Master Drainage Plan

PURPOSE:

This document provides guidance for the preparation of a Master Drainage Plan which may be required for the submission of an application under the *Planning Act*. All Master Drainage Plans shall follow the requirements referenced in this document.

A Master Drainage Plan (MDP) is a technical plan/report that provides information regarding the current and future drainage needs of a given community in the context of sustainable development, and the natural and human environment. A Master Drainage Plan focuses on a broader context than a Sub-Watershed Plan, which addresses local issues for drainage areas within a Watershed Plan. The intent of this plan is to support land use planning and infrastructure planning, to allow and facilitate informed decision making, and to improve the efficiency and effectiveness of the municipal land use planning process.

The Master Drainage Plan shall be conducted in three stages:

- Stage 1: Subwatershed Characterization
- Stage 2: Subwatershed Management Strategies
- Stage 3: Implementation and Monitoring Plans

Each stage shall conclude with the preparation of a study report.

A Master Drainage Plan is required for a Planning Application in support of the following planning processes / development application types:

- Official Plan Amendment;
- Draft Plan of Subdivision/Condominium;
- Site Plan Control; and,
- Consent to Sever.

The objectives of the Master Drainage Plan are as follows:

The Master Drainage Plan is intended to present an approach to managing resources that will protect, enhance, and rehabilitate the environment within the study area limits and downstream. The Plan will provide the following:

- Identification of the location, extent, present status, significance, and sensitivity of the existing natural environment;
- Identification of sensitive areas and hazardous lands, and recommendation of buffers and appropriate management practices related thereto;

DRAFT

- Identification of lands where development may be considered;
- Determination of how existing and future land uses can be developed compatibly with natural features;
- Direction on best management practices (BMPs) (from a drainage perspective);
- An implementation strategy and requirements for environmental monitoring; and,
- Technical information to assist in the completion of a Class Environmental Assessment process.

PREPARED BY:

A Master Drainage Plan must be prepared by a qualified Civil Engineer (C.Eng.) with input of other engineers and scientists, which may include the following areas of expertise: Water Resources, Geotechnical, Hydrogeology, Environmental Science, Fluvial Geomorphology, or Planning.

The Master Drainage Plan must be sealed, dated, and signed by a Professional Engineer (P.Eng.).

CONTENTS:

The applicant is encouraged to discuss the need, scope, concepts and design assumptions with City staff and the Conservation Authority(ies) having jurisdiction over the lands prior to preparing the report. Portions of the City of Hamilton are within the jurisdiction of Hamilton Conservation Authority, Conservation Halton, Grand River Conservation Authority and Niagara Peninsula Conservation Authority.

The Master Drainage Plan must provide sufficient engineering and Natural Heritage System information to allow for the necessary review and acceptance of the proposed drainage schemes in principle. The Plan shall be conducted in three stages, as outlined in the following sections.

1.1 Stage 1: Subwatershed Characterization

Characterization of the study area includes identification and assessment of features through desktop study, field reconnaissance and detailed fieldwork, as well as preliminary identification of issues and opportunities. Documents to be reviewed as part of this process include City planning documents, primary plans, and mapping as well as studies specific to the study area as may have been prepared by or for the City, landowners, Conservation Authorities, and other agencies. Through the Pre-Consultation process, City staff can assist with identification of available background information that must be considered.

Background data used shall be documented in an accepted bibliographic format. A brief summary of each background study referred to shall be provided in the Subwatershed Characterization report. Following review of background data, gaps in the data shall be assessed and a proposed program for collection of missing data shall be prepared.

DRAFT

It is strongly recommended that the proposed scope of study be reviewed and confirmed with the City of Hamilton and other relevant agencies prior to commencement of the specific study.

Studies required in support of the Subwatershed Characterization include:

1.1.1 Hydrology and Hydraulics

Background information on the study area is to be collected from all available sources, refer to Appendix A: Suggested Data Collection Requirement. Maps of the associated data collection locations shall be provided. In addition, the mapping of the watershed's physical features (e.g., watershed boundary, major watercourses, drainage swales and wetland features) shall be verified, and subwatersheds shall be delineated, and nodes at points of interest shall be established with development interests, environmental features, and / or watercourse system importance.

A detailed hydrologic model shall be developed and calibrated for the subwatersheds' existing condition for all events storms, ranging from 25 mm, 2, 5, 25, 100 years up to and including the Regional Storm. The model shall be a continuous, deterministic, hydrologic model, with a strong physical representation of surface runoff, baseflows, and surface and groundwater interaction. Modeling completed for previous studies may be available that can be updated or refined.

A water balance model shall be developed based on the output of the hydrologic model and hydrogeology of the area. The water budget shall include a monthly estimate of precipitation, evapotranspiration, runoff, and infiltration, including groundwater recharge / discharge estimations. The present low flow status shall be evaluated, and the constraints associated to water takings and land use changes shall be identified with reference to the specific locations of interest.

The successful proponent shall be responsible for the numeric modelling to establish the baseline hydrology and hydraulics of the subwatershed systems. The model will be calibrated based upon historical rainfall and flow monitoring data. The exercise should meet the accuracy and completeness to provide a comprehensive understanding of the existing condition of the study area, including an inventory of creeks, road crossings (culverts and bridges), stormwater facilities, etc. The current drainage systems and outlets shall be identified with drainage constraints and opportunities. The intent of modelling is to provide the details required for secondary planning, and identify additional criteria for water quality control, baseflow targets, infiltration targets, erosion, and flood control targets.

The flows at the subwatershed outlets in the calibrated model shall be compared to those determined in previous watershed studies for the given watercourses if such studies exist. The differences in the flow values shall be explained (e.g., more detailed information, change in watershed boundaries). The model input parameters shall be compared to previous studies and modified to represent the more detailed subwatershed model. Hydrographs are to be established at the key nodes in the study area for all event storms, from 2-year to up to and including the

DRAFT

Regional Storm. Model calibration will include the latest available data, incorporate the stream morphology observations.

For watercourses located in the study area, hydraulic analysis shall be conducted. Flood lines shall be established for the Regulatory Storm for existing conditions. For the creeks that have flood hazard delineation, as identified in previous studies, the flood lines shall be updated to reflect current conditions based on recent topographical data. The flood hazard delineation includes the hydraulic modelling, using the Hydrologic Engineering Centers River Analysis System (HEC-RAS) model from the U.S. Army Corps of Engineers, to generate the associated flood lines based on the hydrographs established with the hydrologic analysis conducted for this subwatersheds study. It should be noted that there are limitations with the use of HEC-RAS model, where topography is predominantly flat. The successful proponent shall undertake an assessment of the subwatersheds within the study area and identify through consultation with the Conservation Authority(ies) which features should be subject to flood plain evaluation. The Conservation Authorities' Flood Plain Mapping Standards should also be referred to, as to the approaches for survey, hydrology, hydraulics, and flood hazard maps.

The proposed detailed hydrology plan for this study is included in Appendix B: Proposed Hydrology Plan. The plan includes:

- Model platforms shall be confirmed with City and Conservation Authority(ies) staff;
- Modelling is to be established for discrete design event simulations, to produce runoff hydrographs at the nodes of interest in the study area and to size the required Stormwater Management (SWM) facilities; and,
- HEC-RAS should be used for determination and / or updating of the existing river hydraulics and flood elevations.

Justification of the applicability and sufficiency in utilizing any of the given numerical models shall be provided. The modelling exercises should ensure the hydrology and hydraulics features are quantified for each watershed within the study area. Future City and Conservation Authority use of the model, and model results, must be considered. The model or model result shall be converted to the City's operational models, i.e., MIKE-SHE and MIKE-URBAN models. Further monitoring may be required, in addition to the existing rain gauges and flow monitoring stations that can be used for the study area.

1.1.2 Hydrogeology

The goal of this subwatersheds study with respect to hydrogeology is to establish a geological conceptual model for the study area, determining the key characteristics of the bedrock and overburden systems, in addition to their functions in terms of controlling groundwater movement, availability, and quality in these subwatersheds. An integral component is to assess the interactions between the groundwater system and the surface water system, and to determine the overall role or function of these interactions in an ecosystem context. It is also important to have an understanding of the effects of future development on the local groundwater

DRAFT

resource to assist in the need and implementation of low-impact development.
To accomplish the above goals, all of the data collected in Stage 1 shall be integrated to develop a detailed understanding of the hydrogeological processes operating within the subwatersheds. To that end, the following shall be completed:

- Conduct a detailed site reconnaissance to identify surface watercourses, areas of visible groundwater discharge and recharge, and areas of groundwater piezometer installations. Focus shall be placed on identification of sinkholes and their outlets typical of karst topography, if present within the study area;
- Carry out a karst geology study of the site to the satisfaction of a karst expert. The study shall identify any significant karst features, delineate any hazardous lands because of karst, and identify and characterize key subsurface flow paths within the karst. Groundwater tracing using fluorescent dyes may need to be carried out at selected locations to understand subsurface hydrology and geology;
- Review and compile the following hydrogeological information from the relevant Source Protection Plan; Identify and address any data gaps:
  - General delineation of aquifers and karst topography;
  - Well locations as obtained from the MOE well record database;
  - Areas of ground or surface water takings as permitted by the MOE;
  - Areas of significant groundwater recharge or discharge;
  - Areas susceptible to contamination; and,
  - Areas suitable for stormwater infiltration;
- Install and monitor groundwater piezometers across the study area, when considered necessary, to determine water table levels, assess shallow groundwater flow directions, and determine the functional relationships between the shallow aquifers and watercourses/wetlands;
- Measure stream flow at appropriate locations along the watercourses, to identify areas of groundwater recharge/discharge and establish baseflow conditions. The stream flow monitoring program should first utilize existing monitoring data from sources of Conservation Authorities, municipalities, and other available studies. The monitoring could also be combined with the flow monitoring that is necessary to calibrate the hydrologic model;
- Identify potential impacts of construction and development on the features and functions of surface water and groundwater systems;
- Identify hazard lands in GIS mapping (particularly those relating to karst), in accordance with MNR Guidelines, regarding the Natural Hazards Policies of Section 3.1 of the Provincial Policy Statement.

The proposed detailed hydrogeology plan for this study is included in Appendix C: Proposed Hydrogeological Plan.

1.1.3 Stream Morphology

Some of the objectives concerning aquatic habitat are to protect the morphological and fluvial character of the streams, restore sinuosity (where appropriate and feasible), maintain physical habitat attributes (e.g., pools, riffles etc.) diversity and fluvial processes (e.g., bed load transport, energy reduction through sinuosity, etc.),

DRAFT

and to prevent increases in erosion and deposition through the maintenance of the hydrological regime.

The study shall include review of data collected from all sources and shall confirm and update the existing information. Where unavailable, the successful proponent shall characterize each reach of the watercourses using the Rosgen classification system, or other industry standardized methods. Baseline data requirements and standards for downstream monitoring shall be based on the assessment of a qualified fluvial geomorphologist. A baseline morphologic assessment, according to stream characterization and flood /erosion considerations, are expected including a detailed inventory of the stream morphology observations.

1.1.4 Channel Erosion

The study shall undertake an existing conditions erosion potential analysis, based on the erosion data collected to understand the erosion processes, and to identify areas which are highly prone to erosion, where erosions are occurring, or where structures may be at risk. The erosion potential analysis is also to determine the threshold flows for erosion at strategic points in the subwatersheds. Assessments will identify sites most sensitive to erosion, with reasonable details covering the entire study area.

Erosion potential assessment shall be carried out using continuous simulation of watercourse flows over several years and applying multiple exceedance methodologies such as duration of erosion threshold, cumulative effective work / shear stress, and cumulative effective discharge.

Regulated erosion hazards, setbacks and allowances shall be determined according to Conservation Authority guidelines and included in the mapping.

1.1.5 Aquatic Environment

There are a variety of Core Areas that have been identified as part of the Natural Heritage System within the Rural Hamilton Official Plan. These features include:

- Local natural area-Earth Science Area of Natural and Scientific Interest;
- Significant Woodlands;
- Wetlands;
- Lakes and littoral zones; and,
- Watercourses.

The study shall assess fisheries and benthic invertebrate communities in the subwatersheds. Stream classifications based on the priority of the habitat type as well as cold, cool, and warm water designations shall be identified. An assessment of stream barriers, on-line ponds and temperature survey data will also be undertaken to determine potential impacts of development on aquatic resources. Where applicable, the criteria and considerations contained in Table 1 (see below) will form the basis for evaluating watercourses. The data collected will be used to ensure that future development will have no negative impacts on fish habitat or the ecological functions for which the area has been identified.

DRAFT

It is noted that certain watersheds have more background information than the others. Where a subwatershed is lacking existing aquatic information, reconnaissance of the subwatershed is expected. A data gap analysis is required as part of the background data review to determine what inventories need to be undertaken. Detailed field assessments of the aquatic environments shall generally be provided to the areas of fish and riparian habitat, including areas immediately upstream and downstream of these habitat areas. When assessing species, status should include federal, provincial, and local rankings. In addition, maps that identify the results of the aquatic investigations shall be provided. The study area shall be screened for land uses, with a focus on the green belt areas, to identify the areas of interests.

A detailed protocol to conduct surveys for benthic invertebrates is included in Appendix E: Proposed Protocol to Sample Benthic Invertebrates. The criteria for evaluating the aquatic environment should include the following general requirement as indicated in Table 1, with the seasonally appropriate timelines identified for the work to be completed. Detailed inventory requirement shall be specified for the areas of interests. Fisheries and habitat assessments must be completed during a period when water is present in the watercourses to be assessed (generally in spring from April to June). The Evaluation, Classification and Management of Headwater Drainage Features Guidelines (CVC & TRCA, January 2014) should be used for the assessment of watercourse features in the study area.

DRAFT

Table 1: Aquatic Environment Inventory Requirements

Biophysical Inventory	Inventory Requirements
Fisheries Assessment	Electrofishing may be required. Acceptable protocols (i.e., Ontario Stream Assessment Protocol (OSAP)) should be followed.
Habitat Assessment	Assess watercourse habitat using acceptable protocols, i.e., the OSAP module.
Biophysical Inventory	**Inventory Requirements**
Benthic Invertebrate Assessment	Assess benthic communities in watercourses using acceptable protocols (i.e., OSAP, Ontario Benthos Biomonitoring Network (OBBN), (Biological Monitoring and Assessment Program (BioMAP)). Minimum of family level identification is required for benthic invertebrate assessment.
Species at Risk Screening	Screening should include results from all available sources, i.e., Natural Heritage Information Centre, Ministry of Natural Resources (MNR), Municipal List and Conservation Authority database, and Fisheries and Oceans Canada (DFO) screening map.

DRAFT

1.1.6 Terrestrial Environment

An assessment of terrestrial resources in the subject subwatersheds shall be undertaken. The Natural Area Inventory works from Conservation Authorities should be consulted for any existing information. The data collected shall be used to ensure that future development has regard to Section 2.1 of the Provincial Policy Statement. The criteria for evaluating the terrestrial features should include the following requirements. Depending on the vegetation community Ecological Land Classification (ELC) results and habitats determined to be present in the study area, it may be appropriate to undertake targeted surveys for certain taxa or species, rather than rely solely on incidental observation. Significant Wildlife Habitat Eco-Region 7E Criteria Schedule (MNR, Draft 2012) should be used in conjunction with the Significant Wildlife Habitat Technical Guide when assessing Significant Wildlife Habitat.

The landscape level analyses are required to identify terrestrial features connectivity, species movement, percent natural cover, etc.; while detailed field assessment of the terrestrial resources shall be provided to characterize the terrestrial environment and establish a baseline terrestrial environment for the study area, including the proximity to, and the degree of linkage with other habitats. When assessing species, status should include federal, provincial, and local rankings. In addition, maps that identify natural heritage features and the results of the terrestrial investigations shall be provided.

DRAFT

Table 2: Terrestrial Environment Inventory Requirements

Biophysical Inventory	Inventory Requirements
Vegetation Community Identification	Use Ecological Land Classification to classify vegetation communities.
Botanical Inventory	3 season survey (spring, summer, and fall) to identify species.
Evaluation of Unclassified Wetlands	Use MNR wetland evaluation system to classify unevaluated wetlands.
Breeding Bird Surveys	2 surveys at least 10 days apart; the first between May 24th and June 16th and the second between June 17th and July 10th using Ontario Breeding Bird Atlas protocol.
Amphibian Breeding Surveys	3 surveys between April and July 5th corresponding to specific nighttime temperatures of >50C, >10 0C and >17 0C using the Marsh Monitoring Protocol Salamander surveys are required and should be completed in spring in appropriate ponds to determine the presence of salamander breeding areas
Reptile Surveys	Use active searching, cover boards or other commonly accepted protocols/methods (April- July and Sept.-Oct.)
Incidental Wildlife Observations	Incidental sightings of mammals, butterflies, dragonflies, damselflies, amphibians, and reptiles.
Species at Risk Screening	Screening should include results from all available sources, i.e., Natural Heritage Information Centre, MNR Municipal List and Conservation Authority database.
Assessment of Significant Wildlife Habitat	This assessment will utilize the MNR's Significant Wildlife Habitat Technical Guide 2000) and may include seasonal wildlife concentration areas, rare vegetation communities, specialized wildlife habitat, habitat for species at risk and animal movement corridors.

DRAFT

1.1.7 Surface Water Quality

Background information shall be used to define the baseline water quality in the subject study area, with a focus on sediment loadings in the surface water environment. Where available, existing datasets from Conservation Authorities or other sources shall be reviewed to understand the existing water quality status of the study area. Where background information is unavailable, a water quality sampling program shall be conducted for each subwatershed as described in Appendix A: Suggested Data Collection Requirement to assess baseline water quality conditions. The existing water quality status shall be assessed to provide the baseline reference and identify any water quality concerns and constraints in the study area. Whenever possible, the water quality sampling should be conducted at the same location and time, when surface water and groundwater flow monitoring is conducted. The study will also identify any existing SWM pond and the respective catchment areas, as the baseline reference for stormwater management in terms of water quantity/ quality control.

1.1.8 Stage 1 Report – Subwatershed Characterization

At the completion of Stage 1, the general characteristics of the subwatersheds area will be identified and a clear understanding of the major issues and opportunities will have been developed. The Stage 1 report will provide the general characters of the study area, which will be the starting point from which the land use is developed from. The Stage 1 report shall considerate climate change in accordance with the Provincial Policy Statement.

The Stage 1 report shall include:

- Summary of background literature and data reviewed;
- Subwatersheds characterization based on the findings of the initial subwatersheds study;
- Summary of the subwatersheds major issues, concerns, and constraints; and
- Summary of the obvious opportunities for improvement or enhancement.

The following are considerations to determine the constraint analysis. The constraints shall be assessed with consideration of the core features and linkages and natural hazards, in accordance with the policy and definitions as indicated in the Official Plans.

- High Constraint: Native communities with highly significant habitat attributes present and / or with severe slope constraints and / or located directly adjacent to the permanent watercourse. High constraints should be protected.
- Medium Constraint: Native communities with moderately significant habitat attributes present and / or with moderate slope constraints and / or associated with imperfect drainage and may include successional communities. Features protected and integrated into development where feasible; if not protected, opportunities to replace these features should be examined.
- Low Constraint: Cultural communities with limited significant habitat attributes present, no slope constraints and not associated with hydrological linkages.

DRAFT

These features don't represent direct constraints to development and represent opportunities for habitat restoration.

1.2 Stage 2: Subwatershed Management Strategies

Based on data obtained in Stage 1 through the review of background information sources and supplementary fieldwork, Stage 2 involves assessing the impacts of future land use changes on the natural environment within the study area. The findings from the Stage 1 characterization work, completed for various disciplines, will be considered in an integrated manner in developing the subwatershed management strategies. The Stage 2 work will be completed concurrently to the land use plan, transportation plan and water / wastewater servicing plan. The intent of Stage 2 is to develop the management strategies that.

- protect the critical elements of the subwatershed;
- prevent environmental degradation;
- provide adequate flexibility for integration with adjacent development and redevelopment areas;
- assist in the establishment of open space linkages;
- identify opportunities and constraints to development;
- provide a strategy to manage existing land uses;
- detail location and area requirements for stormwater management facilities; and
- identify restoration and enhancement opportunities.

In Stage 2, a detailed analysis shall be completed to assess the impacts of future land use changes on the subject study area. Different options for mitigating these impacts shall be reviewed and management strategies shall be recommended. The proposed assessment of future land use changes shall include multiple future scenarios. This should include considerations of a scenario that allows for enhancement of environmental conditions by incorporating the use of a connected network of environmental features and functions, as well as low impact development practices for industrial, commercial, and institutional (ICI) lands to help sustain the local groundwater resource. In addition, constraint and opportunity mapping shall be provided.

1.2.1 Hydrologic Analysis

A hydrologic analysis shall be conducted for the future development conditions to determine post- development flows, hydrographs, and water balance.

The existing conditions model shall be modified to reflect post-development conditions for all events storms, ranging from 25 mm, 2, 5, 25, 100 years up to and including the Regional Storm. It shall be used to determine the potential impacts on surface water, groundwater, and water balance, with details of infiltration and runoff character changes. Surface water and groundwater interaction changes shall be addressed due to land use changes on the karst topography in the study area, if relevant. The hydrologic analysis will:

- Delineate a discretized drainage area plan based on potential development;
- Develop a model schematic diagram;
- Include a table of model input parameters;

DRAFT

- Calculate post-development flows with and without stormwater management controls, for all event storms at the predetermined locations, as per the discretized drainage area plan and model schematic diagram within the study area. The post-development flows shall be compared to existing flows for all storm events at the hydrologic nodes of interest;
- Conduct the water balance assessment at the nodes of interests. The water balance for the study area shall be completed in consultation with a hydrogeologist, and shall include an estimate of precipitation, evapotranspiration, runoff, and infiltration, in addition to the groundwater recharge and discharge. Feature-based water balance for wetlands within the study area may also be required to ensure there will be no negative post-development impact to the hydrological function;
- Identify constraints related to imperviousness and intensity of development. Assess the requirement and/or performance of proposed stormwater management facilities; Consideration shall also be given to the timing, phasing, and types of stormwater management measures;
- Develop stormwater management strategies on the principles of at-source control, conveyance control, and end of pipe treatment;
- Investigate potential Low Impact Development (LID) designs for industrial, commercial, and institutional (ICI) lands, when groundwater recharge and discharge is critical; and,
- Assess the future infrastructure discharge impacts on the local watercourse and lake systems and identify appropriate mitigation measures.

Refer to Appendix B: Proposed Hydrology Plan in assessing future development conditions. The future development impact assessment should evaluate the impacts on both runoff volumes and peak flow rates.

1.2.2 Hydrogeology

The hydrogeology analysis shall examine the impact of future development and land use changes on groundwater systems. The report may need to investigate rural septic systems for potential interactions with sub-surface aquifer systems. It will make recommendations to adequately protect groundwater from both water quality and quantity perspectives. The hydrogeology plan also prevents disturbing the significant recharge/discharge areas identified in Stage 1. The hydrogeological component of the subwatersheds investigation shall:

- In accordance with the recharge / discharge areas delineated in Stage 1, ensure the groundwater sensitive areas are recognized and protected from future urbanizing and disturbances;
- Within the water balance assessment, conduct an overall groundwater budget, at the pre- determined nodes of interest in the study area and the subwatersheds outlet, along with the surface water components for both existing and future scenarios; and,
- Make recommendations with respect to Low Impact Development (LID) measures to be implemented in order to mimic the pre-development groundwater conditions.

DRAFT

1.2.3 Hydraulics

The existing hydraulic condition shall be reviewed in the context of the proposed development, with the land use changes, runoff increases and/or channel modifications. The study shall assess the impacts of the proposed development on watercourse water levels, flow velocities and water surface profiles for all storm events. Any potential erosion and flood concern due to the proposed development shall be identified. Current flood line information shall be updated for post-development scenarios, using HEC-RAS models in accordance with standards set out in the City's Flood Damage Reduction Program and Conservation Authority guidelines. The model shall be modified with the updated topography, such as the changes in channel morphology, cross sections, bank lines, culverts, and bridges, etc. Backwater analysis is expected where flows are constrained due to flatness or downstream conveyance limitations.

The updated flood lines are to be presented on the maps, with Regulatory Storm flood line locations and cross sections identified with flood elevations. The overtopping depths, caused by the Regional Storm, shall be assessed, and documented on existing roads at all crossing structures. The flood hazard maps should confirm the post-development flood levels are in consistency with the current condition. Any changes in the flood inundation magnitude must be listed in inventory, with explanations of such changes. For any increases in flow, it must be demonstration that the change does not increase the flood risk or off-site development constraints. Any stormwater management (SWM) strategies, required to match the post-development flows to existing conditions, shall be identified and to be addressed in detail in the following SWM section.

1.2.4 Stream Morphology and Erosion Analysis

The continuous erosion analysis for the existing condition shall be updated with the future development scenarios. Erosion potentials for the study area shall be estimated by applying the existing channel / bank conditions and the post-development flows to the same cross sections, as outlined in the proposed methodology in Appendix D: Tractive Force Analysis. Where flow increases are noted, it must be demonstrated that the change does not increase the flood risk or off-site development constraints. Appropriate mitigation measures shall be recommended for sections showing a significant increase in erosion potential. Stormwater management criteria shall be established for the proposed development to ensure there is no increase in downstream erosion.

The downstream work, to the next flow node at the specific subwatershed' s outlet, shall be linked to the erosion potential assessment from the proposed development. Development usually increases the volume and duration of flows to the watercourse. It is not likely that development will be able to maintain existing conditions, and this is not the expectation. Erosion analysis is to determine how to release the additional flow volume without negatively impacting the watercourse.

DRAFT

Natural channel design principles shall be applied in reaches where it has been previously altered or will be reconstructed through the development process, or where it has been determined that enhancements are required due to the morphological condition of the watercourse. Based on the results presented in Stage 1, the study shall identify which watercourses and drainage features in the proposed development area are stable and have sufficient conveyance capacity; and which need restoration or alteration through natural channel design approaches. Stream morphology shall be assessed in the downstream areas of future development areas, with a focus on the existing and potential erosion concerns. Existing and future development impacts shall be evaluated with development strategy indicated to limit the negative impacts, while accommodating opportunities to restore and improve the existing channel status.

For areas of new development, the size of the channel block, necessary to allow natural channel design to occur, shall be determined. The natural channel design information, on which the preliminary assessments are made, shall be documented for use at the final design stage. The natural channel design strategy must clearly define that all channel blocks have the ability to convey flows associated with the Regulatory Storm event (Regional or 100-year, whichever is greater). Conceptual channel restoration / improvement, where required, shall indicate the overall stream morphology changes with these proposed section changes. The determination should be made based on stream morphology, in addition to the considerations of aquatic and terrestrial features and setbacks. The respective Conservation Authorities and Department of Fisheries Ontario must be consulted for approval of any channel works proposed.

1.2.5 Aquatic Environment

The study shall assess the potential impacts of future land use on the aquatic resources. Recommendations shall be identified for improvement of aquatic habitat, including in-stream, stream bank and flood plain habitat enhancement, removal of barriers and on-line ponds, and retrofitting existing altered habitats. The assessment shall relate physical characteristics and processes of the aquatic environment to biological communities. The assessment shall also identify and protect appropriate buffers/setbacks, and linkage of these habitats, which reflect the specific stream sensitivity and required buffer functions.

Detailed assessment shall be generally focused on the sensitive areas identified in Stage 1 and areas immediately downstream of new developments. Considerations should be given to cooling trenches for SWM facility, i.e., trenches, open channel drainage with shading areas, etc.

1.2.6 Terrestrial Environment

The study shall investigate potential land use impacts for areas adjacent to terrestrial resource features and identify buffer and management strategies. In addition, appropriate buffers/setbacks to disturbance, specific to the resource sensitivity and required buffer functions, shall be identified, and protected. In addition, potential linkages (natural areas that ecologically connect core areas) shall be identified and protected. Linkages are important in reducing the adverse impacts of habitat

DRAFT

fragmentation on natural areas. The management strategies shall be documented, regarding the protection of these sensitive resources and functions. A graphic visualization of corridor and buffer alternatives, including successional habitats under a longer-term scenario (20-50 years), shall be presented in maps to:

- Identify habitat features that may be retained and incorporated into the Natural Heritage System due to their quality;
- Consider the potential impacts of development on wetlands, wildlife habitats, woodlands, valley lands, endangered and threatened species (if present) and their habitat; and
- Propose management strategies to protect these resources.

The assessment shall generally focus on the sensitive areas identified in Stage 1 and areas in the immediate vicinity of new developments. Where a continuous ELC-defined vegetation community extends beyond the subject areas, the assessment shall generally address the entire community, including portions beyond the study area boundaries.

1.2.7 Surface Water Quality

The study shall investigate potential land use impacts and develop strategies to maintain or enhance in-stream water quality. Actions to address existing point and non-point sources of pollution resulting in degraded water quality shall be developed. Best Management Practices (BMPs) for urban stormwater management shall be recommended for all new development to address stormwater quality. The proposed BMPs shall be in accordance with the requirements of the Ministry of Environment and the City of Hamilton.

A detailed stormwater management strategy shall be determined for future development lands. BMPs shall be recommended for source controls and conveyance controls. Conceptual designs of the SWM facilities are required to ensure the discharging water will meet the MECP standards for total suspended solid removal. Water temperature indicators are to be evaluated, especially when receiving water are sensitive, i.e., cold water system for aquatic habitat. Based on the hydrogeological investigation and the recommendations of the hydrogeologist, the stormwater strategy should also identify Low Impact Development (LID) measures, which can be incorporated within industrial, commercial, and institutional developments to maintain the water balance and groundwater recharge in particular.

1.2.8 Development of Stormwater Management Strategy

Results of the hydrologic analysis for existing and developed conditions shall be used to develop a stormwater management strategy to control post-development peak flows because of urbanization. The fluvial geomorphological and erosion assessments, in conjunction with the hydrologic analysis shall be used to determine the control measures. In addition, storm runoff must be treated before it is discharged to receiving waters using source controls, conveyance controls, or end of pipe controls. All proposed SWM strategies shall confirm to acceptable standards as determined in the MOE Stormwater Management Practice Manual (2003), the City's drainage policy and

DRAFT

stormwater management guidelines, in addition to the requirement of the respective Conservation Authorities.

The stormwater management strategy for the proposed development shall incorporate relevant SWM measures, alternate development proposal, including low impact development designs for ICI lands. Constraints and opportunities shall be evaluated for the specific strategy. Conceptual design shall be completed for facilities required to achieve the specific targets. For example, the drainage areas for proposed SWM features are to be delineated; The length of routes, size of conveyance conduits, and open channel drainage vs. SWM ponds are to be evaluated; End of pipe treatments should include the required storage volumes, flow targets, land area requirements and locations; Details should include the stage – storage – discharge charts, SWM facility types and outlet control methods.

In general, with effective SWM source control measures at development stage, the post-development flow rates are to be controlled to pre-development levels as close as feasible. Additionally, the post-development controlled flows should not impact base flow in the watercourses receiving the runoff. Consequently, the future flood plains are expected to be consistent with the existing conditions. As part of the stormwater management strategy for future development, the successful proponent shall:

- Identify any drainage and stormwater management (SWM) works required for the study area, including stormwater management ponds, channel modifications and infiltration works;
- Assess the performance of existing drainage facilities (i.e., ditches, culverts);
- Based on MECP guidelines, establish stormwater management criteria related to water quality (Total Suspended Solid);
- Identify the SWM facility locations and the appropriate outlets to the receiving water bodies;
- Incorporate the proposed stormwater management facilities into the post-development model and select the sizes of the facilities to conform to the established criteria. The City and Conservation Authority(ies) should be consulted if regulatory storm controls are being considered to mitigate the impacts of development;
- Prepare a conceptual design of the proposed stormwater management facilities for water quantity and quality control; and,
- Consider general criteria for stormwater management as described in Appendix F: General Criteria for Stormwater Management.

1.2.9 Reporting – Stage 2 Subwatersheds Management Strategies

The study shall develop a detailed subwatershed management strategy for the proposed development, which will evaluate a range of subwatershed management options based on the subwatershed goals, objectives, and targets. The study shall identify additional studies to be completed in support of future development applications, as required to meet the objectives and targets of this subwatershed study. Each of the subwatershed management options shall be evaluated to determine preferred subwatershed strategies. The study shall recommend a comprehensive plan for the evaluation of the management options, which will form part of the subwatershed

DRAFT

study proposal. Options such as alternative development forms/patterns, stormwater management and best management practices, rehabilitation and retrofitting of existing features shall also be considered in the subwatershed management options.

At the completion of Stage 2, a report shall be submitted to document the evaluation of the stormwater management options and recommended subwatershed management strategies as they relate to the proposed development. The computer modelling input and output files shall be appended to this report and a digital copy of all modelling files submitted. In addition, constraints and opportunities present in the study area, in terms of urban expansion, environment impacts and protection, shall be clearly documented with GIS maps for the associated locations. GIS shape files shall accompany the report.

1.3 Stage 3: Implementation and Monitoring Plans

Stage 3 shall set the framework for implementation and monitoring of the preferred subwatersheds management strategy. An implementation and monitoring plan shall be developed, which sets out the requirements for phasing, financing, operation of facilities, and monitoring to ensure the future developments are in compliance with the approved subwatershed study. The Stage 3 work will be completed at the end of the land use planning work, when a preferred land use plan has been determined. The findings of this study will provide a technical framework for future infrastructure works and support the future development proposals.

Where applicable, Stage 3 shall outline the agencies/organizations that are responsible for carrying out the various recommendations and specify when in the development process the various recommendations need to be initiated. Stage 3 shall include:

- Timing for the construction of any required facilities with respect to the future development;
- Funding formula for the construction of these facilities;
- Recommendations for future studies, if required;
- The operation and maintenance responsibilities for the recommended facilities;
- A monitoring program to ensure compliance with the subwatershed study, and a strategy for corrective actions which may be necessary based on results of the monitoring program;
- Time frame for the review/update of the subwatershed plans; and,
- The estimated cost of the monitoring program.

The implementation plan shall recommend the phasing of development. This will permit changes to recommend mitigation measures and management strategies for future phases of the development, in the case results of monitoring from the initial phases suggest that changes are warranted.

OTHER INFORMATION:

Comprehensive Development Guidelines and Financial Policies Manual (City of Hamilton, current edition).

DRAFT

https://www.hamilton.ca/build-invest-grow/planning-development/planning-policies-guidelines/comprehensive-development

Comprehensive Development Guidelines and Financial Policies - Stormwater Management Design Criteria – Figure G-1 Storm Sewer Sizing Criteria Decision Tree (City of Hamilton, current edition)
https://www.hamilton.ca/sites/default/files/2022-09/pedpolicies-developmentguidelines-financialpolices-manual.pdf

Stormwater Management Planning and Design Manual (Ministry of the Environment, Conservation and Parks, 2003).

Development, Interference & Alteration Regulations for all Conservation Authorities (Ontario Regulations 42/06 and 146/06 to 182/06).
https://conservationontario.ca/fileadmin/pdf/conservation_authorities_section_planning__regulations/Development__Interference___Alteration_Regulations_for_all_Conservation_Authorities.pdf .

Policies and Procedures for Conservation Authority Plan Review and Permitting Activities (Conservation Ontario, 2010)
https://conservationontario.ca/fileadmin/pdf/conservation_authorities_section_planning__regulations/Policies_and_Procedures_for_CA_Plan_Review_and_Permitting_Activities.pdf.

Conservation Halton Policies and Guidelines for the Administration of Part VI of the Conservation Authorities Act and Ontario Regulation 41/24 and Land Use Planning Policy Document (last amended June 21, 2024, or as may be further amended Policies and Guidelines - Conservation Halton

Municipal Class Environmental Assessment (Municipal Engineers Association, current version).

Drainage Act, R.S.O. 1990, and associated Regulations.

REVIEWED AND APPROVED BY:

Development Planning, Planning and Economic Development Department
Development Approvals, Planning and Economic Development Department
Source Water Protection, Public Works Department
The Conservation Authority with regulatory authority over the subject lands, namely:

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

Consultation with provincial agencies such as the Ministry of the Environment, Conservation and Parks, the Ministry of Natural Resources, and the Ministry of Transportation may be required.

DRAFT

Consultation with federal agencies such as Fisheries and Oceans Canada (DFO) may be required.

CONTACT:

Development Planning, Planning and Economic Development
pdgening@hamilton.ca

Development Approvals, Planning and Economic Development
deveng@hamilton.ca

Source Water Protection, Public Work
sourcewater@hamilton.ca

Hamilton Conservation Authority
nature@conservationhamilton.ca

Conservation Halton
envserv@hrca.on.ca

Niagara Peninsula Conservation Authority
planninginfo@npca.ca

Grand River Conservation Authority
grca@grandriver.ca

APPENDICES ATTACHED:

Appendix A: Suggested Data Collection Requirements
Appendix B: Proposed Hydrology Plan
Appendix C: Proposed Hydrogeological Plan
Appendix D: Tractive Force Analysis
Appendix E: Proposed Protocol to Sample Benthic Invertebrates
Appendix F: General Criteria for Stormwater Management
Master Drainage Plan – Summary Checklist
Master Drainage Plan – Standard Format for Table of Contents

DRAFT

APPENDIX A

Suggested Data Collection Requirements

DRAFT

This appendix outlines the suggested data collection to meet the goals and objectives of the study. Where available the study will make use of existing data.

Rainfall

Data for existing rainfall gauges located in proximity to the subject subwatersheds are to be reviewed and analyzed. The successful consultant is to determine if additional temporary rain gauge(s) is necessary for model calibration and water balance evaluation. Next-Generation Radar (NEXRAD) information, as may be available from the various agents in and around the study area, shall be exposed for its suitability to fill any data gaps.

Stream Flow

Recorded flows for the subject watercourses, with rating curves developed for the relationship between flow depth and flow rate. The study is to examine the downstream flow gauges data available from the respective Conservation Authorities, and determine the additional temporary flow monitoring program as needed.

Surface Water Quality

The respective Conservation Authorities manage water quality monitoring stations in and/or around the study area. These datasets shall be reviewed and analyzed. Where existing background information is unavailable, a water quality sampling program shall be conducted to provide a detailed assessment of the existing water quality in the subwatershed. Where appropriate, this information will be used to design Best Management Practices (BMPs) and to provide background information for a post- development monitoring program.

The sampling program will incorporate dry weather sampling for dissolved oxygen, temperature, bacteria, nutrients, general chemistry, pesticides and metals. The dissolved oxygen and temperature monitoring should be conducted over the course of a dry day, from before daybreak to after dark. Ideally, monitoring should be conducted during a warm, dry period. Deployment of logging equipment to capture the entire 24 hour cycle for these parameters should also be reviewed.

If necessary, a composite wet weather sample from at least one significant event will be taken to identify the pollutant constituents in the runoff. Samples will be analyzed for bacteria, nutrients, suspended solids, pesticides and metals. Chloride / sodium sampling would capture the road salt loading.

If necessary, wet weather event quality monitoring, in conjunction with flow monitoring for about three events will be conducted to describe the time-varying water quality characteristics during runoff events. Sampling will be done on a frequent, discrete basis through the course of the event. Sampling frequency required depends on runoff response time of the subwatersheds, but may be as frequent as 15-minute intervals. Samples will be analyzed for bacteria (*E. coli*) and suspended solids only. Where water quality and stream flow are being collected, area based contaminant load could be calculated.

If necessary, an analysis of benthic invertebrates will be conducted as an indicator of long-term water quality.

DRAFT

Stream Geomorphology and Channel Erosion

Collect site specific reach-based geomorphological observations at the appropriate time of year(i.e., in absence of snow and ice). This data would include channel slope, flow velocity, soils, sinuosity, width to depth ratio, channel substrate and bank composition, stream entrenchment ratio, landform feature/stability class, cross-sectional measurements and bank vegetative cover. Each reach should also be assessed using standard, industry accepted tools (e.g., Rapid Geomorphic Assessment and Rapid Stream Assessment Technique).

The erosion database will identify areas that are highly prone to erosion or where structures may be at risk. Data collected will also be used in a flow duration exceedance analysis and as background information in the monitoring plan.

For sections selected for erosion control assessment and monitoring, determination of critical shear strengths, surveyed cross sections, and inventories shall be done reach by reach in order to be sufficiently thorough. Consequently, it provides documentation of areas to be targeted for rehabilitation. The channel erosion monitoring will be extended from the study area to the next hydrologic nodes of interest, typically at the subwatershed outlets where the subject watercourses join other branches. Existing downstream areas of concern from previous studies should also be considered in the erosion assessment.

Groundwater

In an effort to understand the surface and subsurface hydrology of the site, geological and hydrogeological maps shall be reviewed, in addition to the studies in and surrounding the study area published by the MOE, MNR, Ministry of Northern Development and Mines (MNDM) and Conservation Authorities.

Stream flow surveys shall be carried out in the permanent streams where data gaps are identified. The purpose of collecting stream flow measurements is to assess the interaction between the surface water and groundwater regimes, and will specifically answer questions related to the groundwater recharge and discharge. After review of the published information listed above, the requirement for data collection and the proposed locations within the study area shall be determined for data collection. Depending on the duration of the required monitoring and seasonality, some intermittent watercourses may need to be included as well. This work should be coordinated with fisheries habitat consideration and surface water quality modelling.

If data gaps are identified, site specific geological and hydrogeological information should be collected through the installation of groundwater piezometers at selected locations across the study area to ensure a thorough understanding of groundwater recharge, as well as surface water-groundwater interactions. If required, the study is to carry out a site study of karst geology using field mapping, and possibly dye tracing techniques, in an effort to understand the significant subsurface flow paths.

Natural Heritage System

Where necessary, collect site-specific environmental data over four seasons at the appropriate time of year, including the following:

- Field data on vegetation communities and linkages using the Ecological Land Classification System for Southern Ontario;
- Fish (via electrofishing) and benthic invertebrate data from local streams;
- Temperature data related to fisheries;

DRAFT

- Riparian habitat and stream erosion data to evaluate the need and potential for stream restoration and to establish buffer/setback criteria;
- Evaluate unevaluated wetlands using the 3rd Edition Provincial Wetland Evaluation System;
- Update previously evaluated wetlands to the 3rd Edition Provincial Wetland Evaluation;
- Identify significant wetlands, woodlands, valley lands, wildlife habitat, areas of natural and scientific interest and fish habitat, as defined by the Provincial Policy Statement;
- Species occurrences for plants, birds, mammals, reptiles, amphibians, fish, Lepidoptera, Odonata and other invertebrates known to occur in the study area;
- Identify and map (UTM coordinates) for regionally, provincially, nationally or globally rare species.

Where specific locality data is available, species occurrences will be reported to the Natural Heritage Information Centre. Focus shall be placed on core features and the possible linkage of these species.

DRAFT

APPENDIX B

Proposed Hydrology Plan

DRAFT

The Hydrological component of the subwatersheds study will be based on the following hydrologic and hydraulic modelling exercises:

1. SWM 5, PCSWMM, HSP-F, QualHYMO, GAWSER or MIKE-SHE continuous simulation calibrated model to be used for the water balance;
2. Modelling established to produce runoff hydrographs for the study area for existing and future conditions, and to size the required SWM facilities if applicable;
3. Erosion potential assessment shall be carried out, using continuous simulation of water course flows over a period time, to evaluate cumulative shear stress exceeding the erosion threshold. Both the magnitude and duration of the large flows should be considered;
4. HEC-RAS to determine and / or update the existing flood elevations, with consideration given to the prevalent flat study area that requires other applicable tools for hydraulic analysis.

Proposed Hydrology Approach:

Water Balance

1. Evaluate the available meteorological and hydrometric data, including but not limited to, precipitation, flow, solar radial, wind, etc. Examine the statistical characteristics of the study area, in terms of wet, dry and average conditions.
2. Delineate discretized drainage areas in the study area, the drainage area should be indicated with consideration of the subsurface hydrological activities. If required, perform dye tracing (by a hydrogeologist) prior to conducting water balance simulations. Investigate limits of active karst area in the study area (i.e. less than 3 m overburden). The karst investigation is to be performed by the hydrogeologist in cooperation with a karst expert.
3. Establish and calibrate the continuous model to represent the existing and future development hydrologic regimes of all creeks upstream and immediately downstream of the study area, with reference to the potential groundwater recharge /discharge areas. Sufficient details should be obtained regarding the storage and flow capacity characteristics of the karst formation, in order to count for the surface water and groundwater interactions through the conduit flow and storage reservoir unit within the groundwater systems.

Hydrology and hydraulics

1. Develop discrete design event simulation to generate runoff hydrographs for the development area for existing and future development conditions for all storms events, ranging from 25 mm, 2, 5, 25, 50, 100 year up to and including the Regional Storm.
2. The study shall ensure the Intensity-Duration-Frequency (IDF) values are obtained from reliable sources, i.e. Environment Canada, or generated with the approved methodologies, i.e. Consolidated Frequency Analysis (CFA). Peak flow rates derived by different methods should be compared and assessed.

DRAFT

3. Extent of active karst areas should be considered in developing the model input parameters (i.e. surface runoff infiltration). Drainage patterns in and around the karst formation areas shall be verified in the field. This may require sufficient details be obtained, regarding the storage and flow capacity characteristics of karst formations, in support of the karst impacts on surface water and groundwater interactions.
4. The calibration and verification of hydrologic model shall include multiple low and high flow events. Model calibration should focus on providing comparable peak flows, runoff volumes and hydrograph shape (flow timing) to observed flow gauge data.
5. Conduct hydraulic analysis on the established water courses, based on the updated hydrographs for all storm events from the hydrologic model, to assess the water levels, flow velocities, inundation depths, water profiles, etc. under the current land uses and proposed development conditions.

Flood Risk Analysis

1. Review existing flood plain mapping for the watercourse from the Conservation Authority, where available.
2. Update the flood lines using HEC-RAS model to determine existing flood elevations for all storm events up to the Regional Storm.
3. Establish the post-development flood lines with the input of future land uses projections.
4. Determine flood plain extents with existing conditions, and the post-development flood lines with the proposed development. The model results shall be presented in a geo- referenced format such as GIS maps.
5. The model results shall be converted to Mike Urban Model format for easier integration into the City's Sewer Model Systems.

SWM Facility Sizing

1. Identify the existing and proposed stormwater facility locations in the study area, in consideration with the appropriate outlets to the receiving water bodies. Use the pre- and post-development hydrographs to size the required SWM facilities.
2. If SWM ponds are required, it should be extended detention wet basins. Preliminary design of these facilities shall be included to determine stage-storage-discharge curves, outflow hydrographs, etc.
3. Use the proposed SWM pond outflow curves as input to the hydrologic model, and select design storms to test the SWM strategy from a peak flow perspective, for the entire study area extending to the downstream hydrologic nodes of interest, or flow gauge stations.
4. Employ these SWM pond outflow curves into to the continuous model for water balance. Simulate continuous flow data and conduct the statistical analysis of the water balance for existing and post-development conditions in consideration with these SWM facilities. The continuous model could also be used for flow frequency analysis, with sufficient coverage of typical dry and wet year datasets

DRAFT

5. The proposed SWM facilities shall be included in the post-development hydraulic models, to assess the potential impacts on future flood elevations, and to eliminate increased flood inundation and/or erosion concern.

6. Stormwater management facilities are to be evaluated from a water quality perspective. The receiving water systems shall be investigated for the applicable standards of stormwater discharges. The potential stormwater impacts on receiving water body quality must be closely assessed and controlled to eliminate environmental degrading. The SWM water quality control criteria are based the MOE Stormwater Management Practice Manual (2003), and the City's stormwater management guidelines. In addition, the respective Conservation Authority`s requirement are to be confirmed and addressed.

Erosion Assessment

1. Select typical cross sections of the established watercourses in the study area, with existing erosion concerns, downstream of the future development, and/or branches with known downstream erosion concerns, for erosion assessment. Consider the sections selected in previous studies and the ones identified in the field observations of erosion, deposition and incision.

2. Export outflow hydrographs from the hydrologic model for existing and future conditions to the selected cross sections. The outflow hydrographs should include typical dry and wet years, as well as the various design storms.

3. Assess the erosion potential of the selected cross sections and the overall subwatersheds. Based on continuous hydrologic and hydraulic simulations of the watercourse flows, cumulative shear stress exceedances shall be evaluated. The assessment should consider separate shear stress on the channel and creek banks.

4. The erosion concerns are to be identified for existing situation as a baseline. Consequently, the erosion potential during average, dry and wet years, as well as the various design storms, for future condition shall be assessed, with the potential impacts of upstream development on downstream regimes. Opportunities should be evaluated for segments of channels, as to the suitability /feasibility to be naturalized / restored to eliminate erosion concerns.

5. It is critical that conceptual SWM designs for the study area shall include considerations to ensure stormwater is controlled, in an appropriate manner to prevent any increase in erosion potential. The alternate development proposal including source control can be considered to minimize erosion potential at downstream.

6. The continuous modelling shall evaluate the benefits of alternate SWM approaches, on maintaining the existing water balance over the long term as much as feasible, and on preventing any increase in cumulative shear stress and erosion potential.

DRAFT

Summary and Verification

A summary of any software selection and migration shall be documented, with the modelling approach, calibration and any assumptions used in the modelling exercises.

Updating of the flood inundation scenarios (i.e. flood lines) requires a detailed node-by-node comparison of the modelling parameters and results, to ensure that the information is not lost or misinterpreted.

The numeric models included in this study are to be calibrated to a reasonable accuracy, with historic flow data and / or gauge data collected as identified necessary in the monitoring section of this study.

Discussions shall be included regarding verification of the simulated peak flows, hydrographs, erosion assessment, flood lines delineations, and proposed stormwater management strategy.

DRAFT

APPENDIX C

Proposed Hydrogeological Plan

DRAFT

1.1 Objectives

The primary objectives of the hydrogeological investigation are to:

- Define the local and regional geology and hydrogeology of the Study Area;
- Identify any significant karst features, delineate any hazardous lands as a result of the karst, and characterize key subsurface flow paths within the karst formation;
- Identify and evaluate the functional relationship and interactions groundwater has with the existing surface watercourses; and
- Evaluate the potential impacts that the proposed future development may have on the groundwater resources in the study area.

The investigation shall identify the depth, extent and directions of groundwater flow in the aquifer system(s) of the study area. Emphasis should be placed on identifying and evaluating the existing groundwater recharge and discharge areas within the study area, and the potential impact future development may have on them.

1.2 Scope of Work

1.2.1 Literature and Existing Data Review

The data review will assemble, review and collate all available relevant hydrogeological information for the study area. Data will include the published information and relevant documentation provided by Agencies (e.g. City of Hamilton, Niagara Escarpment Commission, Conservation Authorities, Ministries of the Environment, Natural Resources, Northern Development and Mines, etc.). Examples of existing data include, but not limited to, the following:

- 1:10,000 Ontario Base Maps (OBM)
- Ministry of Natural Resources (MNR) Aggregate Resource Maps
- Ministry of Northern Development and Mines (MNDM) Quaternary and Bedrock Geological Maps
- Ministry of the Environment (MOE) Aquifer Maps and Drainage Basin Studies (if any)
- MOE recently published The Hydrogeology of Southern Ontario
- MOE Water Well Records
- Background geological/hydrogeological and other relevant reports

Cross-sections will be drawn to assist in the interpretation of local hydrogeological conditions. The sections will show geological formations, aquifers, aquitards, water tables, potentiometric surfaces, and groundwater flow directions.

Following a review and assessment of available information, data gaps and required updates will be identified and documented; If required, karst studies may further define and evaluate the geological and hydrogeological regime at specific locations with karst formation.

DRAFT

1.2.2 Stream Flow Measurements

Stream flow measurements shall be taken at appropriate locations along the subject creeks, to identify areas of groundwater recharge/discharge and establish baseflow conditions.

1.2.3 Drilling Program (If Applicable)

The purpose of the drilling program is to assess the overburden stratigraphy of the study area, determine depths to bedrock, and to install groundwater piezometers.

The specific purpose of the groundwater piezometers is to measure water table levels and elevations to determine shallow groundwater flow direction and to determine the functional relationships between the shallow aquifer and the surface watercourse in these creeks.

It is difficult to accurately determine the number of groundwater piezometers required to define the shallow groundwater regime of the study area. For the purposes of this Terms of Reference, the proponent is to propose the necessary number of piezometers, with a reasonable explanation of such a decision.

1.2.4 Karst Study

The purpose of the karst study is to identify any significant karst features, delineate any hazardous lands as a result of the karst, and to identify and characterize key subsurface flow paths within the karst.

The extent of the study area for the karst study should be assessed during the initial fieldwork. However, the study area may extend to include any potential resurgences (springs) that may be recharged from groundwater and runoff from the development site. It may include the adjacent areas immediately to the east, west, south and north of the development site.

The study includes three components: 1) Karst geology and field mapping; 2) Groundwater tracing; and 3) Reporting. Each is described below.

Karst Geology and Field Mapping

The scope of work for this component includes:

- Defining the study area based on a field reconnaissance;
- Field mapping the major karst features that may significantly influence the hydrogeology of the site, or that may be affected by surface runoff and groundwater recharge from the site;
- Identifying the specific natural hazards of the study area that result from the karst;
- Delineating any hazardous lands and sites (as described by the Provincial Policy Statement and the Planning Act) that relate to development;
- Preparing a brief interim report that includes results from the field mapping and recommendations regarding the groundwater tracing.

DRAFT

Groundwater Tracing (if applicable)

The scope of work for this component includes:

- Informing the Ministries of the Environment and Natural Resources about the groundwater tracing and obtain approval, if necessary;
- Providing fluorescent dye tracers and preparing them for use in the field;
- Conducting groundwater tracing with injection at specified sites, and water sampling at appropriate springs as required;
- Augmenting groundwater tracing observations with spot measurements of discharge, conductivity and temperature, as required;
- Conducting water analysis in an established laboratory using a scanning fluorometer, and performing data analysis and interpretation;
- Identifying and characterizing the key groundwater flow routes from sink points in the study area; and
- Identifying the subwatersheds within the study area that groundwater contributes flow to the creeks, based in part on the subsurface flow routes determined by tracing.

Reporting

- Preparing and submitting a draft report for review. The report should be concise and document the results of the study. It should focus on karst geology, hydrogeology, and any hazardous lands that result from the karst;
- A map shall be included showing significant karst features, springs, traced groundwater flow routes and any lands deemed as hazardous because of the karst (including its relevance to the development);
- The report shall also include any data relevant to the interpretation of hydrogeology; and
- Finalizing and submitting the final report.

1.2.5 Overall Data Assessment and Interpretation

All collected background information and field data shall be compiled, assessed and interpreted, so as to provide a comprehensive assessment of the groundwater conditions.

1.2.6 Future Development and its Potential Groundwater Impacts

All gathered hydrogeological data shall be assessed, with areas identified as most susceptible to groundwater and surface water impacts resulting from construction and developmental activities. Groundwater protection, mitigation and management measures should be discussed to ensure that the existing groundwater and surface water hydrological regime across the study area is maintained.

DRAFT

1.2.7 Reporting

A comprehensive hydrogeological report summarizing all findings, interpretations and recommendations shall be prepared to include:

- background geological and hydrogeological information;
- descriptions of field activities, procedures and protocols;
- evaluation and interpretation of all results; and
- recommendations for groundwater protection, mitigation and management measures, as well as recommendations regarding future development practices that will promote groundwater sustainability.

DRAFT

APPENDIX D

Tractive Force Analysis

DRAFT

Tractive force analysis is an essential component of any development/environmental study, in that it allows investigators to determine erosion-sensitive reaches and provides guidance for the delivery of flow volumes from stormwater management facilities.

The concept of tractive force analysis is relatively simple: a stream system or watercourse develops over many years with respect to the timing and volume of flow contributions by groundwater (baseflow contributions) and overland flow (volumes greater than baseflow in streams), by the process of erosion and sediment transport. Therefore a watercourse develops a cross-sectional area and profile in the downstream direction for the transfer of water and sediment from headwaters to river mouths. When alterations to the hydrologic regime of a watershed occur, the response of the watercourse is to change either its cross-sectional area (via lateral or vertical erosion) or to modify its gradient (becoming steeper or more gentle depending on the conditions). These changes are not immediate in most cases, nor are they limited to a particular temporal boundary as cumulative impacts usually prevent re-establishment of a natural flow regime.

Development of rural or agricultural lands to a more impervious surface is one such alteration, which has in the past resulted in considerable change to stream systems. Paved surfaces and reduced infiltration result in two major impacts in streams: First, rapid delivery of flow to the watercourse causes increased flow competence and thereby sediment transport and erosion; Second, a decrease in infiltration causes a potential decrease in baseflow contributions as subsurface hydro-potential gradients are altered.

The preferred management strategy to the groundwater recharge issue is the development and maintenance of infiltration galleries within stormwater management ponds. However, the problem of accelerated erosion by overflows during storm events is a more serious and complicated matter.

Stormwater management ponds will discharge excess water during periods of high input to surrounding stream systems. The delivery of that excess flow has the potential to cause erosion by either increased flow velocity or lower velocity over extended periods of time. Both conditions will result in channel alterations downstream of the structure, particularly in erosion-sensitive reaches. The challenge for managers is to effectively create stormwater management strategies which do not impact receiving watercourses and contribute to accelerated (faster than natural rate) erosion.

Methodology

Tractive force analysis (also known as excess shear, excess velocity, and / or excess stream power) allows geomorphologists to work with engineers, as to the rate and timing of stormwater discharge from SWM ponds. The methodology to undertake such analyses includes the following:

1. A stream walk is undertaken at the start of the assessment to document overall watercourse conditions and to identify areas of potential erosion risk. During this walk notations of changes in soil type and bed characteristics are made and digital photographs are taken. A further purpose of the walk is to choose potential cross-sections for further study. The number of cross-sections chosen reflects the concerns of the study area.
2. A rapid reach assessment is undertaken, which identifies particular concerns with respect to channel form, bank properties, riparian conditions, substrate and flow characteristics. Relative erosion sensitivity should be assigned on a reach basis, which can be used comparatively to select reaches for further study.

DRAFT

3. Once all potential cross-sections have been identified, choices are made as to which ones would require further analysis. This decision is based on relative stability to other reaches and the proximity to areas of concerns or specific interests, in particular areas of differing soil type, proximity to structures, or proximity to catchment nodes in the hydrological modelling.

4. Each cross-section is monumented for future use. Cross-sectional measurements of channel and bankfull area are made at tight intervals to get a detailed indication of form. Local slope is determined using a leveling exercise. This cross-sectional data is input into a flow model along with information on channel roughness (Manning's 'n') to determine stage/discharge relationships and specific velocities.

5. Bed samples of pavement and sub-pavement are collected and returned to the lab for grain-size analysis; bank samples are also collected. The grain size distribution is used in the tractive force analysis.

6. Critical shear stress for the bed material (pavement and sub-pavement) is determined using standardized methods for the D_{50} and D_{90} fraction of each sample.

7. Boundary shear stress is determined from the cross-sectional profile, slope and roughness components measured in the field. Comparisons are made between the critical and boundary shear at bank full stage to establish erosion potential for each fraction.

8. Critical discharge to match the critical/boundary shear relationship is then mathematically determined and reported to the engineer for placement in the hydrological model as a threshold value. The hydrological model is then run against the threshold value to determine exceedance for the pre-development and post-development scenarios; this is input into the decision matrix for the sizing of the stormwater management pond.

9. Reporting includes critical shear, critical discharge, critical velocity, stream power and erosion potential for the selected cross-sections. These other critical thresholds are reported in case there are issues surrounding the use of shear stress as a decision-making tool.

10. Recommendations are made, from the perspectives of fluvial functioning of the watercourse, as a component of the final report.

In conclusion, erosion study will be established on each watercourse, in order to comply with the requirements from City of Hamilton, the Conservation Authorities and the Provincial jurisdictions, as to the proposed development. Fieldwork to establish these study sites and collect data is to commence upon approval of this document. Critical discharges for excess shear computations shall be provided with the final reporting meeting the study deadline.

DRAFT

APPENDIX E

Proposed Protocol to Sample Benthic Invertebrates

DRAFT

Purpose

This appendix defines a sampling protocol to identify the benthic macroinvertebrate community of the study area. As the composition of a stream's benthic macroinvertebrate community reflects its substrate, water quality and temperature, repeated sampling of benthic macroinvertebrates may be used to monitor changes in its condition.

Timing

The sampling of benthic macroinvertebrates can yield different results depending on the sampling period, because seasonal disturbances (e.g. spring flood) and stream conditions strongly affect the diversity, abundance, and life stage progression of aquatic insects (Hynes, 1970).

Samples of benthic macroinvertebrates will be collected in early spring after the in stream environment has stabilized following the spring flood. This timing is intended to include the pre-emergence period (typically mid-spring to late summer) to ensure that species representation is at a maximum.

Sampling Locations

Appropriate sample locations, and the number of stations to be sampled, shall be determined based on the length of the stream and the availability of suitable sampling habitat.

Each sample site should be located in areas with run or riffle habitat, moderate to high current velocity and a substratum of diverse particle sizes, but preferably dominated by gravel and larger particles. Only sites that are shallow enough to provide a safe foothold will be selected for sampling.

Sampling Procedure

The effort required to achieve a sufficient sample of benthic macroinvertebrates varies from stream to stream. A standard sampling time (usually between 15 seconds and 1 minute) and length of stream to be sampled (usually between 3 and 5 meters) should be established when initial samples are taken. These standards are to be applied to all sampling stations in the study area.

Benthic invertebrates will be sampled by kick net and preserved in 70-80% ethanol or 10% buffered formalin.

Field Measurements And Observations

Benthic invertebrate sampling will include appropriate descriptions/measurements of stream conditions at sampling sites, including habitat type, stream width and depth, current velocity, substrate composition, the amount of algae and plant material. A photograph of each sample site shall be taken.

Analysis

Sampled invertebrates will be identified to the lowest taxonomic level possible – at a minimum, to family level. Each taxon shall be enumerated and the results are to be used to calculate the proportions of functional feeding groups and EPT taxa (Ephemeroptera, Plecoptera and Trichoptera). Additional indices may be calculated as required.

DRAFT

APPENDIX F

General Criteria for Stormwater Management

DRAFT

The study shall consider the following general criteria for stormwater management.

1. Control of post-development peak flows to pre-development levels is recommended in all areas. Priority should be given to control of runoff increase at source by reducing imperviousness, and maximizing dispersal of runoff and infiltration potential, especially in headwater and cold water subwatersheds, or those subwatershed areas which ultimately feed cold water creeks.

2. Storm runoff must be treated before discharge to receiving waters. General sizing guidelines for water quality control are provided in MOE (2003), which can be used for preliminary ponds sizing. Special design considerations are required to control temperature in cold water subwatersheds, such as bottom draws or other modified outfall structures, and shading. Source controls, reduced imperviousness, swales and small-scale shallow wetland type facilities should be emphasized to reduce the loss or diversion of local stream flow and head water habitat.

3. Duration exceedance characteristics of the SWM discharges shall be addressed to minimize erosion potential. In general, it should be maintained in accordance with the existing functions and values of the stream and drainage system. The SWM design analysis for erosion control shall include a critical flow threshold analysis for the receiving creeks. The flow duration characteristics, specified from the hydrological analysis given in Appendix B: Proposed Hydrology Plan, should be considered in design SWM control measures from an erosion control perspective.

4. The proposed SWM facilities shall identify the unitary control rates (discharge and storage) per hectare of development area from flood control and erosion perspectives. The proponent shall verify the effectiveness of source controls, and the magnitude of the runoff volume reductions, with a detailed analysis of the specific SWM measures proposed.

5. Maintenance of existing groundwater recharge rates on an annual basis and the protection of groundwater quality should be verified through hydrogeological studies. Further field work and hydrologic modelling could be required for implementing and monitoring in this regard.

DRAFT

MASTER DRAINAGE PLAN – SUMMARY CHECKLIST

The form is to be completed by the Professional that prepared the Master Drainage Plan.

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

Refer to the Terms of Reference for the Master Drainage Plan:
Link to Terms of Reference

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

Site Information	
Site Address	
Property Owner	
Project Description	
Land Use	
Date Prepared:	
Prepared By:	

Summary of Key Information:

	Master Drainage Plan Information		**Page # & Section # of Report**	**Report Includes this Information City Staff (Check)**
1	Date of Formal Consultation with City			
2	Date Master Drainage Plan was prepared			
3	Who Prepared the Master Drainage Plan (Consulting Firm)			
4	Name of Author of Master Drainage Plan			

DRAFT

	Site Information	Information is Included in the Study document?	Page # & Section # of Report	Report Includes this Information City Staff (Check)
STAGE 1: SUBWATERSHED CHARACTERIZATION REPORT				
Does the study include the following sections and information?				
5	Description of location, site area, property owners, including relevant figures?	Yes/No		
6	Purpose of the study?	Yes/No		
7	Type of application that triggered the study?	Yes/No		
8	Description of existing conditions?	Yes/No		
9	List of existing reports, studies, standards, guidelines, etc. relied upon?	Yes/No		
10	Summary of the following supporting studies:			
	a) Hydrology and Hydraulics?	Yes/No		
	b) Hydrogeology?	Yes/No		
	c) Stream Morphology?	Yes/No		
	d) Channel Erosion?	Yes/No		
	e) Aquatic Environment?	Yes/No		
	f) Terrestrial Environment?	Yes/No		
	g) Surface Water Quality?	Yes/No		
11	Identification of gaps in the summarized data?	Yes/No		
12	Description of the proposed program for collection of missing data?	Yes/No		
13	Subwatershed Characterization?	Yes/No		
14	Identification of Issues, Concerns and Constraints?	Yes/No		
15	Ranking of Constraints (High/Medium/Low)?	Yes/No/Not Applicable		
16	Identification of protection / integration into development / replacement of constraints?	Yes/No/Not Applicable		

DRAFT

	Site Information	Information is Included in the Study document?	Page # & Section # of Report	Report Includes this Information City Staff (Check)
STAGE 2: SUBWATERSHED MANAGEMENT STRATEGIES REPORT				
Does the study include the following sections and information?				
17	Description of location, site area, property owners, including relevant figures?	Yes/No		
18	Purpose of the study?	Yes/No		
19	Type of application that triggered the study?	Yes/No		
20	Description of existing conditions?	Yes/No		
21	List of existing reports, studies, standards, guidelines, etc. relied upon, including reference to the Stage 1 report?	Yes/No		
22	Assessment of Impacts, including the following:			
	a) Hydrologic Analysis?	Yes/No		
	b) Hydrogeology?	Yes/No		
	c) Hydraulics?	Yes/No		
	d) Stream Morphology and Erosion Analysis?	Yes/No		
	e) Aquatic Environment?	Yes/No		
	f) Terrestrial Environment?	Yes/No		
	g) Surface Water Quality?	Yes/No		
23	Stormwater Strategy			
	a) List of mitigation alternatives?	Yes/No		
	b) Evaluation of alternatives?	Yes/No		
	c) Recommended mitigation?	Yes/No		
	d) Comprehensive stormwater strategy?	Yes/No		

DRAFT

	Site Information	Information is Included in the Study document?	Page # & Section # of Report	Report Includes this Information City Staff (Check)
	e) Summary of the stormwater strategy, including a listing of how each of the constraints identified in the Stage 1 report has been addressed?	Yes/No		
STAGE 3: IMPLEMETATION AND MONITORING PLANS REPORT				
24	Description of location, site area, property owners, including relevant figures?	Yes/No		
25	Purpose of the study?	Yes/No		
26	Type of application that triggered the study?	Yes/No		
27	Description of existing conditions?	Yes/No		
28	Reference to the Stage 1 and Stage 2 reports?	Yes/No		
29	Description of Project Timing?	Yes/No		
30	Definition of funding formula for construction of the facilities?	Yes/No		
31	Recommendations for future studies (if required)?	Yes/No		
32	Description of Operations and Maintenance requirements?	Yes/No		
33	Monitoring			
	a) Description of monitoring requirements?	Yes/No		
	b) Description of the strategy for corrective actions?	Yes/No		
	c) Estimate of costs of the monitoring program?	Yes/No		
34	Time frame for review/update of the subwatershed plans?	Yes/No		

DRAFT

Qualified Professional who completed this report summary:

Name:_____

Email:_____

Phone:_____

Date:_____

Signature and Stamp:_____

DRAFT

Guideline for Applicants completing the Summary Checklist for Master Drainage Plan

Site Information:

Site Address: Provide municipal address, or lot and concession.

Owner: Provide company name if applicable and name of key contact person.

Project Description: Provide brief description – e.g. 20 Ha residential subdivision.

Land Use: e.g. Residential, industrial, commercial/ mixed use residential and commercial.

Prepared By: Provide name of consulting firm that completed the study.

Master Drainage Plan Information:

1. **Date of Formal Consultation with City:** List the date the Formal Consultation was held with the City.

2. **Date Master Drainage Plan was prepared:** List the publication date of the Master Servicing Plan.

3. **Who Prepared the Master Drainage Plan:** List the name of the consulting firm who prepared the Master Drainage Plan.

4. **Name of Author of Master Drainage Plan:** List the name of the professional who has signed and sealed the Master Drainage Plan.

STAGE 1: SUBWATERSHED CHARACTERIZATION REPORT

5. **Description of Location, site area, property owners, including relevant figures.**
   State all pertinent information and show on a plan. Provide sufficient information to define the geographic extent of the study area and all stakeholders.

6. **Purpose of the study.**
   State the purpose of the study.

7. **Type of application that triggered the study.**
   State the type of planning application that triggered the study (e.g., Application for Approval of Draft Plan of Subdivision).

8. **Description of existing conditions.**
   Describe the existing conditions within the study area, including general information with respect to land use, topography, buildings, natural hazards (including vegetative cover, watercourses, wetlands, slopes, karsts, etc.), Conservation Authority Regulation Limits, municipal and private services, etc.

9. **List of existing reports, studies, standards, guidelines, etc. relied upon.**
   Provide, in bibliographic format, a listing of the documents on which the study relies.

DRAFT

10. **Summary of supporting studies.**
    Provide a brief summary of relevant information included in each of the supporting studies on which the study relies.

11. **Identification of gaps in the summarized data.**
    Discuss the completeness of the information included in the supporting studies, and identify any gaps in the information which would impede the completion of the study.

12. **Description of the proposed program for collection of missing data.**
    Based on the gap analysis completed above, present a program through which the missing data will be collected. Include information with respect to timing, and how describe which aspects of the study may or may not continue prior to completion of the data collection.

13. **Subwatershed characterization.**
    Characterize the watershed in terms of all of the supporting studies.

14. **Identification of Issues, Concerns and Constraints.**
    Based on the watershed characterization, identify the issues, concerns and constraints which could impact the future landuse plan of the study area.

15. **Ranking of Constraints (High/Medium/Low).**
    Rank the issues, concerns and constraints.

16. **Identification of protection / integration into development / replacement of constraints.**
    Identify which constraints should be protected, which may be incorporated into the development, and which may be considered for replacement.

STAGE 2: SUBWATERSHED MANAGEMENT STRATEGIES REPORT

17. **Description of Location, site area, property owners, including relevant figures.**
    State all pertinent information and show on a plan. Provide sufficient information to define the geographic extent of the study area and all stakeholders.

18. **Purpose of the study.**
    State the purpose of the study. Describe the relationship between this study and the previous Stage 1 study.

19. **Type of application that triggered the study.**
    State the type of planning application that triggered the study (e.g., Application for Approval of Draft Plan of Subdivision).

DRAFT

20. **Description of existing conditions.**
    Describe the existing conditions within the study area, including general information with respect to land use, topography, buildings, natural hazards (including vegetative cover, watercourses, wetlands, slopes, karsts, etc.), Conservation Authority Regulation Limits, municipal and private services, etc.

21. **List of existing reports, studies, standards, guidelines, etc. relied upon, including reference to the Stage 1 report.**
    Provide, in bibliographic format, a listing of the documents on which the study relies.

22. **Assessment of impacts.**
    Provide a brief summary of relevant information included in each of the supporting studies on which the study relies. Provide a detailed analysis of the impacts of future land use changes on the natural environment, in relation to each discipline of supporting study. Multiple future land use scenarios should be considered. The assessment of impacts should include investigation of different options for mitigation of impacts of the future land use change, as well as opportunities for restoration and enhancement.

23. **Stormwater Strategy.**
    Describe the stormwater management strategy for the future land use. Include qualitative and quantitative targets. Include the required location of stormwater management facilities, Low Impact Development measures, conveyance and end of pipe controls. Development of the strategy shall include assessment of alternate development scenarios. Evaluate constraints and opportunities for each. Provide conceptual design of all facilities required to achieve the specific targets. The strategy is to include assessment of the effectiveness of existing drainage facilities and measures to be implemented to provide necessary improvements. Include sufficient plans and details to illustrate the proposed strategy.

STAGE 3: IMPLEMENTATION AND MONITORING PLANS REPORT

24. **Description of Location, site area, property owners, including relevant figures.**

25. **State all pertinent information and show on a plan.**
    Provide sufficient information to define the geographic extent of the study area and all stakeholders.

26. **Purpose of the study.**
    State the purpose of the study. Describe the relationship between this study and the previous Stage 1 and Stage 2 studies.

27. **Type of application that triggered the study.**
    State the type of planning application that triggered the study (e.g., Application for Approval of Draft Plan of Subdivision).

DRAFT

28. **Description of existing conditions.**

    Describe the existing conditions within the study area, including general information with respect to land use, topography, buildings, natural hazards (including vegetative cover, watercourses, wetlands, slopes, karsts, etc.), Conservation Authority Regulation Limits, municipal and private services, etc.

29. **List of existing reports, studies, standards, guidelines, etc. relied upon.**
    Provide, in bibliographic format, a listing of the documents on which the study relies.

30. **Reference to the Stage 1 and Stage 2 reports.**
    Reference the Stage 1 and Stage 2 reports and provide context of the relationship of the three reports.

31. **Description of Project Timing.**
    Provide a timeline for construction of the various aspects of the future development. Discuss the sequencing of the various aspects.

32. **Definition of Funding formula for construction of the facilities.**
    Provide a itemized breakdown on the source of funding for the various aspects. Where funding is expected from a party(ies) other than the proponent, describe the mechanisms by which cost shares would be recovered, and what role, if any, the City would play in cost sharing agreements. Describe the events and timing that would trigger the various aspects of cost sharing.

33. **Recommendations for future studies (if required).**
    Identify the scope, timing and triggers for any future studies that may be required. Identify the party responsible to undertake the future studies.

34. **Description of Operations and Maintenance requirements.**
    Describe the requirements for operation and maintenance of the facilities. Include the frequency and scope of inspections, routine maintenance, clean out, and ultimately replacement of the facilities. Include discussion of the triggers for maintenance. Estimate the costs associated with the operations and maintenance requirements and responsibility for the works and the costs.

35. **Monitoring:**

    a. **Description of monitoring requirements.**
    Prepare a monitoring program by which the effectiveness of the proposed measures will be assessed. Include a timeline for the frequency of monitoring. Identify the party(ies) responsible for the monitoring. Describe the reporting and record keeping structure, including a list of what documents are to be provided to which agency(ies), and when.

DRAFT

b. **Description of the strategy for corrective actions.**
Provide the strategy by which corrective actions will be undertaken, and by whom, in the event that monitoring demonstrates that the corrective actions are warranted. Provide a listing of potential deficiencies for which corrective actions may be required, as well as an analysis of the likelihood of occurrence and potential impact of each deficiency on the natural environment.

c. **Estimate of costs of the monitoring program.**
Provide an itemized estimate the annual costs of the monitoring program, and indicate which party(ies) is to be responsible for the costs.

36. **Time frame for review/update of the subwatershed plans.**
Discuss the triggers and anticipated timeline for review/update of the subwatershed plans. Indicate the party(ies) responsible to undertake the review/update.

DRAFT

Standard Format for Table of Contents – Master Drainage Plan

It must be understood that the scope of a Master Drainage Plan can vary greatly depending on the scale and complexity of the watershed and its natural heritage features and conditions, and the proposed development. As such, the following is a guideline only; the author must ensure that appropriate sections are included in the report to fully demonstrate all aspects relevant to the existing and proposed conditions.

The Master Drainage Plan shall be conducted in three stages, each of which shall conclude with publication of a study report.

The study reports shall include the following:

A. STAGE 1: SUBWATERSHED CHARACTERIZATION

Title:

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

1. Introduction & Overview

a. Description of location, site area, property owner(s)

b. Purpose of the study (Why is it required)

c. Type of application that triggered a requirement for the study (When is it required)

2. Background Information

a. Describe existing conditions related to the type of study

b. List existing reports, studies, standards, guidelines, etc. relied upon in the preparation of the study

c. Include subsections summarizing information relied upon from other studies, including:

- Hydrology & Hydraulics
- Hydrogeology
- Stream Morphology
- Channel Erosion
- Aquatic Environment
- Terrestrial Environment
- Surface Water Quality

DRAFT

3. Gap Analysis

a. Identify any gaps in the data summarized in the previous section.

b. Describe the proposed program for collection of missing data.

4. Subwatershed Characterization

Characterize the subwatershed based on the findings of the preceding sections.

5. Issues, Concerns and Constraints

a. Describe issues, concerns and constraints associated with the subwatershed.

b. Identify each issue, concern and constraint as high, medium or low constraint.

c. Identify which constraints are to be protected, which may be integrated into development, and which may be considered for replacement.

B. STAGE 2: SUBWATERSHED MANAGEMENT STRATEGIES

Title:

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

1. Introduction & Overview

a. General description of the development and plans

b. Description of location, site area, property owner(s)

c. Description of larger development (if phased and/or applicable)

d. Purpose of the study (Why is it required)

e. Type of application that triggered a requirement for the study (When is it required)

f. Provide reference to the Stage 1 report completed previously for the project.

DRAFT

2. Assessment of Impacts

a. Identity and describe the impacts of the future land use as they relate to the issues, concerns and constraints identified in the Stage 1 report, for each of the disciplines identified in the Stage 1 report, including:

- Hydrologic Analysis
- Hydrogeology
- Hydraulics
- Stream Morphology and Erosion Analysis
- Aquatic Environment
- Terrestrial Environment
- Surface Water Quality

3. Development of Stormwater Strategy

a. Identify a list of mitigation alternatives to address the contemplated impacts of the development.

b. Evaluate the alternative mitigation measures in terms of their feasibility, effectiveness, cost and other relevant factors.

c. Determine the recommended mitigation measures to be carried forward.

d. Incorporate the recommended mitigation measures into a comprehensive stormwater strategy.

e. Summarize the stormwater strategy, including a listing of how each of the constraints identified in the Stage 1 report is addressed by the strategy.

C. STAGE 3: IMPLEMENTATION AND MONITORING PLANS

Title:

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

DRAFT

1. Introduction & Overview

a. General description of the development and plans

b. Description of location, site area, property owner(s)

c. Description of larger development (if phased and/or applicable)

d. Purpose of the study (Why is it required)

e. Type of application that triggered a requirement for the study (When is it required)

f. Provide reference to the Stage 1 and Stage 2 reports completed previously for the project.

2. Project Timing

Describe the timing for construction of any required facilities with respect to the future development.

3. Project Funding

Define the funding formula for the construction of the facilities.

4. Future Study Requirements

Provide recommendations for future studies, if required.

5. Operation & Maintenance

Describe the operation and maintenance responsibilities for the recommended facilities.

6. Monitoring

a. Describe the monitoring program for the facilities, to ensure compliance with the subwatershed study.

b. Describe the strategy for corrective actions which may be necessary based on the results of the monitoring program.

c. Estimate the costs of the monitoring program, including identification of the party(ies) responsible for the costs.

7. Review Requirements

Identify the time frame for the review/update of the subwatershed plans.

DRAFT