long-term;
- 29. If instream works are required to mitigate erosion, natural channel design principles should be used at the discretion of the Practitioner; and,
- 30. Prepare a report that documents the above activities, including the date of field work, extent of drainage features/watercourses assessed, and any constraints or opportunities associated with the assessment/design (e.g., presence of valley walls or excessive erosion, evidence of channel degradation).

Natural Channel Design

Natural channel design may be completed at the reach scale or as part of local, site specific restoration works. In many cases, conceptual and detailed channel designs are initiated after the completion of a larger overall study such as a comprehensive plan or subwatershed study and follows watercourse management recommendations (e.g., net constraint rankings).

- 31. Complete Items 1 to 5 above;
- 32. Consideration of the location of HDFs may also be required, subject to the proposed extent of watercourse/drainage feature realignment;
- 33. Complete a detailed geomorphic field assessment along a suitable reference reach to inform the design. The assessment will include a longitudinal profile survey of the channel centreline and cross sections, and a detailed review of channel substrate grain size distribution and bank material composition and structure;
- 34. Provide rationale/describe reasons for channel realignment/restoration;
- 35. Complete bankfull channel sizing calculations to ensure there is an appropriate connection between the channel and its floodplain to dissipate energy during higher flow events (if site constraints permit). Bankfull channel sizing should be based on data collected along the surveyed reference reach and a review of hydraulic/hydrologic modelling;
- 36. Determine appropriate channel planform, gradient and morphology based on proposed development plan and any specific site constraints and ecological targets;
- 37. Confirm that the potential erosion hazard of the designed channel is accommodated with the realigned corridor, if applicable;
- 38. Complete substrate sizing using velocities/shear stresses/discharges to ensure the design remains stable over a range of flow events (to be refined as detailed design proceeds);
- 39. Prepare design drawings in planview and profile following principles of natural channel design;
- 40. Provide general recommendations regarding mechanical stabilization and suitable plantings;
- 41. Phasing, erosion, and sediment control plans may be prepared at the detailed design stage by practitioner or the project engineer; however, a general understanding of how the project is to be implemented is required at the initial project stage to ensure it is feasible; and,
- 42. All natural channel designs should be accompanied by a technical brief that

details previously completed studies and data reviewed, existing conditions, opportunities and constraints for the design, and rationale for the design approach. In addition, general recommendations for implementation and post-construction monitoring are to be provided.

Stormwater / Dewatering Outlet Siting and Treatment Design

43. Complete Items 1 to 5 above along the reach receiving stormwater / dewatering discharge;
44. Consideration of the location of HDFs may also be required, subject to the proposed outlet location;
45. Provide technical input and recommendations for the siting of outlet locations, including consideration of the erosion hazard associated with the receiving watercourse and outlet treatment concepts to mitigate erosion. For example, proposed outlets should be situated at the base of defined watercourse valleys, in previously disturbed and/or open areas where possible, and adjacent to relatively stable sections of channel;
46. Outlet treatments are to consider bioengineered measures to ensure positive drainage and promote detention and infiltration;
47. All stone should be hydraulically sized using velocities/shear stresses/discharges to ensure the outlet treatment remains stable over a range of flow events (to be refined as detailed design proceeds);
48. General recommendations regarding mechanical stabilization and suitable plantings should also be provided; and,
49. All outfall treatment designs should be accompanied by a technical brief that details previously completed studies and data reviewed, existing conditions, opportunities and constraints for the design, and rationale for the design approach. In addition, general recommendations for implementation and post-construction monitoring are to be provided.

Baseline Instream Monitoring

Should the proposed development for a site include a storm water/dewatering outlet to a watercourse, baseline monitoring may be required as part of the approvals process to determine watercourse flow regime, understand sediment quality / transport, and characterize instream conditions and natural erosion rates in the pre-development phase. This allows for a comparison of the stability of a feature receiving stormwater/dewatering discharge in the post-development phase to ensure that any potential impacts have been adequately mitigated. The scope of work for baseline monitoring shall include:

50. Collect continuous water level and temperature measurements from April to November to characterize conditions at the upstream and downstream extents of the development and that coincide with major tributary confluences, where applicable;
51. Establish hydrological monitoring cross-sections at instream monitoring locations to assist in calibrating baseline discharge at each site. Cross-sections will be surveyed, and velocity measurements will be collected during a range of flow

- conditions to develop a stage discharge curve for each feature;
52. Installation of a rain gauge may be recommended if a reliable rain gauge is not operating nearby;
 53. If required, conduct surface water quality sampling following applicable guidelines (e.g., Ontario Stream Assessment Protocol). Parameters may include temperature, conductivity, dissolved oxygen, turbidity, and total suspended solids (TSS). The sampling program should be confirmed with the City and Conservation Authority prior to the initiation of work;
 54. Conduct geomorphic monitoring at monumented channel cross-sections on a seasonal or annual basis to document erosion and changes in overall channel form;
 55. Assess channel substrate quality at monumented cross sections on a seasonal or annual basis through sediment sampling or substrate characterization (e.g., pebble counts), as appropriate;
 56. Collect monumented photographs at each sampling location to confirm the location, timing and local conditions during all sampling and monitoring activities;
 57. If conducting baseline monitoring to classify the watercourse thermal regime, document the technique used and illustrate results in graph format; and,
 58. Summarize and compile all results of baseline monitoring in a report. Results of baseline monitoring will be used to characterize existing pre-development instream conditions including hydrology, sediment quality, and natural erosion, and will act as a reference for the post-development condition.

Additional Information

At a minimum, the following resources are recommended when conducting a fluvial geomorphology study:

- Erosion and Sediment Control Guide for Urban Construction (Toronto and Region Conservation Authority, 2019);
- Technical Guidelines for Watercourse Crossings – Version 1.0 (Credit Valley Conservation, 2019);
- Ontario Stream Assessment Protocol – Version 10 (L. Stanfield, 2017);
- Credit Valley Conservation Fluvial Geomorphic Guidelines (Credit Valley Conservation, 2015);
- Crossing Guidelines for Valley and Stream Corridors (Toronto and Region Conservation Authority, 2015);
- Evaluation, Classification and Management of Headwater Drainage Features Guidelines (Credit Valley Conservation and Toronto and Region Conservation, 2014);
- Evaluating the Effectiveness of ‘Natural’ Channel Design Projects: A Protocol for Monitoring New Sites (TRCA et al., 2009);
- Belt Width Delineation Procedures (Toronto and Region Conservation Authority, 2004);
- Stormwater Management Planning and Design Manual (Ministry of the Environment, 2003); and,
- Technical Guide – River & Stream Systems: Erosion Hazard Limit (Ministry of Natural Resources, 2002).

REVIEWED AND APPROVED BY:

Development Planning and Economic Development Department
Natural Heritage, Planning and Economic Development
Development Approvals, Planning and Economic Development Department
Source Water Protection

The Conservation Authority with regulatory authority over the shoreline for which the Shoreline Assessment Study / Coastal Engineers Study is being completed, namely:

- Hamilton Conservation Authority
- Conservation Halton
- Niagara Peninsula Conservation Authority
- Grand River Conservation Authority

For projects that involve inwater works, consultation with provincial and federal regulatory agencies may be required, including Ministry of Environment, Conservation and Parks, Ministry of Northern Development, Mines, Natural Resources and Forestry, Fisheries and Oceans Canada, and Transport Canada.

CONTACT:

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Niagara Peninsula Conservation Authority
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Grand River Conservation Authority
grca@grandriver.ca

APPENDICES ATTACHED

Channel Design and Geofluvial Assessment – Summary Checklist
Channel Design and Geofluvial Assessment – Standard Format for Document and
Annotated Table of Contents

DRAFT



FLUVIAL GEOMORPHOLOGY STUDY – SUMMARY CHECKLIST

The form is to be completed by the Professional that prepared the _____.

Use of the form by the City of Hamilton is not to be construed as verification of content.

Refer to the Terms of Reference, Fluvial Geomorphological Study:

[Link to Terms of Reference](#)

IF ANY OF THE REQUIREMENTS LISTED BELOW HAVE NOT BEEN INCLUDED IN THE _____, THE STUDY WILL BE CONSIDERED INCOMPLETE.

Summary of Key Information:

	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Site Information		
Site Address		
Property Owner		
Project Description		
Land Use		
Date Prepared		
Prepared By (Consulting Firm)		
Fluvial Geomorphological Characterization		
The Report is dated and signed by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Summary of local surficial geology and physiography		
Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate		
Rapid assessment field work conducted within the 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT)		
If required, headwater drainage features assessments (HDFAs) undertaken following applicable guidelines (e.g., CVC and TRCA, 2014)		
Representative photographs of the watercourse reach(es), any valley slopes, and riparian conditions during ice-free and snow-free conditions		
Mapping that clearly shows the study area, watercourses and waterbodies, topography, and reach breaks and associated labels overlain on recent aerial imagery		
Erosion Hazard Assessments		
The Report is dated, signed and stamped by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of Fluvial Geomorphology		



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<p>The erosion hazard assessment considers valley setting (e.g., confined, unconfined, partially confined) and is prepared in accordance with the following, as appropriate:</p> <ul style="list-style-type: none"> • Technical Guide – River & Stream Systems: Erosion Hazard Limit (MNR, 2002) • Belt Width Delineation Procedures (TRCA, 2004) • Credit Valley Conservation Fluvial Geomorphic Guidelines (CVC, 2015) 		
<p>Summary of local surficial geology and physiography</p>		
<p>Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate</p>		
<p>Rapid assessment field work conducted within the last 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT)</p>		
<p>Representative photographs of the watercourse reach(es), any valley slopes, and riparian conditions during ice-free and snow-free conditions</p>		
<p>Mapping that clearly shows the study area, watercourses and waterbodies, topography, and reach breaks and associated labels overlain on recent aerial imagery</p>		
<p>Mapping showing the erosion hazard limit</p>		



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Erosion Threshold and Mitigation Assessments		
The Report is dated, signed and stamped by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology		
Summary of local surficial geology and physiography		
Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate		
Rapid assessment field work conducted within the last 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT) to determine sensitivity to erosion		
Detailed geomorphological data collected within a representative section of a sensitive reach(es) (e.g., longitudinal profile and cross section survey, channel bank and substrate characterization and size distribution) located downstream of proposed stormwater outlet(s) Assessment to include a minimum of two monumented cross sections with erosion pins to facilitate field verification and multi-year monitoring, if required		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
<p>Representative photographs of the watercourse reach(es), any valley slopes, and riparian conditions during ice-free and snow-free conditions</p> <p>Photographs of monumented cross sections from set vantage points to facilitate field verification and multi-year monitoring, if required</p>		
<p>Erosion threshold calculated based on scientifically- defensible modelling. Field verification may be required at the discretion of the City</p>		
<p>Post- to pre-exceedance analysis using hydrologic modelling</p> <p>Hydrologic modelling approach / requirements to be confirmed in consultation with the City of Hamilton and Conservation Authority prior to initiation of study</p>		
<p>Erosion modelling hydrographs provided as a report appendix</p>		
<p>Mapping that clearly shows the study area, watercourses and waterbodies, reach breaks and associated labels, detailed geomorphic assessment location, and proposed stormwater outlet location(s) overlain on aerial imagery</p>		
<p>Assessment of impacts of proposed stormwater management strategy on downstream receiving watercourse(s) provided</p>		



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Infrastructure Crossing Assessments (Underground Services and Watercourse Crossings)		
The Report is dated, signed and stamped by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology		
Summary of local surficial geology and physiography		
Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate		
Rapid assessment field work conducted within the last 3 to 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT)		
Representative photographs of the watercourse reach(es), proposed infrastructure crossing location(s), any valley slopes, and riparian conditions during ice-free and snow-free conditions		
Infrastructure crossing(s) is located along a relatively straight section of channel where there are no significant erosion concerns (e.g., avoids large meanders)		
Mapping that clearly shows the study area, watercourses and waterbodies, reach breaks and associated labels, and crossing infrastructure overlain on aerial imagery		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Infrastructure crossing design accommodates the channel and potential erosion hazard		
If applicable, road crossing inlet(s) and outlet(s) are appropriately designed to remain stable over a range of flow conditions		
If applicable, any substrates proposed within road crossings have been hydraulically sized to remain stable during a range of flow events		
If required, scour analysis completed to confirm adequate depth of cover and inform erosion control requirements		
Natural Channel Design		
The Report is dated, signed and stamped by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology		
Summary of local surficial geology and physiography		
Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate		
Rapid assessment field work conducted within the last 3 to 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT) for all watercourse reaches, whether being retained, modified or realigned		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Representative photographs of the watercourse reach(es), any valley slopes, proposed outlet location(s) and riparian conditions during ice-free and snow-free conditions		
Detailed geomorphological assessment along a reference reach to inform the design that includes a survey of the longitudinal profile, and representative cross sections, characterization of bank materials, channel substrate composition (sampled for grain size analysis or pebble counts, as appropriate) and a general description of immediate riparian conditions		
Mapping that clearly shows the study area, watercourses and waterbodies, reach breaks and associated labels		
Design Brief documents rationale for the proposed channel planform, gradient, bankfull channel geometry, geomorphology and selected bioengineered treatments		
Drawings in planview: <ul style="list-style-type: none">• Proposed grading• Work area limits• Watercourse alignment and channel banks• Existing and proposed infrastructure and utility crossings• Proposed treatment type / extent• Restoration planting plan		
Drawings in profile view: <ul style="list-style-type: none">• Existing ground/channel and proposed channel bed and bankfull gradients• Proposed grading		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
<ul style="list-style-type: none"> Existing and proposed crossing infrastructure and utility crossings 		
<p>Drawings in cross section view:</p> <ul style="list-style-type: none"> Cross sectional view(s) of geomorphic units, wetlands and bioengineered treatments, as required Proposed substrate composition Mechanical stabilization measures Restoration planting plan 		
<p>Hydraulic stone sizing completed based on velocities/shear stresses/discharges</p>		
<p>Drawings showing details:</p> <ul style="list-style-type: none"> Restoration planting plan (e.g., live stake planting detail) Floodplain features (e.g., snake hibernacula, basking logs, turtle nesting site) Mechanical stabilization measures 		
<p>Phasing, erosion and sediment control plans are provided at detailed design stage that follow appropriate guidelines and standards and include typical details (e.g. TRCA, 2019)</p>		
<p>Stormwater / Dewatering Outfall Siting and Treatment Design</p>		
<p>The Report is dated, signed and stamped by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology</p>		
<p>Summary of local surficial geology and physiography</p>		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Review of historical and recent aerial imagery and remote sensing data to assess channel adjustments and land uses, as appropriate		
Rapid assessment field work conducted within the last 5 years on a reach basis (site access permitting) using standardized assessment tools (e.g., RGA and RSAT) where the stormwater outlet(s) is proposed		
Representative photographs of the watercourse reach(es), any valley slopes, proposed outlet location(s) and riparian conditions during ice-free and snow-free conditions		
Mapping that clearly shows the study area, watercourses and waterbodies, reach breaks and associated labels, and proposed stormwater outlet location(s) overlain on aerial imagery		
Design considers valley setting and topography, and avoids areas of active erosion and sensitive habitats to the extent feasible		
Extent of topographic survey encompasses 15 m upstream and downstream of the proposed stormwater outlet location and includes: <ul style="list-style-type: none">• Watercourse inverts and thalweg• Water level at the time of survey• Channel banks• Valley slopes and any existing erosion protection measures• Existing infrastructure and utilities		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
<p>Drawings in planview are to include:</p> <ul style="list-style-type: none"> Proposed grading Work area limits Watercourse alignment and channel banks Existing and proposed crossing infrastructure and utilities Extent of the erosion hazard for the receiving watercourse Proposed outlet treatment type(s) / extent Restoration planting plan 		
<p>Drawings in profile view:</p> <ul style="list-style-type: none"> Existing and proposed longitudinal profile of the storm sewer outlet Proposed grading Existing and proposed infrastructure and utility crossings Proposed outlet treatments, including any connecting channel to receiving watercourse Proposed substrate composition for outlet treatments Mechanical stabilization measures Restoration planting plan 		
<p>Drawings in cross section view:</p> <ul style="list-style-type: none"> Cross sectional view(s) of outfall treatment(s) Proposed substrate composition for outlet treatment(s) Mechanical stabilization measures Restoration planting plan 		
<p>Hydraulic stone sizing completed based on maximum proposed velocities at the stormwater outlet</p>		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
<p>Drawings showing typical details:</p> <ul style="list-style-type: none"> • Restoration planting plan (e.g., live stake planting detail, seed mixes) • Bioengineered outfall treatment(s) • Mechanical stabilization measures 		
<p>Phasing, erosion and sediment control plans are provided at detailed design stage that follows appropriate guidelines and standards and includes typical details (e.g., TRCA, 2019)</p>		
<p>Baseline Instream Monitoring</p>		
<p>The Report is dated and signed by a Qualified Geomorphologist licensed by the Association of Professional Geoscientists of Ontario or a Professional Engineer licensed by Professional Engineers Ontario with experience in the field of fluvial geomorphology</p>		
<p>Continuous flow monitoring locations established at the upstream and downstream extents of study area and the confluence(s) of major tributaries to measure discharge and water temperature (site access permitting)</p> <p>Monitoring period to extend from April to November</p>		
<p>Monumented hydrological monitoring cross sections established to calibrate discharge at each monitoring location</p>		
<p>Summary of surface water quality parameters measured and associated results and interpretation</p>		



	Page # & Section # of Review	Review Includes this Information City Staff (Check)
Monumented geomorphic monitoring cross sections and longitudinal profile established to characterize pre-development erosion rates and substrate composition		
Sediment size distribution characterized using pebble count techniques or sampled for grain size analysis		
Monumented photographs as a visual record of instream conditions at the time of each monitoring visit		
Characterization of channel erosion based on natural variability		

Qualified Professional who completed the report summary:

Name: _____

Email: _____

Phone: _____

Date: _____

Signature and Stamp: _____



Fluvial Geomorphology Characterization Standard Format for Document and Annotated Table of Contents

Title and Report Details:

- Project Name
- Type of Report
- Project Location
- Prepared for: Client
- Prepared by: Company name
- Date of Original Report
- Date of Revised Report (if applicable)

Table of Contents:

1.0 Introduction

- description of location, site area, property owner(s)
- general description of the development and plans
- description of larger development (if phased and/or applicable)
- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- include information regarding the history of the development or project, if applicable
- review of previously completed studies (i.e., master plan, subwatershed study, etc.), if available

2.1 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form
- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

2.2 Site History (historical and contemporary aerial imagery assessment)

- describe historical changes in land use within and upstream of the development that may affect current and future channel form
- describe visible changes to channel planform and instream characteristics over the period of record, where feasible, that influence current channel form and may impact proposed development plans (e.g., meander bend cut-offs, oxbows, evidence of active erosion, historical or contemporary impoundment, etc.)
- Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used to complete the historical assessment, including but not limited to LiDAR, false infrared and satellite imagery

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach and methodology for delineation, as well as a broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context

3.2 General Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and/or aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment
- provide a brief description of the rapid geomorphic assessment tools used and associated results
- at minimum, rapid geomorphic assessments (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis
- additional assessment techniques may and should be used at the discretion of the practitioner

- document observed dominant modes of adjustment and erosion sensitivity

3.4 Detailed Geomorphological Assessment (if applicable)

- describe the rationale for the selection of the detailed geomorphic assessment location(s)
- describe field methodology, including the length of channel surveyed and the number of cross sections surveyed
- at minimum, the following parameters should be tabulated for each reach assessed:
 - measured parameters:
 - average bankfull channel width (m)
 - average bankfull channel depth (m)
 - bankfull channel gradient (%)
 - substrate size: D_{50} and D_{84} (mm)
 - Manning's roughness coefficient
 - computer parameters:
 - bankfull discharge (m^3/s)
 - average bankfull velocity (m^2/s)
 - unit stream power at bankfull discharge (W/m^2)
 - tractive force at bankfull (N/m^2)
 - critical shear stress or velocity for bed and bank materials based on appropriate methodologies selected by the practitioner

4.0 Headwater Drainage Feature Assessment (HDFa) (if applicable)

- describe headwater drainage feature assessment field methodology, timing of surveys, and cite relevant guidelines
- tabulate the properties of each headwater drainage feature including hydrology, riparian conditions, fish and fish habitat and terrestrial function
- this work may be undertaken in tandem with or by the Project Ecologist

5.0 Watercourse and Headwater Drainage Feature Management Recommendations (if applicable)

- Identify opportunities and constraints to the development from a geomorphological perspective

- discuss watercourse constraint rankings and rationale for management recommendations (e.g., reaches impacted by historical land uses that may benefit from restoration/realignment)
- provide detailed discussion of HDF management recommendations and justification for classification
- discuss development plans that have the potential to affect HDFs and how

6.0 Summary and Recommendations

- summarize desktop-based and field-based activities completed as part of the project scope
- briefly summarize reach observations and rapid field assessments results, and note key findings
- summarize watercourse and HDF management recommendations, as appropriate
- identify anticipated requirements or recommendations for future project stages, if applicable (e.g., conceptual and detailed design requirements, monitoring, anticipated regulatory agency approval requirements)

7.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Tables (as needed, examples listed below)

Table 1: General reach characteristics summary (bankfull measurements and general observations)

Table 2: Rapid assessment results

Table 3: Summary of detailed geomorphological results

Table 4: Headwater drainage feature classification

Appendices (supplemental information as needed, examples listed below)

Appendix A Study Area and Reach Delineation

Appendix B Historical Aerial Photographs (include aerials used to complete historical analysis)

Appendix C Photographic Record (photographs taken as part of field observations)

Appendix D Field Observations (provide copies of completed field sheets)

Appendix E Detailed Assessment Summary



Erosion Hazard Assessment Standard Format for Document and Annotated Table of Contents

Title and Report Details

- Project Name
- Type of Report
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- Prepared for: Client
- Prepared by: Company name
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- description of location, site area, property owner(s)
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- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- include information regarding the history of the development or project
- review of previously completed studies (i.e., master plan, subwatershed study, etc.), If available

2.1 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form
- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

2.2 Site History (historical and contemporary aerial imagery assessment)

- describe historical changes in land use within and upstream of the development that may affect current and future channel form
- describe visible changes to channel planform and instream characteristics over the period of record, where feasible, that influence current channel form and may impact proposed development plans (e.g., meander bend cut-offs, oxbows, evidence of active erosion, historical or contemporary impoundment, etc.)
- Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used to complete the historical assessment, including but not limited to LiDAR, false infrared and satellite imagery

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach, methodology, and broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context
- appropriate delineation is a key component as erosion hazard limits are typically delineated on a reach basis

3.2 Generation Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment
- a brief description of the rapid assessments and relevant data collected
- at minimum, rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis

- additional assessment techniques may and should be used at the discretion of the practitioner
- document observed dominant modes of adjustment and erosion sensitivity

4.0 Erosion Hazard Analysis

4.1 Meander Belt Width Assessment (unconfined systems)

- describe methodology used to determine the meander belt width(s)
- justify the selected approach and demonstrate conformance with applicable guidelines (e.g., PPS, 2020; TRCA, 2004; MNR 2002)
- Analysis may include aerial photo interpretation/historical watercourse digitization to determine meander migration rates and measure meander amplitudes, or application of empirical modelling, as determined by the Practitioner
- tabulate the results of the meander belt width analysis, if necessary
- describe any additional setbacks to the meander belt width (e.g., additional setbacks required by the conservation authority/municipality)

4.2 100-yr Erosion Rate / Toe Erosion Allowance (partially confined/confined systems)

- note reaches where meander migration may be constrained by valley walls
- describe methodology used to determine the 100-yr migration rate / toe erosion allowance
- meander migration rates should be measured laterally towards a given valley wall (i.e., not meandered in the downstream direction)
- outline toe erosion allowance recommendations and provide supporting justification
- note any additional studies required/completed (e.g., geotechnical slope stability analysis)
- describe any additional setbacks in addition to the toe erosion allowance (e.g., erosion access allowance)

5.0 Summary and Recommendations

- describe key findings of the desktop- and field-based assessments
- describe any areas of erosion concern or channel instability
- summarize the erosion hazard assessment methodology and erosion hazard limit
- discuss the erosion hazard limit relative to the proposed development

6.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Tables (as needed, examples below)

Table 1: General reach characteristics summary (bankfull measurements and general observations)

Table 2: Rapid assessment results (rapid assessment results)

Table 3: Meander belt width summary (on a reach basis)

Table 4: 100-yr erosion hazard limit/toe erosion allowance recommendations (on a reach basis)

Appendices (supplemental information as needed, examples listed below)

Appendix A Study Area and Reach Delineation Mapping

Appendix B Historical Aerials (include historical aerials used to complete analysis)

Appendix C Photographic Record (photographs taken as part of field observations)

Appendix D Field Observations (provide copies of completed field sheets)

Appendix E Erosion Hazard Delineation (mapping of erosion hazards on a reach basis, as appropriate)



Erosion Mitigation Assessment Standard Format for Document and Annotated Table of Contents

Title and Report Details

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- Project Location
- Prepared for: Client
- Prepared by: Company name
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- general description of the development and plans
- description of larger development (if phased and/or applicable)
- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- include information regarding the history of the development or project
- review of previously completed studies (i.e., master plan, subwatershed study, etc.)

2.1 General Site Characteristics

- describe overall drainage area conditions such as land use, surficial geology and physiography
- describe site specific subsurface conditions based on available boreholes collected by others (e.g., geotechnical assessment or hydrogeological assessment), if available

2.2 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form

- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

2.3 Site History (historical and contemporary aerial imagery assessment)

- describe historical changes in land use within and upstream of the development that may affect current and future channel form
- describe visible changes to channel planform and instream characteristics over the period of record, where feasible, that influence current channel form and may impact proposed development plans (e.g., meander bend cut-offs, oxbows, evidence of active erosion, historical or contemporary impoundment, etc.)
- Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used to complete the historical assessment, including but not limited to LiDAR, false infrared and satellite imagery

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach, methodology, and broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context
- appropriate delineation is a key component as erosion hazard limits are typically delineated on a reach basis

3.2 General Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment

- a brief description of the rapid assessments and relevant data collected
- at minimum, rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis
- additional assessment techniques may and should be used at the discretion of the practitioner
- document observed dominant modes of adjustment and erosion sensitivity

3.4 Detailed Geomorphological Assessments

- describe the rationale for the selection of the detailed geomorphic assessment location(s)
- describe field methodology, including the length of channel surveyed and the number of cross sections surveyed.
- Provide description of bank materials as determined through field observations
- at minimum, the following parameters should be tabulated for each detailed assessment:
 - measured parameters:
 - average bankfull channel width (m)
 - average bankfull channel depth (m)
 - bankfull channel gradient (%)
 - substrate size: D_{50} and D_{84} (mm)
 - Manning's roughness coefficient
 - computer parameters:
 - bankfull discharge (m^3/s)
 - average bankfull velocity (m^2/s)
 - unit stream power at bankfull discharge (W/m^2)
 - tractive force at bankfull (N/m^2)
 - critical shear stress or velocity for bed and bank materials based on appropriate methodologies selected by the practitioner

4.0 Erosion Threshold Analysis

- describe the purpose of determining erosion thresholds for this study site
- describe the stormwater management plan and relevant structures, typically including outlet locations relative to watercourses and drainage features in the study area

4.1 Methods

- describe methods used to determine the erosion threshold and critical velocities, citing documentation and equations
- document any assumptions used in the analysis

4.2 Results

- this section will discuss the results of the erosion threshold analysis
- note whether the erosion threshold was based on bed or bank materials
- discuss the validity for results of each reach, using supporting field observations and relevant documentation
- compare results to expected values or if any, previously calculated values
- the following parameters should be tabulated for each reach assessed:
 - cross section characterization:
 - bankfull width (m) and depth (m)
 - substrate size: D_{50} and D_{84} (mm)
 - Manning's n roughness coefficient used
 - bankfull velocity (m/s) and discharge (m^3/s)
 - parameters and calculated values for bed and bank limited models
 - bank or bed material and cited literature
 - critical velocity (m/s) or shear stress (N/m)
 - apparent velocity (m/s) or shear stress (N/m)
 - critical discharge (m^3/s)
 - final limiting critical discharge (m^3/s) for each reach
 - unitary erosion threshold ($m^3/s/ha$) for each reach

5.0 Post- to Pre- Development Erosion Exceedance Assessment (if required)

- describe the purpose of the post- to pre- development erosion exceedance assessment

5.1 Methods

- summarize methods used to calculate erosion exceedance, including equations and parameters
- summarize the model and data origin (i.e., data type, version, data quality, scope, relevance)

- discuss model parameters used and provide rationale

5.2 Results

- tabulate the calculated cumulative effective volume (CEV), cumulative effective discharge (CED), time of exceedance (t_{ex}), number of exceedances for each reach, as appropriate
- interpret results and predict erosion potential for each reach in the post-development condition
- discuss whether the proposed stormwater management plan adequately mitigates erosion in receiving feature. If not, are there any alternatives or additional recommendations to address erosion mitigation concerns?

6.0 Summary and Recommendations

- summarize the key findings from the field assessment
- restate the results of the erosion threshold calculations
- summarize the stormwater management strategy and results of the erosion exceedance analysis
- confirm if the proposed stormwater management plans adequately address erosion mitigation. If not, provide additional recommendations, as appropriate

7.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Tables (as needed, examples listed below)

Table 1: Reach characteristics (general reach observations and measurements)

Table 2: Rapid assessment results

Table 3: Detailed geomorphological assessment results

Table 4: Erosion threshold results

Table 5: Erosion exceedance results (results of continuous/single storm post- to pre-development erosion analysis)



Appendices (supplemental information as needed, typical examples listed below)

Appendix A Study Area and Reach Delineation

Appendix B Photographic Record (photos taken during field work with captions)

Appendix C Field Observations (provide copies of completed field sheets)

Appendix D Detailed Assessment Summary (summary of detailed assessment information, including calculated parameters with representative cross sections)

Appendix E Erosion Modelling Hydrographs (hydrograph results from Post- and Pre- Erosion Exceedance Modelling)

DRAFT



Fluvial Geomorphological Crossing Assessment Standard Format for Document and Annotated Table of Contents

Title and Report Details

- Project Name
- Type of Report
- Project Location
- Prepared for: Client
- Prepared by: Company name
- Date of Original Report
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- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- include information regarding the history of the development or project
- review of previously completed studies (i.e., master plan, subwatershed study, etc.)

2.1 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form
- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

2.2 Site History (historical and contemporary aerial imagery assessment)

- describe historical changes in land use within and upstream of the development that may affect current and future channel form
- describe visible changes to channel planform and instream characteristics over the period of record, where feasible, that influence current channel form and may impact proposed development plans (e.g., meander bend cut-offs, oxbows, evidence of active erosion, historical or contemporary impoundment, etc.)
- Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used to complete the historical assessment, including but not limited to LiDAR, false infrared and satellite imagery

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach, methodology, and broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context
- appropriate delineation is a key component as erosion hazard limits are typically delineated on a reach basis

3.2 General Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment
- a brief description of the rapid assessments and relevant data collected
- at minimum, rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis

- additional assessment techniques may and should be used at the discretion of the practitioner
- document observed dominant modes of adjustment and erosion sensitivity

3.4 Detailed Geomorphological Assessment (if required based on project scope)

- complete if required within the scope of the scour assessment (e.g., detailed design project stage)
- describe the rationale for the selection of the detailed geomorphic assessment location(s)
- describe field methodology, including the length of channel surveyed and the number of cross sections surveyed
- the following parameters should be tabulated for each detailed assessment, in addition to any other relevant parameters considered by the practitioner:
 - measured parameters:
 - average bankfull channel width (m)
 - average bankfull channel depth (m)
 - bankfull channel gradient (%)
 - substrate size: D_{50} and D_{84} (mm)
 - Manning's roughness coefficient
 - computer parameters:
 - bankfull discharge (m^3/s)
 - average bankfull velocity (m^2/s)
 - unit stream power at bankfull discharge (W/m^2)
 - tractive force at bankfull (N/m^2)
 - critical shear stress or velocity for bed and bank materials based on appropriate methodologies selected by the practitioner

4.0 Scour / Erosion Hazard Assessment

4.1 Vertical Scour Analysis (if required)

- describe the location/ type of each watercourse/ drainage feature crossing, whether existing or proposed
- describe any current crossing infrastructure including date of construction, general condition, dimensions, depth of cover/degree of exposure and previously installed erosion mitigation measures, as appropriate

- summarize existing watercourse conditions at each crossing location, focusing on channel planform characteristics, bankfull channel dimensions, sediment transport processes, and local degradation/aggradation concerns
- describe methodology of scour analysis, including data sources used (e.g., channel survey data/bankfull channel characteristics, hydraulic modelling, as-built drawings)
- document results of scour analysis
- both modelled and field-observed scour depths are relevant with reliance on any one method at the discretion of the practitioner and in consultation with the City, as appropriate

4.2 Lateral Erosion Analysis

- describe the location/type of each watercourse/ drainage feature crossing, whether existing or proposed
- describe any current crossing infrastructure including date of construction, dimensions, general condition, and previously installed erosion mitigation measures, as appropriate
- summarize existing watercourse conditions at each crossing location, focusing on channel planform characteristics, bankfull channel dimensions, sediment transport processes, and local degradation/aggradation concerns
- describe methodology used to delineate the potential lateral erosion hazard associated with the channel following relevant guideline documents
- document results of analysis

5.0 Watercourse/Drainage Feature Crossing Recommendations

- describe if the proposed crossing location is suitable from a geomorphologic perspective (e.g., crossing skew limits length of structure required, crossing located along a stable, straight section of channel, crossing located in a previously disturbed area)
- identify the minimum road crossing span required to accommodate natural channel processes and the potential erosion hazard following applicable Conservation Authority/municipal guidelines
- provide justification, particularly if recommendations deviate from industry crossing guidelines (e.g., TRCA, 2015; CVC, 2019)
- provide recommendations to consider as part of the engineering design (e.g., depth of cover required over underground infrastructure, depth of crossing structure footings) and erosion mitigation, as required
- should local watercourse/drainage feature realignment be recommended to accommodate a crossing structure, natural channel design principles should be followed

- if applicable, provide additional recommendations such phasing, erosion and sediment control, and monitoring
- identify anticipated regulatory agency approval requirements, as appropriate

6.0 Summary and Recommendations

- restate the purpose of the crossing assessment and summarize the location and type of infrastructure crossings proposed
- summarize the results of the scour/erosion hazard assessment, as appropriate
- summarize crossing recommendations
- state any additional recommendations (e.g., erosion control measures, natural channel design for local realignment), if applicable

7.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Tables (as needed, examples listed below)

Table 1: Reach characteristics (general reach observations and measurements)

Table 2: Rapid assessment summary

Table 3: Results of scour assessment

Appendices (supplemental information as needed, examples listed below)

Appendix A Study Area, Reach Delineation, Infrastructure Crossing Locations

Appendix B Photographic Record (photos taken during field work with captions)

Appendix C Field Observations (provide copies of completed field sheets)

Appendix D Detailed Assessment Summary (summary of detailed assessment information, including calculated parameters with representative cross sections)

Appendix E Erosion Hazard Delineation



Natural Channel Design Standard Format for Document and Annotated Table of Contents

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2.0 Background Review

- include information regarding the history of the development or project
- review of previously completed studies (i.e., master plan, subwatershed study, etc.), if available

2.1 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form
- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

2.2 Site History (historical and contemporary aerial imagery assessment)

- describe historical changes in land use within and upstream of the development that may affect current and future channel form
- describe visible changes to channel planform and instream characteristics over the period of record, where feasible, that influence current channel form and may impact proposed development plans (e.g., meander bend cut-offs, oxbows, evidence of active erosion, historical or contemporary impoundment, etc.)
- Ontario base mapping (OBM) and data collected using remote sensing techniques may also be used to complete the historical assessment, including but not limited to LiDAR, false infrared and satellite imagery

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach and methodology for delineation, as well as a broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context

3.2 General Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and/or aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment
- provide a brief description of the rapid geomorphic assessments tools used and associated results
- at minimum, rapid geomorphic assessment (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis
- additional assessment techniques may and should be used at the discretion of the practitioner

- document observed dominant modes of adjustment and erosion sensitivity

3.4 Detailed Geomorphological Assessment

- describe the rationale for the selection of the detailed geomorphic assessment location(s)
- describe field methodology, including the length of channel surveyed and the number of cross sections surveyed.
- at minimum, the following parameters should be tabulated for each reach assessed:
 - measured parameters:
 - average bankfull channel width (m)
 - average bankfull channel depth (m)
 - bankfull channel gradient (%)
 - substrate size: D_{50} and D_{84} (mm)
 - Manning's roughness coefficient
 - computer parameters:
 - bankfull discharge (m^3/s)
 - average bankfull velocity (m^2/s)
 - unit stream power at bankfull discharge (W/m^2)
 - tractive force at bankfull (N/m^2)
 - critical shear stress or velocity for bed and bank materials based on appropriate methodologies selected by the practitioner

4.0 Natural Channel Design

4.1 Design Objectives

- provide rationale for the modification of existing features and cite recommendations provided in previously completed studies (e.g., master plan or subwatershed study), if applicable
- outline the goals and objectives of the design (e.g., restore the channel, protect infrastructure, accommodate new development, enhance aquatic habitat, fish barrier remediation, etc.)
- document any design opportunities and constraints based on existing and proposed conditions and recommendations from previously completed studies

4.2 Channel Planform

- outline approach to determining channel planform parameters and assumptions used
- describe channel planform characteristics (e.g., radius of curvature values, meander wavelengths, and riffle spacing)
- discuss how the goals and objectives of the channel design are addressed by channel planform characteristics

4.3 Bankfull Channel

- outline methods and assumptions used to design bankfull channel geometry, including designed discharge return period (e.g., 1.5-yr flow, 2-yr flow) and data used (i.e., reference reach, modelling, etc.)
- summarize the recommended channel geometry
- discuss any additional benefits to the recommended bankfull channel geometry
- a range of parameters are generally calculated to determine bankfull channel geometry that may include:
 - bankfull width (m)
 - average and maximum bankfull depth (m)
 - bankfull width to depth ratio
 - channel bed and bankfull gradients (%)
 - radius of curvature (m)
 - riffle-pool spacing (m)
 - Manning's roughness coefficient (n)
 - mean bankfull velocity (m/s)
 - bankfull discharge (m³/s)
 - discharge to accommodate (m³/s)
 - tractive force at bankfull (N/m)
 - stream power unit stream power (W/m²)
 - Froude number (unitless)
 - maximum grain size entrained (m)
 - mean grain size entrained (m)
- Provide additional appropriate and justifiable parameters, as selected by the practitioner

4.4 Corridor Requirements

- Calculate the meander belt width for the designed channel and describe the potential erosion hazard
- Identify minimum corridor requirements for the designed channel
- Confirm whether the design channel can be accommodated with the corridor

4.5 Hydraulic Channel Substrate Sizing

- summarize methodologies and velocities/shear stresses/discharges used to size designed substrates
- provide recommended material types and stone sizes, with supporting information from field observations, previously completed reports, or other data
- discuss the benefits of the recommended stone sizing (e.g., aquatic habitat, opportunities for enhanced infiltration and detention for water, and channel stability)

4.6 Crossing Recommendations

- summarize the location, size, and structure type for proposed corridor crossings
- document designed bankfull channel geometry within the crossing
- confirm whether the proposed crossing is of sufficient span to accommodate the designed channel and the erosion hazard
- complete hydraulic substrate sizing and include a description of methodology
- comment on the velocities in the low flow channel within the crossing with regard to fish passage (i.e., do the anticipated velocities at the proposed crossing allow fish passage for target species?)

4.7 Design Elements (examples)

4.7.1 Bioengineered Treatments

- provide a brief description of the types of bioengineered treatments and rationale for their selection and proposed locations (e.g., vegetated buttress, crib wall, brush mattress)

4.7.2 Wetland Features

- provide a brief description of the types of wetland features to be added, if applicable
- discuss their anticipated function (e.g., hydroperiod, overwintering turtle habitat, breeding amphibian habitat)
- provide additional guidance on wetland features including general installation methods and plantings, as required
- Water availability / feature-based water balance assessment may be required

4.7.3 Terrestrial Habitat Features

- describe terrestrial habitat elements to be incorporated into the channel corridor, and their anticipated benefits to the overall natural heritage system (i.e., mounds, rock/brush piles, basking logs, etc.)

4.8 Site Restoration Recommendations

- this section is pertinent to discussing methods to reduce erosion, both in the long and short term
- discuss mechanical stabilization measures in the short-term prior to the establishment of vegetation
- discuss areas of greater potential erosion (i.e., outer meander bends) and how stability is addressed over the long-term

5.0 Design Implementation

- document monitoring recommendations/requirements for the duration of construction
- outline industry standard practices applicable to construction (i.e., dewatering requirements, material and equipment storage), as appropriate

5.1 Post Construction Monitoring

- recommend a post construction monitoring plan to ensure the design is functioning as intended and to satisfy regulatory agency requirements
- include a description of the activities, time intervals (e.g., storm events, seasonally, annually), monitoring period (e.g., 1, 3, or more years), and reporting schedule

6.0 Summary and Recommendations

- recap why the natural channel design is required
- summarize key findings from the desktop- and field-based assessments
- summarize goals, objectives and key elements of the proposed design
- identify anticipated future project requirements, if any (e.g., recommendations for detailed design when a project is at the conceptual design stage)

7.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)



List of Tables (as needed, examples listed below)

Table 1: General reach characteristics (general reach observations and bankfull channel measurements)

Table 2: Rapid assessment results

Table 3: Summary of detailed geomorphological results

Table 4: Designed channel parameters

Table 5: Corridor sizing calculations (designed channel meander belt width)

Table 6: Substrate sizing calculations

Appendices (supplemental information as needed, examples listed below)

Appendix A Study Area and Reach Delineation

Appendix B Photo Record (photos taken during field work with captions)

Appendix C Field Observations (provide copies of completed field sheets)

Appendix D Detailed Assessment Summary

Appendix E Channel Design Drawings



Outfall Siting and Treatment Design Standard Format for Document and Annotated Table of Contents

Title and Report Details

- Project Name
- Type of Report
- Project Location
- Prepared for: Client
- Prepared by: Company name
- Date of Original Report
- Date of Revised report (if applicable)

Table of Contents

1.0 Introduction

- description of location, site area, property owner(s)
- general description of the development and plans
- description of larger development (if phased and/or applicable)
- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- review of previously completed studies (i.e., master plan, subwatershed study, etc.)
- include information regarding the history of the development or project

2.1 Surficial Geology and Physiography

- summarize any relevant information regarding the surficial geology and physiography of the study site and upstream drainage area, and its influence on channel form
- If available, cross reference published mapping with geotechnical reporting to confirm local conditions
- Cross-reference field observations (e.g., parent material exposures, channel bank composition) with published mapping and available geotechnical reporting

3.0 Watercourse Characteristics

3.1 Reach Delineation

- describe approach and methodology for delineation, as well as a broad description of reaches within the study area
- each reach should have a unique identifier and label
- include a reach map in the body of the report or as an appendix to provide context

3.2 General Reach Observations

- note that date of field work and any relevant guidelines that were followed for the assessment
- describe general reach characteristics such as valley setting (i.e., confined, unconfined, partially confined) bankfull channel geometry, geomorphology (e.g., presence of riffle-pool sequences), channel substrates, channel disturbances, areas of erosion concern and/or aggradation, riparian vegetation, adjacent land uses etc.
- observations should be accompanied by a photographic record of conditions at the time of the assessment

3.3 Rapid Field Assessments

- note that date of field work and any relevant guidelines that were followed for the assessment
- provide a brief description of the rapid geomorphic assessments tools used and associated results
- at minimum, rapid geomorphic assessments (RGA) and rapid stream assessment technique (RSAT) results should be tabulated and discussed on a reach basis
- additional assessment techniques may and should be used at the discretion of the practitioner
- document observed dominant modes of adjustment and erosion sensitivity

4.0 Design Considerations

- document recommendations for the siting of outlet locations, including consideration of the erosion hazard associated with the receiving watercourse and outlet treatment concepts to mitigate erosion in receiving watercourses
- describe the context and goals of the outfall treatment design (i.e., erosion mitigation, erosion protection, infrastructure replacement, etc.)
- restate any recommendations regarding the outfall treatment design from previous studies and cite relevant documentation

- highlight any areas of erosion that require special consideration with reference to reach observations, if possible
- discuss additional considerations when designing the outfall treatment such as infiltration or soil conditions

4.1 Outfall Treatment Design

- describe the location and configuration of the outfall treatment design
- describe anticipated benefits of outfall treatment design

4.2 Hydraulic Substrate Sizing

- summarize methodologies and velocities/shear stresses/discharges used to size designed substrates
- provide recommended material types and stone sizes, with supporting information from field observations, previously completed reports, or other data
- discuss the benefits of the recommended material types and stone size (e.g., aquatic habitat, opportunities for enhanced infiltration and detention for water, and channel stability)

5.0 Design Implementation

5.1 Construction Timing

- document monitoring recommendations/requirements for the duration of construction
- outline industry standard practices applicable to construction (i.e., dewatering requirements, material and equipment storage), as appropriate

5.2 Post Construction Monitoring

- recommend a post construction monitoring plan to ensure the design is functioning as intended and to satisfy regulatory agency requirements
- include a description of the activities, time intervals (e.g., storm events, seasonally, annually), monitoring period (e.g., 1, 3, or more years), and reporting schedule

6.0 Summary and Recommendations

- recap why the outfall treatment design is required
- summarize key findings from the desktop- and field-based assessments
- summarize goals, objectives and key elements of the proposed design
- identify anticipated future project requirements, if any (e.g., recommendations for detailed design when a project is at the conceptual design stage)

7.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Tables (as needed, examples listed below)

Table 1: General reach characteristics (general reach observations and measurements)

Table 2: Rapid assessment results

Table 3: Substrate sizing

Appendices (supplemental information as needed, examples listed below)

Appendix A Study Area and Reach Delineation

Appendix B Photo Record (photos taken during field work with captions)

Appendix C Field Observations (provide copies of completed field sheets)

Appendix D Outfall Treatment Design Drawings



Baseline Instream Monitoring Standard Format for Document and Annotated Table of Contents

Title and Report Details

- Project Name
- Type of Report
- Project Location
- Prepared for: Client
- Prepared by: Company name
- Date of Original Report
- Date of Revised report (if applicable)

Table of Contents

1.0 Introduction

- description of location, site area, property owner(s)
- general description of the development and plans
- description of larger development (if phased and/or applicable)
- purpose of the study (**Why is it required**)
- type of application that triggered a requirement for the study (**When is it required**)

2.0 Background Review

- include information regarding the history of the development or project, if applicable
- review of baseline data collected as part of previously completed studies (i.e., master plan, subwatershed study, etc.), if available

2.1 Existing Conditions

- describe existing land uses and watercourse/drainage feature conditions

3.0 Monitoring Procedures and Sampling Methodology

3.1 Water Level / Discharge Monitoring

- summarize the monitoring plan, including the location of monitoring stations, monitoring frequency/duration, instrumentation that was used, and parameters measured
- document rationale for the selection of monitoring locations
- cite guidelines that were followed to collect measurements/conduct sampling

3.2 Surface Water Quality Monitoring

- summarize the monitoring plan, including the location of monitoring stations, monitoring frequency/duration, instrumentation that was used, and parameters measured
- document rationale for the selection of monitoring locations
- the following are typical instream water quality parameters (additional parameters may be required based on project scope and jurisdiction):
 - temperature
 - total suspended solids
 - turbidity
 - conductivity
 - dissolved oxygen
- cite guidelines that were followed to collect measurements/conduct sampling (e.g., Ontario Stream Assessment Protocol)
- tabulate the number of events sampled, the date, precipitation 24 hours preceding sampling, and event type (e.g., baseflow or wet-weather sampling)
- installation of a rain gauge may be recommended if a reliable rain gauge is not operating nearby

3.3 Geomorphological/Erosion Monitoring

- outline the geomorphological monitoring plan, including monitoring locations, duration and frequency of monitoring visits (.e.g., monumented channel cross sections, longitudinal profile, erosion pin measurements)
- outline what information is collected at each site during each visit and the purpose of data collected

4.0 Monitoring Results

4.1 Water Level/Discharge

- summarize precipitation during the monitoring period (e.g., minimum and maximum daily rainfall, number of storm events)
- note any extreme weather events or atypical conditions during the monitoring period (e.g., unseasonably dry or wet, occurrence of infrequent return period storm events)
- provide a data summary table (e.g. minimum and maximum water level/discharge by year or month, as appropriate)
- document any challenges encountered during the monitoring period that influence interpretation of the results and/or data quality (e.g., instrument failure, lack of flowing water)
- describe the flow regime of the watercourse or drainage feature based on collected data
- provide complete data records in tabular or graph format in the appendices, as appropriate

4.2 Surface Water Quality

- results can be organized under a series of subheadings or in tabular format, depending on the suite of parameters being investigated
- provide definitions of parameters and how they are used to determine surface water quality
- interpret results based on climatic and instream conditions with reference to expected ranges of values or targets (e.g. guidelines for the protection of aquatic life)
- summarize/tabulate minimum and maximum values for each parameter measured on an annual or monthly basis, as appropriate
- identify any data outliers and potential reasons for variances
- if conducting monitoring for thermal classification, summarize the technique used and illustrate results in graph format
- provide complete dataset in tabular or graph format in the appendices
- provide any laboratory reporting in the appendices (e.g., total suspended solids)

4.3 Geomorphological/Erosion Monitoring

- describe existing drainage feature/watercourse reach conditions with specific reference to the section of feature being monitored including geomorphology, flow regime, and riparian vegetation

- provide rationale for monitoring locations (e.g., proximity to infrastructure, control site outside of the influence of development, downstream of future stormwater management facility, area of erosion concern)

4.3.1 Longitudinal Profile

- Indicate the channel bed and bankfull channel gradients, length surveyed, location(s) of control points and the date(s) of data collection
- Longitudinal profiles can be provided in an appendix or as a figure(s) in the body of the report
- If possible, provide a comparison of longitudinal profiles between years and evaluate any adjustments
- Confirm whether any adjustments are within the anticipated range of natural variability and if required, provide recommendations for management

4.3.2 Bankfull Channel Geometry

- describe methodology used to survey cross section geometry, noting the locations of monumented cross sections and control points, geomorphic unit (e.g., riffle, pool), and date of data collection
- tabulate the bankfull width and maximum bankfull depth surveyed at each cross section for the duration of the monitoring period
- evaluate changes in cross section geometry on a seasonal/annual basis, if possible
- confirm whether any adjustments are within the anticipated range of natural variability and if required, provide recommendations for management

4.3.3 Erosion Pins

- describe the purpose and location of erosion pins
- tabulate the measured lengths of erosion pins at each location and date of data collection for the duration of monitoring
- evaluate changes in length of erosion pin exposure on a seasonal/annual basis, if possible
- identify any locations where previously installed erosion pins could not be located and were re-installed

4.3.4 Grain Size

- describe the purpose of and the field/laboratory methodology used to determine grain size distribution for each monitoring location
- tabulate grain size (D_{50} and D_{84}) for each monitoring location assessed for the duration of the monitoring period, including a description of geomorphic unit sampled

- evaluate changes to grain size distribution on a seasonal/annual basis, if possible
- confirm whether any shifts in distribution are within the anticipated range of natural variability and if required, provide recommendations for management

5.0 Summary and Recommendations

- summarize the overall monitoring program in terms of locations, duration, frequency and parameters measured
- summarize key findings for all parameters measured and note any conditions that could affect future results (e.g., formation of large woody debris jam, beaver activity, etc.)
- outline any changes to the monitoring program due to unforeseen circumstances, for example, due to road works or development on adjacent lands etc.
- summarize the status of the monitoring plan, including how many years the monitoring has been completed, next scheduled monitoring/reporting period

6.0 References

- provide a list of references used for the report (e.g., scientific articles, previously completed studies, gray literature etc.)

List of Figures (as needed, examples listed below)

Figure 1: Thermal Classification (if required)

Figure 2: Surveyed Longitudinal Profile

Figure 3: Surveyed Monumented Cross Sections

List of Tables (as needed, examples listed below)

Table 1: Water quality and quantity monitoring locations, sampling parameters, frequency and duration

Table 2: Minimum and maximum water depth/discharge

Table 3: Wet and dry weather event surface water quality sampling events

Table 4: Minimum and maximum water quality parameter measurements

Table 5: Measured channel bed and bankfull gradients

Table 6: Measured bankfull channel width

Table 7: Measured maximum bankfull channel depth

Table 8: Measured erosion pin exposure lengths for each location

Table 9: D_{84} and D_{50} grain sizes



Appendices (supplemental information as needed, examples provided below)

Appendix A Monitoring Location Map

Appendix B Monitoring Data (detailed tables and graphs summarizing all monitoring data)

Appendix C Photographic Record (photos taken during site visits with captions)

Appendix D Laboratory Results

Appendix E Surveyed Longitudinal Profiles and/or Monumented Cross Sections

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