CITY OF VAUGHAN

EXTRACT FROM COUNCIL MEETING MINUTES OF JUNE 28, 2022

Item 1, Report No. 29, of the Committee of the Whole (Working Session), which was adopted, as amended, by the Council of the City of Vaughan on June 28, 2022, as follows:

By approving that staff report back to a Committee of the Whole (Working Session) in Q2-2023 with a policy to address storm water management facilities and issues raised regarding life cycle costs; and

That the following Communications be received:

C17. Augusto R. Nalli, ARN Project Management Inc., Bathurst St., King City, dated June 7, 2022; and
C35. Memorandum from the Deputy City Manager, Infrastructure Development and the Deputy City Manager, Public Works, dated June 28, 2022.

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1. CITY APPROACH ON NON-CONVENTIONAL STORMWATER MANAGEMENT INFRASTRUCTURE

The Committee of the Whole (Working Session) recommends:

1) That the recommendations contained in the following report of the Deputy City Manager, Infrastructure Development, dated June 8, 2022, be approved; and

2) That staff report back on the costs of operations and maintenance of an existing underground storage tank that is currently under review; and

3) That the presentation by Steven Van Haren, WSP, Commerce Valley Drive West, Thornhill, Communication C1, entitled, *"Peer Review: Dual-Use Stormwater Facilities Policy Paper"*, dated June 8, 2022, be received.

Recommendations

1. THAT the City's current interim approach of reviewing and accepting proposed non-conventional stormwater infrastructure continue to be accepted until such time that a formal City policy and procedure is developed by the City; and

2. THAT Council direct staff to retain a consultant to develop a formal City policy and procedure for reviewing and accepting non-conventional stormwater infrastructure and that funding in the estimated amount of $250,000 be provided from the City-Wide Engineering DC reserve for the 2023 budget year.

Committee of the Whole (Working Session) Report

DATE: Wednesday, June 8, 2022 **WARD(S):** ALL

TITLE: CITY APPROACH ON NON-CONVENTIONAL STORMWATER MANAGEMENT INFRASTRUCTURE

FROM:
Vince Musacchio, Deputy City Manager, Infrastructure Development

ACTION: DECISION

Purpose

This Report updates Council on the status of the City's current interim approach to approving and accepting proposed non-conventional stormwater management infrastructure for greenfield and infill/intensification developments in the City of Vaughan. In addition, staff are seeking Council approval to proceed with the development of a formal City policy and procedure for proposed non-conventional stormwater management infrastructure. This will require the procurement of an external consultant to develop a policy and procedure as extensive consultation with internal and external stakeholders, and technical expertise of non-conventional storm water technologies will be required to assess all aspects of non-conventional stormwater infrastructure in the development planning approval process.

Report Highlights

- Status of the City's current interim approach for reviewing and accepting non-conventional stormwater infrastructure and the associated financial contribution required to offset operation, maintenance, and replacement costs of the new infrastructure.
- The City retained a stormwater engineering consultant to undertake a peer review of a Dual-Use Stormwater Management Facilities Policy Paper and provide responses to City staff inquiries on non-conventional stormwater management infrastructure.
- Recommendation for the development of a formal City policy and procedure on proposed non-conventional stormwater management infrastructure.

Recommendations

1. THAT the City's current interim approach of reviewing and accepting proposed non-conventional stormwater infrastructure continue to be accepted until such time that a formal City policy and procedure is developed by the City; and

2. THAT Council direct staff to retain a consultant to develop a formal City policy and procedure for reviewing and accepting non-conventional stormwater infrastructure and that funding in the estimated amount of $250,000 be provided from the City-Wide Engineering DC reserve for the 2023 budget year.

Background

Stormwater management techniques are necessary to mitigate the effects of urbanization on the hydrologic cycle and have been incorporated as part of the installation of municipal services for new development sites in the City since the early 1980s. Stormwater management facilities (SWMFs) are designed to help maintain the existing hydrologic cycle while protecting water quality and preventing increased erosion and flooding.

Currently, the City owns approximately 150 conventional stormwater management facilities (SWMFs), which encompass both wet and dry stormwater management ponds. With the increased demand for housing and development within the City, additional SWMFs will be required to be constructed over the next years. More recently, SWMFs have been integrated as focal naturalized features in new communities.

As a result of increasing land costs, developers are looking at alternative options to best utilize their developable land. The City has recently approved non-conventional stormwater infrastructure such as underground storage tanks (UGSTs) and superpipes to provide inline storage which provide similar functionality as SWMFs for a limited number of sites. However, based on the City's and other municipalities' experience, UGSTs are costly to install, operate, maintain, and replace and require specialized inspection requirements such as confined space entry. As such, for previously approved non-conventional stormwater infrastructure, the City has been collecting a one-time cost contribution from the developer, calculated on a case-by-case basis through an evaluation of the stormwater characteristics and design requirements specific to a site.

Recent pilot projects and studies completed in Ontario by the Toronto Region Conservation Authority (TRCA) are supportive of UGSTs to provide stormwater management controls, especially where temperature mitigation is a concern.

Although, UGSTs have been used for many years on private properties to provide stormwater management controls, they remain a new and evolving concept for municipalities, as the operation and maintenance activities can be complicated, costly and inherently carry a higher replacement cost. Due to this evolving shift from conventional SWMFs to publicly owned non-conventional stormwater infrastructure such

as UGSTs, municipalities are trying to ensure the financial cost differential from the commonly installed conventional stormwater infrastructure is secured.

A scan of neighbouring municipalities in the region indicate that most have limited experience with the implementation of non-conventional stormwater infrastructure and are managing them on a case-by-case basis. None of the municipalities within the Greater Toronto Area (GTA) have created a formal approved document or policy that outlines the design criteria and financial contributions for proposed non-conventional stormwater infrastructure on public lands. The only municipality where City staff have identified a document addressing non-conventional stormwater infrastructure is the City of Markham who has implemented an Alternative Infrastructure Policy (not Council approved) to collect contributions for the cost differential should non-conventional stormwater management infrastructure be proposed by the developer. City of Vaughan staff are recommending that a similar approach be adopted on an interim basis to overcome evolving stormwater best management practices.

Previous Reports/Authority

N/A

Analysis and Options

Current interim non-conventional stormwater infrastructure approval process

City staff are currently managing new development proposals for non-conventional stormwater infrastructure on a case-by-case basis. The City has adopted an approach that is similar to the policy framework implemented by the City of Markham that requires a cost differential be calculated and paid by the developer from the conventional SWMFs to non-conventional SWMFs over a 50 year timeframe.

Specifically, staff are recommending the implementation of the following interim policy and procedure for the evaluation of proposed non-conventional stormwater infrastructure:

- The proposed development should provide reasons for the non-compliance of the City approved OP policies for the proposed stormwater infrastructure.
- A recommendation report shall be prepared by a qualified storm water engineer identifying and documenting the benefits of the proposed non-conventional stormwater infrastructure. The report should address items such as the protection of the environment, the social and economic benefits, technical design factors, operation & maintenance requirements, cost implications and replacement costs, etc. This report shall be submitted to the City for review and approval prior to a development application proceeding to a technical report to the Committee of the Whole. Should City staff disagree with the rationale or not have the technical

expertise on the proposed non-conventional stormwater infrastructure, the City shall retain a peer review consultant to provide their professional opinion, with costs of the peer review paid for by the developer.

- For greenfield development situations, consideration of non-conventional stormwater infrastructure will not be supported unless a compelling argument outlining the overwhelming benefits to the City and to the environment can be demonstrated and, if required, the City's peer reviewer agrees with it.
- For specific growth areas and intensification/infill developments, consideration of non-conventional stormwater infrastructure may be considered based on factors such as a development proposal's land constraints and the proposed density.
- Prior to final approval of the plan, the owner shall provide a one-time cost contribution in present value for non-conventional stormwater management infrastructure to compensate for any increase in costs when compared to conventional stormwater management infrastructure, based on operation, maintenance, rehabilitation, and replacement costs over a 50 year lifecycle.
- Non-conventional stormwater infrastructure proposed under the road right of ways should be avoided due to the potential of future encumbrances to City roads, particularly when rehabilitation is required.
- For park development on top of non-conventional stormwater infrastructure, due consideration and review should address:
    - Park programming flexibility and design restrictions;
    - Technical details such as but not limited to soil depths, structure footings, tree canopy requirements;
    - Disruption due to routine operation and maintenance;
    - Long term life cycle costs on park replacement due to structure renovations;
    - Additional capital costs due to structural constraints; and
    - The requirements for the developer to build the park to ensure warranties are not voided with the introduction of future 3rd party contractors.
- Provision of parkland credits for dual-use parks/underground storm water management facilities is being considered through the Parkland Dedication By-law update currently underway for enactment by September 18, 2022.

The above noted interim approach can be effective in ensuring stormwater management is achieved and for securing appropriate cost differential contributions, but it ignores important social, economic, environmental factors and overall integration within future communities. For example, the cost of major repairs and replacement of non-conventional stormwater infrastructure is not well known due to the relative infancy of this non-conventional stormwater infrastructure which may pose a potential financial risk for municipalities.

There is a need of updating City Official Plan Policies to account for non-conventional stormwater infrastructure and to fully assess the community benefits and drawbacks of

the proposed infrastructure for future residents and the City. As such, the development of a formal City policy and procedure for non-conventional stormwater infrastructure is recommended which provides assessment for social, economic, technical and environmental components and ensures all development planning matters are considered in the approval process.

Industry review on Dual-Use stormwater management facilities (Dual-use SWMFs)

The City received an unsolicited submission on Dual-use SWMFs policy paper dated December 2021, prepared by Malone Given Parsons (MGP) on January 17, 2022 (the "policy paper") included as Attachment No.1. This policy paper focused on the implementation of dual-use SWMFs by providing underground stormwater management storage under the City's future parks to achieve land use efficiency to facilitate more development areas. The MGP policy paper cited recent examples of dual-use SWMFs in Vaughan and other neighbouring municipalities, such as City of Toronto, Town of Caledon, City of Markham, etc.

To assist in the review of the policy paper, the City retained the engineering consulting services of WSP Canada (WSP) to undertake a peer review of the MGP policy paper and to produce a peer review memorandum report. In addition, the feedback, comments and questions received from City departments were addressed by WSP and incorporated in WSP Engineering Consultant peer review memorandum report, dated May 24, 2022 included as Attachment No.2.

The WSP peer review report, in general, agreed with the findings of the MGP report in that Dual-use SWMFs can be technically and financially feasible as land values continue to increase in the GTA and recommended they can be considered as a valid stormwater management approach for land development applications. In consideration of Dual-use SWMFs, WSP recommended certain technical design requirements (e.g., closed bottom UGST and no permanent pool) that should be considered to ensure proper functioning and effectiveness of the stormwater management facility. As such, the City's interim approach when considering a proposed non-conventional stormwater infrastructure design will include ensuring conformance to the recommended WSP technical design requirements.

WSP generally foresees advantages in adopting Dual-use SWMFs over conventional SWMFs. However, additional research will be required to address the uncertainties in adapting to Dual-use SWMFs, including major capital works repair costs during the life span of the infrastructure. The capital cost to install a Dual-use SWMFs are significantly higher when compared with conventional SWMFs. Although WSP has estimated that the lifecycle cost between a conventional SWMF and an UGST appear to be more or less equivalent, they do not take into consideration the eventual replacement cost of the UGST which would result in a higher overall lifecycle cost to the City when compared to conventional SWMFs. WSP has noted that given the relative infancy and limited number of examples of UGSTs implemented in municipalities at the moment, the overall lifecycle comparative costs between SWMFs and UGSTs are still yet to be accurately determined

and can be considered highly variable depending on a number of factors including but not limited to the location, the size of the drainage area, major repairs, replacement costs, regulatory impacts, etc. WSP recommends a full detailed analysis of life cycle costs between traditional SWMFs and UGSTs be included in future policy development.

Development of a formal policy and procedure for non-conventional stormwater infrastructure

A formal City policy and procedure to assess future proposals for a non-conventional stormwater infrastructure is necessary to mitigate financial and operational risk to the City. The policy and procedure should consider social, environmental, economic, and technical design factors in addition to cost differential contributions to ensure all development planning matters are considered in the approval process.

A stakeholder consultation plan will be critical to complete this undertaking in order to capture input from all parties that would be impacted by non-conventional stormwater infrastructure. It should be comprised of internal City departments such as Development Engineering, Environmental Services, Development Planning, Parks Infrastructure Planning and Development, Parks, Forestry, and Horticulture Operations, Infrastructure Planning and Corporate Asset Management, etc. and external stakeholders, such as the Toronto & Region Conservation Authority (TRCA), The Building Industry and Land Development Association (BILD), Ministry of the Environment, Conservation and Parks (MECP), Engineering Consultants, etc.

Given that non-conventional stormwater infrastructure is still relatively new from a public sector implementation perspective; the need for technical expertise in developing design criteria standards for non-conventional stormwater infrastructure; the complexities of coordinating a high number of varying stakeholders; and the need to evaluate a number of socio-economic factors, it is recommended that the City retain an external consulting engineering firm with the appropriate expertise in stormwater engineering, municipal development, stakeholder engagement, and policy development. Internal City departments will consult with the external consulting firm to develop the policy which is expected to take approximately 18 months to complete.

Financial Impact

The proposed development of a policy and procedure for non-conventional stormwater management infrastructure was not foreseen in the last DC update and therefore, no budget was allocated for it. It is anticipated that the financial impact for the development of a formal City policy and procedure for reviewing and accepting non-conventional stormwater infrastructure would be estimated at approximately $250,000. The funding for this work is expected to be provided through the City-Wide Engineering DC reserve for the 2023 budget year.

Broader Regional Impacts/Considerations

N/A

Conclusion

The land use optimization and the evolving changes in stormwater best management practices has resulted in staff recommending an interim approach for the design and cost recovery of non-conventional stormwater management infrastructure.

Staff further recommend that a formal City policy and procedure be developed for non-conventional stormwater infrastructure and that the City retain a consulting engineering firm to assist in completing the policy and procedure, with an anticipated timeline of completion of 18 months. The funding for this work is suggested to come from the City-Wide Engineering DC reserve for the 2023 budget year.

For more information, please contact Frank Suppa, Director, Development Engineering, Ext.8255.

Attachments

1. Dual-use SWMFs policy paper dated December 2021, prepared by Malone Given Parsons (MGP) on January 17, 2022.
2. WSP Engineering Consultant peer review memorandum report, dated May 24, 2022.

Prepared by

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Approved by

Vince Musacchio, Deputy City Manager
Infrastructure Development

Reviewed by

Nick Spensieri, City Manager

Attachment 1

DUAL-USE STORMWATER FACILITIES POLICY PAPER

Policy Paper

Prepared For:
The City of Vaughan

December 2021

Policy Paper

Dual-Use Stormwater Facilities Policy Paper

Prepared for:
The City of Vaughan, ON

Prepared by:

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December 2021

MGP File: 21-3087

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Appendix B: Letter from Concrete Durability Associates Inc. to DECAST dated March 12, 2021, Service Life Predictions for Proposed Underground Precast Stormwater Storage Tanks

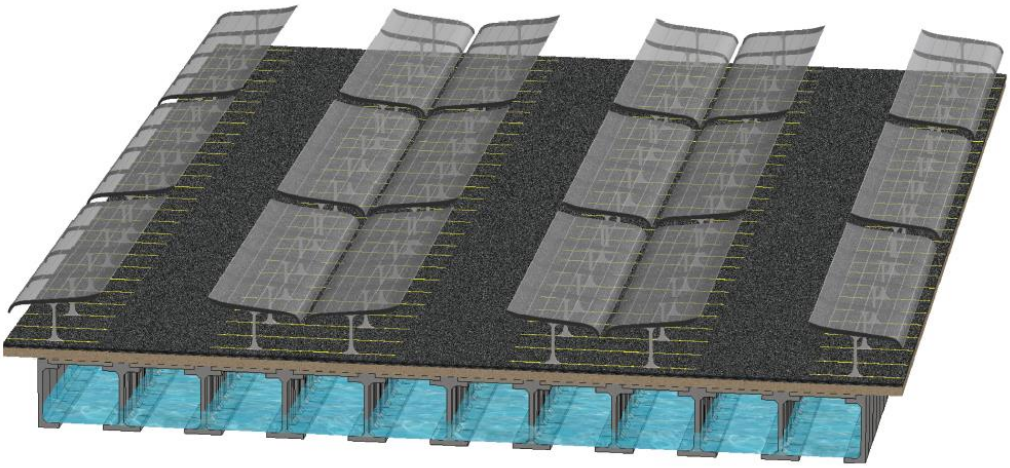
Appendix C: City of Markham Development Services Committee Minutes dated June 7, 2021, Item 9.1, Recommendation re City of Markham Tanking Storm Ponds and Creating Parkland on Top

1.0 Overview

Executive Summary

This policy paper is intended to assist municipal staff in the implementation of dual-use stormwater management facilities. The dual-use approach to stormwater management is generally more efficient in terms of the use of land, improves safety, provides more usable public spaces and reduces long-term cost, amongst other benefits. The efficient use of land and adequate provision of greenspace/park areas are promoted and encouraged through the applicable land use policies at provincial, regional and local levels. Underground stormwater management facilities can be designed to accommodate quality, quantity and erosion control. Similar to traditional stormwater management ponds, underground facilities require routine inspection, maintenance, and upkeep, however properly maintained facilities can achieve a life-cycle that can exceed 100 years. Numerous at-surface uses can be implemented over top of underground facilities, including parks, multi-use paths, sports fields, etc.

The intention to implement a dual-use stormwater management facility will be initiated by the developer early in the application process which will be supported by technical documents and design drawings. There are a variety of products available, which can be utilized on a site-by-site basis to address unique site conditions and accommodate the proposed uses and capacities. Typically, dual-use facilities are considered to be a component of the City's municipal infrastructure, like traditional open ponds, and are typically owned and operated by the City. A number of successful underground facility projects have been implemented throughout the Greater Toronto Area, which provide guidance and serve as precedents for future implementation within the City of Vaughan.



Source: DECAST I-Storm Stormwater Management System, Inspection & Maintenance Manual

Stormwater management ("SWM") facilities are important components of urban development. They are necessary to control the rate of runoff from rainfall events rainwater flow and mitigate the conveyance of pollutants into downstream receiving watercourses and water bodies. Traditionally, stormwater management ponds have been used in the design of new communities to retain and treat stormwater runoff. These facilities typically require a significant quantum of land in proportion to the development area and are a static feature of the community that is required to be maintained by the City.

As municipalities continue to grow, there is an increasing pressure to build housing and employment areas to accommodate the rising population numbers. There is a need to efficiently use land to ensure that residential density and employment uses are optimized. In response, many municipalities have adopted a dual-use approach to stormwater management, which uses less land, provides usable public spaces above the SWM infrastructure, and has a reduced long-term cost, among other benefits. The dual-use approach involves an underground stormwater management facility ("UG/SWMF") with above-ground uses, including passive and active parkland. This approach is supported by the Toronto and Region Conservation Authority ("TRCA") as an effective means to address stormwater management requirements.

The purpose of this policy paper is to:

1. Describe the application of dual-use stormwater facilities for the City of Vaughan;
2. Explain the benefits of dual-use stormwater facilities;
3. Outline the policy rationale for dual-use stormwater facilities;
4. Provide a technical overview of dual-use stormwater facilities;
5. Describe life-cycle characteristics and operational costs associated with dual-use stormwater facilities;
6. Describe potential surface uses;
7. Delineate the roles and responsibilities of each relevant party in terms of ownership, operation and maintenance;
8. Identify available stormwater infrastructure products; and,
9. Provide examples of existing dual-use stormwater facilities.

2.0 Application of Dual-Use Stormwater Facilities in the City of Vaughan

Generally, there are three categories of growth areas within the City that would benefit from the implementation of dual-use stormwater facilities: Greenfield development areas, intensification areas, and the Vaughan Metropolitan Centre ("VMC"). The retrofitting of existing SWM ponds could also be considered to create additional public park space.

Based on the policies outlined in the sections below, there is a clear direction and an opportunity to produce a more efficient use of land resources within all three categories of growth areas.

Greenfield Development

Greenfield development, being defined as development that is proposed to be located outside of the urban area of the City, typically involves large-scale subdivisions. Greenfield communities require storage and treatment of stormwater as a standard industry practice and regulatory requirement. Stormwater management (quality and quantity control) has typically been provided by utilizing ponds that have no above-ground usability and therefore only serve as a passive visual resource for the community, or the maintenance access route for the pond may be integrated into the local trail system. The pond and associated buffers/service areas will typically consume between 6% to 8% of the greenfield development area. In addition, to service the proposed community, another 5% or more of greenfield area will be required for parkland.

To promote the efficient use of land in greenfield areas, the integration of an UG/SWMF with a neighbourhood park at-surface over top of the UG/SWMF is recommended. As outlined in Section 7.0 of this paper, the location of an UG/SWMF below an active playing field does not impact the function of either uses and will instead provide a community benefit for residents.

In the case of a Regional Storm control SWM facility and where topography allows, the dual-use could include location of park space/playing fields within a depressed open surface area while the quality and more frequent quantity storage could be provided in a separate underground facility below the park uses.

Intensification Development

Intensification, being development within the designated urban area of the City, typically involves smaller-sized land parcels. However, given the current growth projections and density requirements, intensification can also include intensified development within greenfield areas. In intensified urban settings, where developable land is limited, land use development continues to require a balance between optimizing residential units, non-residential gross floor area, parking spaces, public and private amenities and appropriately servicing the proposal. Often at this scale, stormwater is captured through internal site drainage and discharged to municipal storm sewers. Underground stormwater chambers are required for stormwater management. These are typically located in the underground parking structure. Where possible, Low Impact Development ("LID") methods are utilized, such as bioswales, pervious pavement, green roofs, or water re-use, to achieve water quality control and water balance objectives.

In this context, dual-use facilities provide the opportunity to create parks, which are a recreational and social benefit to residents, enhance the liveability of the community and contribute to healthy, active lifestyles. In comparison, a traditional stormwater management pond is limited in its contribution to recreational and functional benefits to the residents. As outlined in Section 7.0 of this paper, the location of a stormwater tank below a park does not impair the function of either use and will instead provide a functional benefit for the community.

Vaughan Metropolitan Centre Development

The Vaughan Metropolitan Centre ("VMC") is a major development area and that is planned to accommodate the greatest population growth within the City. The VMC Secondary Plan identifies a robust parks and open space system to serve the expected population. However, development in the VMC has exceeded initial expectations, and the Secondary Plan is currently being reviewed and updated. Based on the Phase 1 VMC Secondary Plan Update Background Study Report, it is our understanding that it is Staff's intent to ensure that the provision of parks and community facilities is calibrated with the intensity of development to ensure that the overall urban development is balanced and the needs of the future community are well-served.

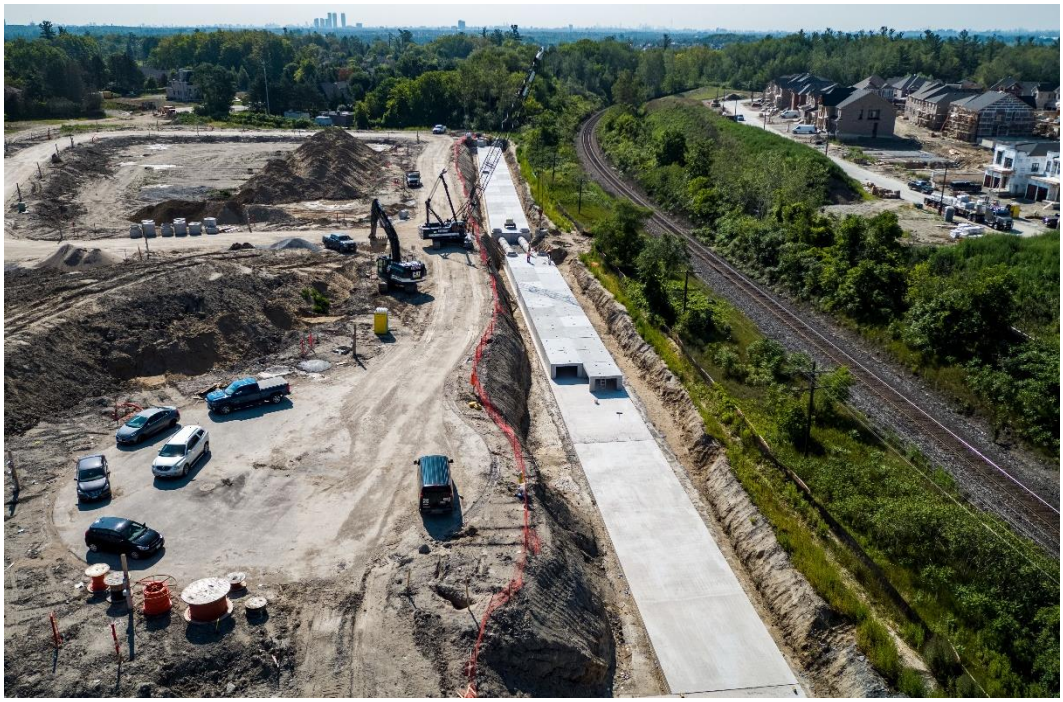
As part of the VMC Secondary Plan update, there has already been some consideration for dual-use stormwater facilities, as identified in the Black Creek Class EA and the DC Background Study. To create a complete community, development within the VMC must also balance issues that are similar to many urban intensification scenarios, however, the VMC master plan includes an extensive parks and open space system as well. In this context, lands within the VMC would be more efficiently utilized through the development of UG/SWMF with parks or parking lots situated at-surface, above the UG/SWMF. As outlined in Section 7.0 of this paper, the location of a stormwater tank below a park or a parking area will not compromise the function of either use and will instead provide a benefit to residents and businesses. To encourage more dual-use facilities and to

facilitate the implementation of dual-use UG/SMWF facilities in the VMC and throughout the City, the City should consider adopting a standard guideline or policy document for use by staff, the development industry and the general public.

3.0 Benefits of Dual-Use Stormwater Facilities

Summary of Benefits:

- *Maximizes the utility of land resources;*
- *Enhances safety in comparison to traditional open stormwater management ponds:*
    - *No public access*
    - *Mitigates the risk of drowning*
- *Reduces visual and nuisance impacts on community*
    - *Reduces open water surfaces that attract mosquitos and other wildlife*
    - *Does not require maintenance of debris and open water*
- *Provides cool water discharge, protecting downstream aquatic habitat*
- *Recharges groundwater and reduces stormwater runoff*
- *Enhances water quality*
- *Provides an extended life-cycle that can exceed 100 years;*
- *Affords easy, accessible, cost-effective maintenance and inspections*
- *Modular units are flexible and enable efficient installation*



Source: DECAST, Installation of UG/SWMF in the City of Vaughan

Land Utilization

In addition to the efficient use of the lands by making the land at-surface available for other land uses, the total area required for an UG/SWMF is approximately 25% less than that of a traditional open pond SWM facility for a similar storage volume due to the efficiency of the vertical side walls of the UG/SWMF in comparison to the graded side slopes of the conventional open pond. In addition to the facility itself, sufficient space is typically required around the UG/SWMF to allow for an open trench excavation around the perimeter of the facility without the need for sheet piling or other trench stabilization methods. Maintenance access to the outlet of a conventional open pond is typically required to be provided within the boundary of the designated SWM pond block, however in the case of the UG/SWMF, segments of the maintenance access route can typically be situated above the tank itself, since most underground SWM storage products that are available in the marketplace can accommodate highway loading. Consequently, additional land area is typically not required to accommodate a maintenance access beyond the limits of the UG/SWMF and the required setbacks for excavation and/or separation from the property boundary. For municipalities that require sediment drying areas, this function can be provided above the tank itself, thereby not consuming additional land area to accommodate this temporary operation. The ability to use land for additional parkland or community gathering place that would otherwise have been needed to provide a traditional SWM pond allows the City to involve the community more meaningfully with respect to planning and implementation of the above-ground amenities, prompting a stronger sense of ownership and engagement from the residents within the community.

Safety

The primary safety consideration with open wet SWM ponds is the potential for drowning related to the open water surface or through the risk presented by thin ice. This could also apply to a dry SWM pond during a storage event. Safety considerations implemented in accordance with municipal and MECP design criteria include the use of flatter slopes, safety shelves at the normal water level, safety equipment and signage, the installation of plant material to discourage pedestrian access and, in some cases, fencing of the entire facility to restrict public access altogether. Some municipalities require flatter slopes (i.e. > 5:1) if fencing is not provided, which results in a larger area of land being consumed to accommodate the SWM pond blocks and a less efficient land use. Many urban municipalities have encouraged the integration of pedestrian trails with SWM ponds, thereby encouraging public access near the water surface. This approach has been adopted in the City.

Despite the additional safety considerations implemented by the City, residents continue to require frequent reminders about access restrictions around open SWM ponds (such as the prohibition of skating or sledding on frozen ponds) and the City continues to carry some liability for residents' safety. This issue is remedied in UG/SWMF as access is strictly controlled and only accessible to maintenance personnel, possibly reducing insurance

costs that the City is required to carry as applicable to SWM facilities. Any above-ground uses above the UG/SWMF would be designed to be usable by the public year-round.

A secondary safety consideration for open wet SWM ponds, from a public perception perspective, is the potential for the development of mosquito larvae. Open water surfaces such as SWM ponds are less prone to mosquito development than smaller confined and still-water sources such as catch basins, blocked gutters or other trapped still water sources, however there is still a continued public perception of concern in this regard.

UG/SWMF are inaccessible to the public. All access to the facility would be for maintenance crews only, either through a locked grate or typical cast iron maintenance hole access lid or grate, negating public safety concerns.

Safety protocols must be followed when inspecting or maintaining an UG/SWMF in accordance with confined space entry guidelines. Municipal staff, consultants and contractors will need to be trained accordingly and will need to be provided with appropriate equipment and informed of the necessary protocols to address the associated safety requirements.

Aesthetics

Well-maintained dry or wet SWM ponds can be an attractive and desirable component of a municipality's public open space system. As with any stormwater management system, ponds require regular maintenance and upkeep to maintain both aesthetic qualities and provide the required level of SWM control. While most municipalities have an effective maintenance and operations program related to SWM ponds, there have been many examples of municipally owned and operated open SWM ponds that have not been effectively managed and, as a result, have become overgrown with weeds which can impact adjacent residents, have become filled with sediment, which detracts from the visual appeal of the open water surface and the functional performance of the facility, and/or have become filled with floating or blown debris. These issues also may become more apparent in open ponds as they approach the end of their maintenance cycle, leading to homeowner complaints related to overgrown vegetation, accumulated debris and odour and aesthetic issues.

Stormwater management ponds also have the potential to become an attraction for water birds such as Canadian Geese. This creates concerns related to water quality and also may present potential aviation safety concerns where ponds are located within the regulated flight paths of existing and planned airports and aerodromes.

UG/SWMF by their nature are generally not visible to the public and therefore the storage component itself has no visually aesthetic impact. Each underground facility will require a series of access points for maintenance and operations. These access locations can be planned together with the surface land use to minimize the associated visual impact. Access locations which do not require frequent use can also be buried beneath a shallow soil and vegetation cover. Incorporation of trees, lighting, sport infrastructure, etc. can be

accommodated together with UG/SWMF at the design stage by either placing them directly on top of the facility or designing the modular facility to work around the structures as described in detail in Section 7.0 of this paper. Parkland amenities with few safety risks (such as drowning) offer a relaxing and enjoyable recreational space for residents, which leads to improved mental health within the community and can attract visitors from other communities to the area.

Thermal Impacts

Due to direct exposure to sunlight, stormwater management ponds have the potential to increase water temperatures in downstream watercourses, which is a significant concern in coldwater habitat subwatersheds. The Province has provided specific design criteria associated with the protection of endangered species to address this concern, including minimum 3 m deep permanent pool areas and bottom draw outlets, along with cooling trenches and vegetation cover. Alternate measures such as floating balls to shade the water and time-release outlets have been used on a trial basis.

UG/SWMF are not subject to direct exposure to sunlight and therefore thermal issues associated with SWM ponds are not a concern. UG/SWMF promote the cooling of stormwater runoff from warm roof and asphalt surfaces, thereby enhancing downstream fish habitat, as confirmed by the Toronto and Region Conservation Authority (“TRCA”) (see Appendix A). The cool water discharge can also serve to recharge groundwater (where water table and depth to bedrock conditions are conducive) and enhance the overall water quality.

Maintenance and Installation

UG/SWMF offer easy, accessible, and cost-effective options for maintenance and installation. Modular precast units, which provide a flexible design to allow for various system configurations, enable a quick and efficient installation process. Site-specific elements, such as weir walls, bumpouts, infiltration locations, structures at inlets and outlets can also be accommodated during installation.

Large accessible openings in the top can be constructed to allow for easy maintenance and inspection when required. In the case of the I-Storm product, access openings can be constructed to be large enough to allow a skid steer machine to be lowered inside the UG/SWMF to efficiently clean the entire system. Smaller celled underground storage systems would have sufficient access ports provided to facilitate a flushing/hydro-vac maintenance program.

When properly maintained and inspected, UG/SWMF can have a life-cycle that exceeds 100 years, contingent on the type of product utilized. The potential cost efficiency of these facilities, compared with that of open stormwater management ponds, is discussed in Section 6.0 of this document.

4.0 Policy Framework and Rationale

UG/SWMF achieve the objectives of provincial, regional, and municipal planning policies.

Provincial Policy Framework

Provincial Policy Statement, 2020

The Provincial Policy Statement, 2020 ("PPS"), encourages the efficient use of land and resources to support Ontario's long-term prosperity, environmental health and social well-being. Within the province, efficient land use and development patterns support sustainability by promoting strong, liveable, healthy, and resilient communities, protecting the environment and public health and safety, and facilitating economic growth (Section 1.0). The PPS provides that land use must be carefully managed to accommodate appropriate development to meet the full range of current and future needs, while achieving cost-effective and efficient development patterns, avoiding significant or sensitive resources and areas which may pose a risk to public health and safety, and minimizing land consumption and servicing costs.

Within Settlement Areas, it is in the interest of all communities to use land and resources wisely, to promote efficient development patterns, protect resources, promote green spaces, ensure effective use of infrastructure and public service facilities, and to minimize unnecessary public expenditures (Section 1.1.3). Healthy, active communities with parkland, public spaces, open space areas, trails and linkages, and, where practical, water-based resources are generally encouraged under the PPS (Sections 1.5.1 a and 1.5.1 b). In accordance with Section 2.2.1 i), it is stated that planning authorities shall protect, improve, or restore the quality and quantity of water in part by ensuring stormwater management practices minimize stormwater volumes and contaminant loads, and maintain or increase the extent of vegetative and pervious surfaces.

Under Section 1.6.6.7, the PPS articulates that planning for stormwater management shall:

a. be integrated with planning for sewage and water services and ensure that systems are optimized, feasible and financially viable over the long term;
b. minimize, or, where possible, prevent increases in contaminant loads;
c. minimize erosion and changes in water balance, and prepare for the impacts of a changing climate through the effective management of stormwater, including the use of green infrastructure;

d. mitigate risks to human health, safety, property and the environment;
e. maximize the extent and function of vegetative and pervious surfaces; and
f. promote stormwater management best practices, including stormwater attenuation and re-use, water conservation and efficiency, and low impact development.

Generally, the policies of the PPS support and encourage the efficient use of land and resources through the integration of land use planning, growth management, and infrastructure development. The PPS promotes best practices for stormwater management and articulates the importance of accessible built and natural settings for recreation. The proposed innovative approach to stormwater management which is the subject of this policy paper, related to integrating subsurface stormwater retention and treatment facilities with useable and accessible public space, aligns with the policies of the PPS with regard to stormwater management and healthy, complete communities. The proposed implementation of dual-use stormwater management facilities promotes the objectives set out by the PPS and is consistent with the policies for managing land use to achieve efficient and resilient development.

A Place to Grow: Growth Plan for the Greater Golden Horseshoe, 2019

The Growth Plan for the Greater Golden Horseshoe (the "Growth Plan"), as amended, is the Ontario government's approach to growth and development within the Greater Golden Horseshoe region. The Growth Plan supports economic prosperity, protects the environment, and helps communities achieve a high quality of life. In order to accommodate the forecasted growth, the Growth Plan sets out to encourage more compact built form to reduce the rate at which land is consumed. In accordance with the Growth Plan's vision, the Greater Golden Horseshoe will be supported by modern, well-maintained, sustainable, and resilient infrastructure built in alignment with a broad plan for managing growth. This vision is affirmed through the Growth Plan's guiding principles which set out to support the achievement of complete communities that are designed to support healthy and active living and meet people's needs for daily living throughout an entire lifetime; that prioritize intensification and higher densities in strategic growth areas to make efficient use of land and infrastructure and support transit viability; and, that improve the integration of land use planning with planning and investment in infrastructure and public service facilities, among other principles.

The application of Growth Plan policies will support the achievement of complete communities that expand convenient access to an appropriate supply of safe, publicly-accessible open spaces, parks, trails, and other recreational facilities (Section 2.2.1.4 d. iii). The Growth Plan requires municipalities to develop a strategy to achieve minimum intensification targets within delineated built-up areas which will, among several factors, support the investment in infrastructure and public service facilities (2.2.2.3 e)).

The Growth Plan articulates that well planned infrastructure is essential to the viability of Ontario's communities and critical to economic competitiveness, quality of life, and the delivery of public services (Section 3.1). In this respect, the Plan provides a framework to

guide and prioritize infrastructure planning and investments in the GGH to support and accommodate forecasted growth to the horizon of this Plan and beyond. According to the policies of the Growth Plan, infrastructure planning, land use planning and infrastructure investment will be co-ordinated to implement the policies of the Growth Plan (Section 3.2.1.1). Under the Plan, municipalities are required to develop stormwater master plans or equivalent for serviced settlement areas (Section 3.2.7) that, among other considerations, identify the full life-cycle costs of the stormwater infrastructure, including maintenance costs (Section 3.2.7 f). Proposals for large-scale development will incorporate an integrated treatment approach to minimize stormwater flows and reliance on stormwater ponds, which includes appropriate LID and green infrastructure (Section 3.2.7.2 b).

Generally, the policies and provisions of the Growth Plan promote modern, well-maintained, sustainable and resilient infrastructure to support growth. Compact and efficient development are central factors in reducing the rate at which land is consumed. As such, the implementation of dual-use stormwater management facilities aligns with the Growth Plan's objective to render a more efficient use of land. The park /open space aspect of the dual-use facilities will help to further support the goals and objectives set forth in the Growth Plan. Dual-use facilities are also able to achieve the objectives and goals of comprehensive stormwater master plans and add to a municipality's toolkit for managing stormwater that corresponds with the Growth Plan's requirements for large-scale development.

Conservation Authority Policy Framework

The TRCA has expressed support for alternative approaches to traditional SWM ponds, provided they can meet all applicable design criteria, including protection from flooding, maintaining water quality, mitigating erosion and managing water balance. As noted by the TRCA (provided in correspondence to the City of Markham and DECAST, attached as Appendix A), underground tanks/chambers have proven to be an effective alternative to open stormwater ponds within TRCA's jurisdiction, particularly when employed in high-density urban areas. When located below parks, dual-use SWM ponds have the potential to significantly reduce the surface footprint of the developed area, allowing for greater conservation of natural lands and more efficient and compact land use planning. The TRCA has acknowledged that, based on monitoring of recent projects (namely Unionville in Markham by the Sustainable Technologies Evaluation Program (STEP)), UG/SWMF are capable of providing "enhanced" water quality with much cooler discharge temperatures.

The application of stormwater tanks is also described within both the Stormwater Management Planning and Design Manual (MOE 2003) and TRCA's Low Impact Development Stormwater Management Planning and Design Guide. Both documents emphasize the importance of the treatment train approach, which promotes the treatment of runoff at the source, enroute, and at end-of-pipe as an integrated approach to every SWM strategy.

UG/SWMF that are designed and sited appropriately can deliver both land conservation

and water quality benefits, effectively mitigating flooding and satisfying the TRCA's criteria related to water quality, quantity and water balance, as outlined in TRCA's Stormwater Criteria Document. The possibility of open bottom chambers, combined with pre-treatment, can be effective at providing infiltration needed to maintain water balance. The TRCA has stated that Stormwater Management Innovation, combined with sound engineering and environmental principles, will continue to be encouraged and accepted provided that the necessary technical analyses, documentation, and approval from the municipality or SWM infrastructure owner are achieved. The UG/SWMF proposal must also satisfy all other applicable requirements and criteria, including provisions for long-term operations, monitoring and maintenance.

York Region Policy Framework

York Region Official Plan, 2010

The York Region Official Plan, 2010 ("YROP") represents York Region's ongoing collaboration with its partners and stakeholders to rethink the way communities are designed, serviced and supported. Within the Provincial Context, York Region and its municipalities are directed to formulate new plans to accommodate additional population and employment growth to 2031 in more compact, complete communities and protect and enhance the environment and strengthen the economy (Section 1.3). A key aspect of this Plan includes City building with focus on Regional Centres and Corridors and including innovation in urban design and green building (Section 1.2.1). Other key elements include the establishment of new community areas, designed to a higher standard that includes requirements for sustainable buildings, water and energy management, public spaces, mixed-use, compact development, and urban design (Section 1.2.3) and the establishment of progressively higher standards in energy and water efficiency, renewable energy systems and waste reduction (Section 1.2.8). Generally, the YROP applies a "Sustainability lens" through which York Region formulates, enhances and implements policy.

Section 2.3 of the YROP establishes an objective to maintain and enhance water system health to ensure water quality and quantity, and to maintain the natural hydrologic function of water systems. The policies of the YROP require the preparation of comprehensive master environmental servicing plans as part of secondary plans to protect, improve or restore water quality and quantity including hydrologic function of water systems. It is noted that such plans will incorporate best management practices with a goal that water balance and hydrologic functions will be maintained as much as possible. Notably, these plans will emphasize water conservation and may include water reuse and innovative technologies (Section 2.3.17).

The Stormwater Management section of the YROP details that stormwater is runoff that occurs in urbanized areas which, if unmitigated, results in increased downstream watercourse erosion, pollution and, increased water temperatures. According to the YROP, the use of sustainable stormwater planning and practices will help ensure the continued health of the streams, rivers, lakes, fisheries and terrestrial habitats in our

watersheds. It is the objective of the Plan to ensure the careful management of stormwater through the use of innovative techniques. Policy 2.3.40 specifically articulates that it is the policy of council to work in partnership with local municipalities, the Province, conservation authorities and other agencies in the implementation of stormwater management initiatives.

The Region is dedicated to implementing the policies of this Plan in a fiscally efficient and effective manner, including the co-ordination and streamlining of service delivery, optimizing service levels, eliminating duplication and seeking innovative and efficient approaches to implementing the objectives and policies of the YROP. In this respect, it is the policy of Council to ensure the most efficient and effective use of infrastructure, and to design and implement urban services to meet the capacity requirements of the Urban Area (Section 4.5.17). Likewise, it is the policy of Council that development have an integrated and innovative approach to water management, be water efficient, and minimize stormwater volumes and contaminant loads and maximize infiltration through an integrated treatment approach, which may include a variety of low-impact development techniques, including the preservation and enhancement of native vegetation cover (Section 5.2.11).

Under Section 5.6 of the YROP, New Community Areas will prioritize people, sustainability and liveability. A Regional Greenlands System that is connected to a network of parks and open spaces is a key component of new community areas. Similarly, the planning and design in intensification areas will provide well-designed public open spaces that create attractive and vibrant places and support walking, cycling and transit for everyday activities.

The in-effect YROP generally sets out to address issues associated with climate change and public health. In terms of stormwater management, the YROP supports the use of innovative techniques and initiatives to ensure the careful management of stormwater. In this regard, the YROP supports the application of new and innovative approaches that promote water efficiency, minimize stormwater volumes and contaminant loads, and maximize infiltration. Providing tandem uses aligns with the Region's objectives to facilitate the most efficient and effective use of infrastructure while helping the Region achieve increased opportunities for establishing connected park space.

York Region Draft Official Plan, December 2021

In November 2021, York Region presented the Draft York Region Official Plan (the "Draft YROP") to York Region Committee of the Whole. The Draft YROP sets out to update Regional land use policies as part of York Region's Municipal Comprehensive Review and Growth Plan conformity exercise. Similar to the in-effect YROP, the Draft YROP is intended to provide direction pertaining to land use and guide the long-term vision for York Region's physical form and community structure.

An important objective for the Region's Community Areas is to ensure they are walkable, pedestrian-oriented, and amenity rich locations which provide residents with a range of

services and open spaces within a 15-minute walk or cycle of their home. The policies of this section under the Draft YROP enhance existing communities and create new communities which integrate greenspaces, pedestrian, transit and active transportation networks in a manner that offers a variety of housing, transportation, human services and employment options (Section 4.1). Within New Community Areas, phasing will ensure that communities are developed as complete communities for residents to have access to a wide range of services and amenities within the same community such as schools, parks, libraries, transit, and jobs in a timely manner (Section 4.2.2).

The draft polices provide guidance for Stormwater Management under Section 6.5. The draft policies continue the intent of the in-force YROP to require that development and site alteration proposals meet applicable stormwater management policies, guidelines, and best practices, while promoting integrated and innovative approaches to stormwater management (Section 6.5.9).

Although the policies are presently in draft form, the Draft YROP provides an indication of proposed land use policies for the future of York Region. The draft policies generally emphasize the importance of using land efficiently and promote optimizing infrastructure with a compact, mixed-use, pedestrian-friendly built form. In this regard, the implementation of dual-use facilities aligns with the proposed policy framework and would assist the Region in achieving the objectives provided by the Draft YROP.

City of Vaughan Policy Framework

City of Vaughan Official Plan, 2010 (2020 Office Consolidation)

The Vaughan Official Plan ("VOP") as adopted by City Council on September 7, 2010, generally outlines land use policies that have been set out to shape the future of the City and guide its continued transformation into a vibrant, beautiful, and sustainable City. The VOP was partially approved by the then Ontario Municipal Board and the majority of policies are presently in force and effect. In alignment with the current YROP, the VOP plans for growth to the 2031 planning horizon.

Section 2.1 of the VOP outlines a number of Key Planning Objectives that are deemed to be integral. Notably, section 2.1.3 of the VOP outlines concerns associated with the historical pattern of growth and current urban structure which has resulted in a number of significant issues including sprawling development that Vaughan, and other suburban municipalities, have begun addressing by encouraging the creation of more compact and complete communities that make better use of land and resources.

Under the VOP, it is the policy of Council to recognize stormwater management facilities as a functioning part of Vaughan's natural water system and ecosystem (Section 3.6.6). New development will employ stormwater management practices that are sensitive to the natural environment and natural heritage features (Section 3.6.6.2). The VOP policies provide that new stormwater facilities shall be integrated into the design of proposed developments to positively contribute to the overall character of the development

(Section 3.6.6.5). As noted in Section 3.6.6.6 of the Vaughan Official Plan, new SWM facilities are to be designed as local amenities while also providing a utilitarian function by integrating SWM facilities into surrounding developments as publicly accessible open space. This is achieved in part by locating stormwater facilities adjacent to open spaces, parks and/or natural heritage areas contributing to a connected system and to encourage public access to these facilities, where appropriate; integrating stormwater facilities into surrounding developments as publicly accessible open space; and, designing stormwater facilities as naturalized or formal landscapes that are complementary to adjacent features, including adjacent landscapes or natural heritage features. It is the policy of Council to accommodate a variety of open space types, including stormwater management facilities, which provide opportunities for trails and resting areas and can improve linkages to other parks and open spaces (Policy 7.3.1.3 d).According to the Parks and Open Space Design policies of the VOP, Vaughan's parks and open spaces assume many forms and are located throughout the City. It is noted that parks and open spaces may include a range of community amenities, including sports facilities, playgrounds, pavilions and shelters, outdoor amphitheatres, and picnic areas. As Vaughan grows and intensifies, more opportunities for a diversity of new parks and open spaces will be identified.

The VOP states that parks shall be located and oriented to be in a central location or in the community to be served in order to act as a focal point for the community; uninterrupted by major physical barriers, such as rail lines, arterial, and collector streets, and other physical barriers that restrict access; and connected to other parks, open spaces and natural features to create an interconnected network of parks and open spaces (Section 7.3.2.3). The design of parks and open spaces are intended to cater to a broad range of users by providing space and facilities that support a range of activities (Policy 7.3.2.4 b) as well as incorporate best practice principles of sustainable design, including natural heritage enhancement, naturalized stormwater management features, use of native plant species, incorporation of environmental education features and use of low maintenance and energy efficient facilities and landscapes (Policy 7.3.2.4 f).

The policies of the VOP are generally supportive of the implementation of dual-use stormwater management ponds. These proposed facilities are designed as local amenities while also providing a utilitarian function, in alignment with the policies detailed above. The VOP currently contemplates the coupling of parkland and infrastructure and integrating the development of stormwater management facilities in a manner that positively contributes to the overall character of a development. Dual-use stormwater management facilities provide an opportunity to encourage the efficient use of land and deliver novel options for new and diverse parks and open spaces. As such, the proposed dual-use stormwater management ponds align with and promote the policies and provisions of the Vaughan Official Plan.

City-Wide Stormwater Management Master Plan Municipal Class EA, 2014

The City's SWM Master Plan has identified underground storage as an alternative for meeting the City's SWM objectives and has specifically recommended the use of underground storage in the Yonge Steeles Secondary Plan area, the Woodbridge Core Secondary Plan Area, the West Vaughan Employment Area, the Huntington Road Community, Vaughan Mills Centre, Concord Centre, the Vaughan Health Campus of Care, the Dufferin St./Centre St. area and the Promenade Mall. The report also notes that SWM quantity control for new communities such as Blocks 27 and 41 should be provided by SWM facilities, along with combination of parking lot/surface, rooftop and underground storage where feasible.

As demonstrated in the Class EA, the City has already established the groundwork for the use of underground storage as an acceptable method of SWM control.

5.0 Engineering Overview of Dual Use Stormwater Facilities

Groundwater Interaction

Both traditional SWM ponds and UG/SWMF must consider the implications of seasonally high groundwater elevations and hydraulic conductivity of the native or imported soils.

SWM ponds typically have a permanent pool which, although not required to stay full for water quality purposes, is preferred from an aesthetic perspective. If the existing soils are pervious and the groundwater elevation is low, a pond liner is typically required to allow the pond to maintain a permanent water level. Alternatively, if the groundwater elevation is higher than the normal water level in the pond, a liner and subdrain system could be required to ensure that the existing groundwater elevation does not cause bank instability both during normal operation and for dewatering conditions when the pond is maintained.

UG/SWMF do not present an aesthetic concern related to maintaining a normal water level. In the case of a wet facility with a permanent pool, if the groundwater level is low and soils are pervious, there is no requirement for an impervious liner since aesthetics of a “full” permanent pool are not required. Although seepage into the facility is not a stormwater management or operational concern, if there is a high groundwater situation, an impervious liner or sealant materials between the internal joints, along with a sub-drain, can be provided for the facility to facilitate future maintenance operations.

In an excessively high groundwater condition, floatation potential for the UG/SWMF must be addressed by the geotechnical and structural engineers. This can typically be accommodated by depth of cover, subdrains or the weight of the facility itself.

SWM Facility Design Considerations

Both SWM ponds and UG/SWMF can provide stormwater quality, quantity and erosion control. Traditional SWM ponds are typically designed as wet pond facilities, along with extended detention and quantity storage to provide the appropriate quality control, erosion control and quantity control. Water balance opportunities are typically not provided in SWM ponds since infiltration opportunities are generally not readily available, however there are examples of infiltration galleries within SWM ponds in areas of highly pervious soils and low groundwater.

UG/SWMF can also be designed to accommodate quality, quantity and erosion control. With appropriate based on-site conditions and upstream pre-treatment constraints, a permanent pool can be created within an UG/SWMF by creating an outlet at an elevation above the base of the facility. Alternatively, UG/SWMF are often paired with upstream quality control measures, including oil-grit separators, filters and various LID measures to minimize the cleanout frequency of the underground structure. The use of LIDs is strongly encouraged by the MECP and Conservation Authorities and have therefore become common practice for meeting water balance, erosion and quality control requirements. In many cases, this leaves only an end of pipe quantity control requirement for flood control.

Outlet Design Considerations

Both SWM ponds and UG/SWMF store stormwater runoff, creating a hydraulic backwater condition which must be considered in the upstream infrastructure design and associated foundation drain interaction.

Traditional SWM ponds typically have a piped and overland flow inlet design. The 100-year hydraulic grade line in the pond must be considered in the upstream storm sewer design. The pond outlet structure typically provides a restricted outlet to provide quality and quantity control, and also includes an emergency overland flow structure to by-pass the unrestricted 100 year or regulatory flows in the event of an outlet structure blockage to avoid hydraulic implications to the upstream storm sewer system.

UG/SWMF provide a similar hydraulic condition to SWM ponds during normal operating conditions to provide water quantity and possibly quality control. Major system inlets to the UG/SWMF are required at the downstream limit of the development drainage area. This is typically accommodated with overland flow routes and inlet grates directly above the facility or inlet control grates above a trunk storm sewer which directs flows to the storage facility. Grates are typically designed to account for 50% blockage. Outlet structures for UG/SWMF must also account for the uncontrolled stormwater discharge from the associated drainage area without impacting the upstream storm sewer hydraulic gradeline. This is typically achieved with an outlet conduit, grate or structure located immediately above the maximum storage elevation. The associated hydraulic gradeline elevations must be considered in the upstream storm sewer design.

Erosion and Sediment Control During Construction

Traditional SWM facilities are typically built together with a new development area's earthworks program and are utilized as a temporary erosion and sediment control facility during both the earthworks and servicing phase of construction.

UG/SWMF require a different approach than typical SWM ponds in that they are typically built at the end of the construction program, together with the site servicing, to avoid unnecessary sediment build-up in the tanks and pre-treatment systems. The tank location can be pre-graded to the depth of the proposed facility and utilized as a

temporary erosion and sediment control facility during the earthworks program. Regarding the timing of the ultimate construction of the facility, it can be completed either together with the site servicing or potentially in a phased development, or it could be delayed until future phases if the temporary excavation can be maintained to provide interim SWM control during the initial house construction phases, to minimize the construction-based sediment build-up in the tank. Regardless, the UG/SWMF will be fully cleaned prior to assumption by the municipality.

6.0 Maintenance, Installation, Life Cycle, and Costs

Inspection

Regulations require all SWM systems to be inspected on a regular basis and maintained as necessary to ensure performance and protect downstream receiving waters. Monitoring and maintenance responsibilities are an important component of an effective SWM system.

Traditional SWM ponds are recommended to be subject to routine inspection programs in accordance with good practice and the MECP Environmental Compliance Approval (ECA) conditions. Per the ECA, a logbook should be maintained to record the results of the inspections and any cleaning and maintenance activities. Every municipality takes a different approach to this with regard to the techniques used and the frequency of the inspections. SWM ponds are typically proposed to have bi-annual visual inspections which can be undertaken by a single municipal inspector walking around the facility to review vegetation, slope stability, obvious sediment accumulation, inlet/outlet blockage, outfall erosion, condition of structures, visual water quality etc. Sediment accumulation should also be monitored every 5 years, which requires a bathymetric survey using a boat and two-person crew.

UG/SWMF should be similarly inspected and monitoring reports prepared, typically annually, or in accordance with the prescribed inspection frequency of the ECA conditions. Personnel must be properly trained and equipped before entering any underground or confined space structure. Training includes familiarity with and adherence to any and all local, provincial and federal regulations governing confined space access and the operation, inspection, and maintenance of underground structures.

Similar to a SWM pond, during the first two years of operation, the UG/SWMF should be inspected periodically and after every significant rainfall (precipitation of ≥25 mm) to ensure proper functioning or as per the ECA conditions. TRCA recommends that a SWM system should be inspected a minimum of four times per year and maintained as required; inlet and outlet openings and structures should be inspected for blockages and damage.

The annual inspection of UG/SWMF should include the following activities:

- Visually inspect through the access chamber lids for evidence of sediment

deposits in the underground storage facility the inlet structure, the outlet structure and the outfall channel;
- Visually inspect to confirm no oil sheen is present on the water surface and no presence of visible contaminants or odours;
- Confirm control orifice, weir, overflow grate, and inlet/outlet pipes are unobstructed;
- Confirm outfall is unobstructed; and
- Confirm the outfall channel and confluence with the tributary is stable and unobstructed;

A bi-annual inspection of underground SWM facilities would include:

- Dip measurement of sediment accumulation from surface access chambers;
- Visual inspection of the tank's interior. This exercise can be completed by accessing the inside of the tank using confined space entry procedures for concrete chambers and via video inspection for smaller concrete structures or multi-cell plastic chambers. This exercise requires a two-person crew to meet the confined space entry guidelines.

Maintenance Activities/Cleanout

Traditional SWM ponds require a routine and on-going maintenance program throughout the year including vegetation cutting, weed control, trash removal, debris removal, etc. Longer term maintenance is required for quality control wet ponds to remove accumulated sediment, in accordance with MECP ECA requirements. The maintenance frequency is site specific and is driven by the amount of runoff and pollutant loading encountered by a given system. Local jurisdictions may also dictate inspection and maintenance frequencies. The frequency of the cleanout is a function of the pond design and tributary area loading but can be expected to be required every 10 to 20 years on average but could be longer. SWM pond cleanout is typically completed either in a dry condition by dewatering the pond and excavating the material, or in a wet condition by vacuuming the sediment out of the pond. "Dry" excavation typically still results in relatively wet excavated material which must be managed prior to being taken off-site. Vacuuming sediments is typically achieved with an enviro-tank to add flocculants and pumping into sediment bags. Both operations are relatively slow and costly.

Care must be taken with SWM pond cleaning to avoid damaging an impervious liner which could lead to additional costs if the liner is compromised.

SWM pond cleanout, especially in a valley setting, could possibly have a fish rescue program requirement prior to drawing down the water level. This typically requires the appropriate agency approvals and permits and could add 6 months to the overall process.

UG/SWMF typically have a pre-treatment methodology, such as an oil-grit separator or various low impact development techniques, which serve to reduce the sediment accumulation in the underground tank, and therefore reduce the required frequency and

volume of sediment removal. Subject to bi-annual cleaning of the pre-treatment devices (i.e. vacuuming an oil-grit separator), the frequency of cleanout of an UG/SWMF could be up to twice as long as a traditional SWM facility Total Suspended Solids (TSS) are expected to accumulate at a specified rate in accordance with site conditions and geohydrological assessments. While the rate of accumulation will be site-specific, typical TSS removal frequency is roughly every 50 years for a system outfitted with pre-treatment devices.

Sediment removal from underground SMW facilities can be undertaken by flushing and vacuuming the facility through the access chambers via access ports or grates. Confined space entry procedures must be followed for personnel entering the facility to operate the flushing hoses. In some instances, large concrete storage facilities could also be cleaned out using small excavation machinery. The I-Storm Stormwater Management Manual outlines the following considerations.

The design provides strategically placed access points to facilitate efficient and effective inspections and debris removal when required. Personnel must be properly trained and equipped before entering any underground or confined space structure. To complete an inspection, safety measures including traffic control must be deployed before the access covers are removed. The following procedures are to be completed as part of a facility inspection:

- Obtain a copy of As-Built drawings of the facility to identify the locations and design of components being inspected
- Determine if inlets and outlets are clear of debris, trash or blockages
- Visually inspect water surface to confirm there is no oil sheen or the presence of visible contaminants and odours
- Observe internal components (baffles, flow control orifices, steps, ladders, pre-treatment devices, etc.) to determine whether they are damaged, missing or obstructed
- Measure sediment depths within the I-STORM SWM system
- Check inlet and outlet pipe connections for cracks, leaks or movement
- Inspect interior condition of modules for concrete cracking or deterioration
- Remove any floating debris/trash with a net, if possible
- For retention facilities, confirm that permanent water level is correct
- Record the date of inspection, date of previous inspection, and track any changes to site conditions
- Refer to the inspection checklist available at the end of this manual

Corrective maintenance must be scheduled if any of the following conditions are identified during an inspection:

- Inlets or outlets are blocked or obstructed
- Internal components are broken, missing or obstructed
- Sediment depth of 150mm or greater is present on the floor of the system
- Significant amount of floating debris/trash is present and cannot be retrieved with

a net
- System is not draining properly and does not meet permit requirements • Any hazardous material is observed or reported
- Emergency Spill Conditions - excessive accumulation of hydrocarbons (oil, gasoline, diesel fuel, transmission oil or antifreeze) usually resulting from an accidental discharge. Excessive accumulation is described as any amount larger than a thin sheen visible on the water surface. The incident must be reported to the appropriate authorities and shall be mitigated by authorized and trained personnel.

Maintenance should be conducted during dry weather when no or minimal flow is entering the system. If personnel are required to enter the I-STORM SWM system to complete maintenance, confined space training and certification is mandatory. After safety measures are in place (i.e. traffic control and pedestrian signage) access covers may be removed and the following maintenance activities can occur:

- Use mini track loader (skid steer) to push accumulated sediment toward strategically placed maintenance hole locations for ease of removal (equipment will be lowered into the tank through the provided access hatch(es))
- Remove debris, trash or any blockages using a net (if possible) or vacuum truck. Flushing/jetting may be necessary to fully eliminate the sediment from the system
- All material removed from the system during maintenance must be disposed of in accordance with local regulations
- If inlet and outlet connections have cracking or leaks, or if internal components are damaged, missing or obstructed contact DECAST for an appropriate repair procedure
- Be sure to securely replace all access covers following inspection and/or maintenance

Because of the hard bottom and enclosed nature of the underground facilities, fish rescue programs or concerns of impervious liner damage are not relevant for this type of SWM facility.

Lifecycle and Costs

Conceptual life-cyle cost evaluations have been undertaken utilizing the operating and maintenance characteristics of a wet SWM pond and an UG/SWMF, along with land efficiency benefits associated with the underground facility. Details are provided below and demonstrate that an underground SWM facility can have a considerably more efficient overall net cost to the municipality when taking into account all relevant factors. Every site-specific application will have varying design and cost parameters however the consistent benefitting factor of the underground facility is the associated land efficiency opportunities.

DECAST retained University of Toronto Civil Engineering professor Dr. R.D. Hooton to

conduct a study on the service life of underground precast stormwater storage tanks based on predicted chloride exposure and found that (depending on modelling scenario) the product had a life cycle of 100+ or 150+ years (see Appendix B).

Lifecycle Cost Breakdown

The maintenance processes considered as part of an asset's lifecycle include: repair, rehabilitation, refurbishment, and disposal. The following will outline the expected maintenance activities and associated costs for both a SWM pond and an I-STORM concrete tank system to provide quality and quantity control for a generic 20 ha residential development area to provide a high-level comparison of the two SWM applications. As noted previously, every specific installation will have varying design parameters and costs depending on various factors including the products used, however the following comparison provides a general overview of the associated life-cycle cost components for a typical pond vs. a concrete tank UG/SWMF. There are underground tank system products available that use other materials that may involve less costs, lower loading capability for surface uses, and shorter lifespans. Section 10 of this paper provides examples of installed UG/SWMF throughout the Greater Toronto Area, including concrete, polyvinyl chloride (plastic), and hybrid chambers and products.

Inspection and Maintenance

Stormwater management ponds require routine inspection and sediment cleanout. A one-year frequency has been assumed for inspections. A 20-year interval has been assumed for sediment removal which is typical for a wet SWM facility based on the MECP cleanout frequency criteria.

With regard to the I-Storm SWM facility, a similar annual inspection program has been assumed. Since the tank will be a "dry" quantity control facility only with upstream quality control, sediment removal from the tank floor has been assumed to be required once every 50 years to remove built-up silt or other foreign materials. Based on the upstream storm sewer pre-treatment, the accumulation of sediment has been assumed at a rate of roughly 2 mm/year and will need to be cleared away using a hydro-vac truck or mini excavator/skid-steer at the specified frequency. Costs are based on equipment, labour, and sediment disposal fees.

Rehabilitation

SWM pond rehabilitation costs are included within the maintenance and refurbishment costs.

With regard to the underground concrete facility, occasional repairs have been assumed, similar to other municipal concrete facilities, to address sealing of any spalling or cracks that may become evident over time. The lifecycle cost analysis has been prepared assuming rehabilitation activities that may need to be performed at a frequency of once every 100 years for the internal tank and would consist of small in-situ patching of spalled

or cracked concrete. Costs are based on material and labour necessary to repair 20 locations, increasing at a rate of ~45% every 100 years.

Refurbishment/Disposal

Stormwater management ponds are assumed to have a perpetual maintenance program, with the long-term replacement of inlet and outlet structures every 50 years. The underground facility lifecycle cost assessment has been prepared with the assumption that the facility in its entirety will not be replaced at one time, but instead, a perpetual maintenance program will be implemented where its components will be replaced on an as-required basis.

Capital Cost Summary

The following tables demonstrate the lifecycle cost comparison between a SWM pond (average stormwater pond block size of 1.4 ha) and an underground facility for a typical 20 ha drainage area. As demonstrated in this analysis, the typical average annual lifecycle costs are comparable between a traditional SWM pond and an underground SWM facility with pre-treatment. The major difference however is in the municipal revenue benefits realized by the municipality with regard to both development charge credits and on-going tax revenue assuming that the dual park use above the UG/SWMF will result in additional development intensification potential for the site.

Table 1: Typical Lifecycle Cost of SWM Pond

Item	Maintenance Period (Yrs)	Quantity	Unit	Price ($/Unit)	Total Cost Per Year ($)
Inspection (Inlet/Outlet, etc.)	1	1	each	$1,500	$1,500
Trash Removal	1	1.4	ha	$2,000	$2,800
Weed Control	1	1.4	ha	$2,500	$3,500
Vegetation Maintenance	5	0.1	ha	$3,500	$70
SWM Pond Cleanout	20	1.4	ha	$180,000	$12,600
Access Road Maintenance	5	1,200	m^2	$15	$5,200
SWM Pond Inlet/Outfall Structure Reconstruction	50	1	each	$200,000	$4,000
		Annualized Cost			**$29,670**

Table 2: Typical Lifecycle Cost of Concrete Tank System

Item	Maintenance Period (Yrs)	Quantity	Unit	Price ($/Unit)	Total Cost Per Year ($)
Inspection	1	1	each	$2,500	$2,500
Cleaning/Maintenance	50	1	each	$195,000	$3,900
Concrete Rehabilitation (Internal)	100	1	each	$50,000	$500
Cleanout OGS	1	1	each	$3,500	$3,500
Replace OGS	50	1	each	$140,000	$2,800
LID Inspection	1	1	each	2,500	$2,500
LID replacement	50	1	each	$430,000	$8,600
Access Road Maintenance	5	1300	m^2	$20	$5,200
			Annualized Cost		**$29,500**
Additional DC Revenue (City)*					**(-$2,110,000)**
Additional Annual General Municipal Tax Revenue **					**(-$92,935)**
Additional Annual Total Tax Revenue **					**(-$337,668)**

* Assuming 30 units/ha for 1.4ha at 3.5 ppu = 42 TH units.
**Assuming $1.2M/unit

7.0 Above Ground Uses

Potential uses:

- *Parks*
- *Multi-use paths and trails*
- *Sports fields*
- *Off leash parks*
- *Urban plazas*
- *Playgrounds*
- *Skating rinks*
- *Landscaping*
- *Parking lots*

Park Uses

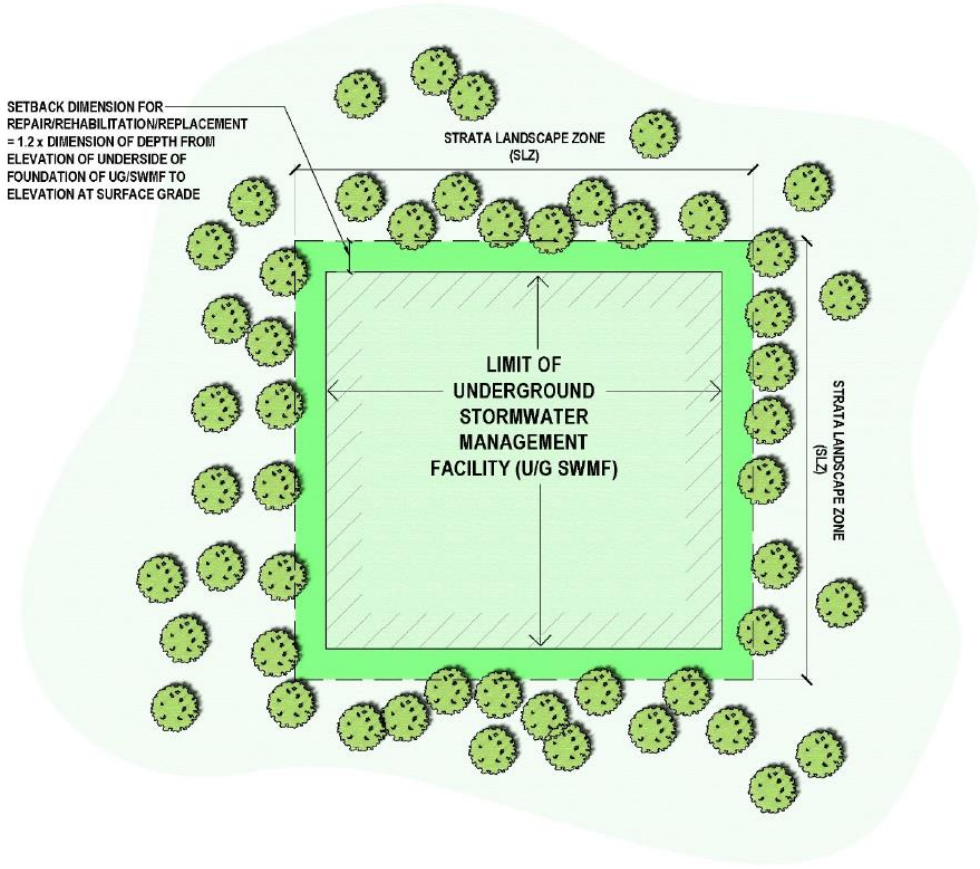
Strata Landscape Zone

The Strata Landscape Zone (SLZ) is the area where the presence of the UG/SWMF can have a direct or an indirect influence on the overlying landscape. It is important to note that these influences do not preclude the SLZ from functioning as viable parkland. They may, however, limit the ability to accommodate certain types of recreational facilities or components thereof, based on physical constraints and/or practical considerations. The SLZ is defined as the area that is located directly over top of the UG/SWMF, as well as a defined setback area around the perimeter of the UG/SWMF and related underground infrastructure. The provision of this setback area is necessary to enable the repair and/or replacement of the UG/SWMF. The width of the setback area is determined by the depth of the UG/SWMF, based on the requirement for excavation to facilitate access for repair/replacement having a corresponding width that is equal to approximately 1.2 times the dimension from surface grade to the underside of the foundation of the UG/SWMF.

The SLZ can be utilized for numerous purposes, including passive or active parkland, parking lots or landscape areas, public right-of-ways or structures. Access locations are required to allow for long-term inspection and maintenance, which typically requires the installation of a 600mm diameter lid flush with the surface or potentially slightly buried below a shallow layer of topsoil and sod.

Figure 1 illustrates the SLZ.

Figure 1: Strata Landscape Zone (SLZ)



Source: Schollen & Company Inc.

Influencing Factors

The composition of the landscape within the SLZ will be influenced by the following:

- Life span of the UG/SWMF
- Depth of soil cover over the UG/SWMF
- Load capacity of the UG/SWMF structure
- Requirements for access to maintain the UG/SWMF
- The ability to customize the configuration of the UG/SWMF to suit requirements for increased structural soil depth and/or to accommodate footings

Each of the above factors influences the types of plant communities and suite of recreational facilities and park amenities that can be implemented within the SLZ. For example, the depth of soil cover over top of the UG/SWMF will affect the following:

- Potential to install footings and foundations to support components of recreational facilities, such as high-mast sports field lights;
- Potential to accommodate underground infrastructure such as drainage and irrigation systems, storm and sanitary sewers and water and electrical services; and,
- Type of soft landscaping (turf, wildflowers and shrubs and/or trees) that can be sustained over top of the UG/SWMF

The section below provides recommendations to direct the types of recreational facilities, park amenities and vegetation communities that can be implemented within the SLZ. This section also sets out the recommended depths of soil cover to sustain various types of vegetation.

Strata Landscape – Principles

The following principles have been established to guide the selection and integration of the landscape that will overlay the UG/SWMF.

- **Independence** – The Strata Landscape should be independent of the UG/SWMF structure;
- **Minimization of Potential Impact** – The Strata Landscape should not negatively impact the structural integrity or function of the UG/SWMF;
- **Provision for Maintenance** – The components of the Strata Landscape should accommodate the short and long-term maintenance requirements of the UG/SWMF; and,
- **Future Environmental Implications** – The requirement to remove components of the Strata Landscape to facilitate future maintenance, repair, rehabilitation or replacement of the UG/SWMF should not result in adverse environmental impacts or regulatory complications.

In response, the components of the Strata Landscape should be designed with regard for the following:

- The type and configuration of the UG/SWMF;
- The load-bearing capacity of the UG/SWMF structure;
- Requirements for drainage over top of the UG/SWMF;
- Requirements for maintenance of the UG/SWMF;
- The base design capabilities of various available UG/SWMF products;
- Potential for modification and/or customization of the design of the UG/SWMF to

facilitate the installation of specific components of the Strata Landscape;

- Requirements for maintenance of the various components of the Strata Landscape; and,
- The strategy for removal/re-installation of the components of the Strata Landscape should rehabilitation or replacement of the UG/SWMF be required.

Composition of the Strata Landscape

The Strata Landscape can comprise both hard and soft landscape elements, including a wide variety of vegetation communities, as well as social, cultural and recreational facilities and amenities. As such, the Strata Landscape offers the potential to accommodate a diverse range of facilities in order to serve the recreational and social programming requirements of the City of Vaughan. However, in consideration of the principles set out above, some recreational facilities and/components of these facilities may not be suitable for implementation within the SLZ, based on the specific characteristics of the UG/SWMF installation. Municipalities and developers shall work with tank manufacturers to ensure tanks are designed to be compatible with the proposed recreational facilities/components.

Recreational Facilities

Tables 3 and 4 below provide a summary of the suitability for implementation within the SLZ of the various recreational facilities that comprise the City's overall catalogue. In determining the suitability of the various recreational facilities, the following assumptions were adopted:

- The structure of the UG/SWMF will be adequate to support the weight of the recreational facility; and,
- The depth of soil cover over top of the UG/SWMF in the "Base Condition" will be a minimum of 1.2m to accommodate conventional footings for small structures such as low chain link fences, goal posts and other elements that do not require foundations beyond 1.2m in depth. The Base Condition also presumes that the design of the UG/SWMF will not be customized to suit specific recreational facility foundation requirements.

Figure 2: Baseball Diamond Overlay on SLZ / UG/SWMF – Base Condition

Source: Schollen & Company Inc.

Structures that require foundations in excess of 1.2m in depth (baseball diamond backstops, light standards, tennis court fences, etc.) cannot be located within the SLZ under the Base Condition but may be able to be accommodated contingent on the characteristics of the specific product or if specific modifications are able to be made to the UG/SWMF. For the purposes of this paper, UG/SWMF systems/installations that exceed the "Base Condition" assumptions, such as providing an increase in the depth of soil cover over the UG/SWMF or other physical characteristics of, or modifications to the structure to accommodate extended footings or other infrastructure are referred to as the "Modified Condition". Note, certain structural concrete products are intrinsically suitable for Modified Condition applications.

Figure 3: Baseball Diamond Overlay on SLZ / UG/SWMF – Modified Condition

Source: Schollen & Company Inc.

Table 3 defines the components of various recreational facilities that are suitable for implementation within the SLZ under the Base Condition. Table 4 identifies appropriate recreational facilities for implementation within the SLZ under the Modified Condition.

Table 3: Suitability of Recreational Facilities within SLZ – Base Condition

	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
PATHS AND TRAILS							
	TRAILS			**YES**	**NO**	**PARTIAL**	
	Multi-use Asphalt (Unlit)	3-4 m Wide	1	✓			
	Multi-use Asphalt (Lit)	3-4 m Wide	1			✓	Light Standards must be located outside of SLZ
	Recreational Trail - Granular (Unlit)	1.5-2.5m Wide	1	✓			
	Nature Trail - Soft Surface (Unlit)	1.2-2.1m Wide	N/A	✓			

	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
	Skating Track - Refrigerated (Lit)	3-5m Wide	1		✓		
SPORTS FIELDS / PLAY FIELDS							
	BALL DIAMOND			**YES**	**NO**	**PARTIAL**	
	Ball Diamond (Junior/Softball/T-Ball)	60.96m Foul Line - Unlit	67 x 67			✓	Infield fence must be located outside of SLZ
	Ball Diamond (Senior)	102m Foul Line - Drainage & Unlit	112 x 112			✓	Infield fence must be located outside of SLZ
	Ball Diamond (Senior)	102m Foul Line - Drainage & Lit	112 x 112		✓		
	Ball Diamond (Premium Senior)	111.96m Foul Line - Drainage, Close-out, Lit	131 x 131		✓		
	CRICKET						
	Cricket Practice Cage/Pitch	1-Lane, Unlit	5 x 30		✓		
	Cricket Practice Cages/Pitch	3-Lane, Unlit	15 x 30		✓		
	Cricket Practice Cages/Pitch	5-Lane, Unlit	25 x 30		✓		
	Cricket Field (Class C)	100m Dia - Unlit	100 x 100	✓			
	Cricket Field (Class B)	137m Dia - Unlit	110 x 127.5	✓			
	Cricket Field (Class A)	150m Dia - Unlit	150 x 168	✓			
	SOCCER						
	Mini-Mini Soccer	Unlit	35 x 50	✓			Goal posts must be surface mounted
	Mini Soccer	Unlit	50 x 65	✓			
	Minor (9V9) Soccer	Unlit	56 x 83	✓			

	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
	Major/Senior Soccer	Unlit	78 x 120	✓			
	Major/Senior Soccer	Lit	78 x 120			✓	Light standards must be located outside of SLZ
	MULTI-PURPOSE FIELD						
	Multi-Purpose Field (Rugby)	Artificial, Lit	78 x 147			✓	Goal posts and lights must be located outside of SLZ
	OFF LEASH PARK						
	Off Leash Park	126.5 x 79	1 ha	✓			Perimeter Fence must be located outside of SLZ
PLAZAS AND GATHERING SPACES							
	OPEN SPACE/PLAZAS			**YES**	**NO**	**PARTIAL**	
	Urban Open Space	24 x 23.5, 150 Capacity	559 m^2	✓			All structures must be on slab footings, Light standards must be outside of SLZ
	Neighbourhood Open Space	24 x 23.5, 150 Capacity	560 m^2	✓			
	Neighbourhood/District Open Space	44 x 46, 250 Capacity	0.2 ha	✓			
	District Open Space	77 x 78, 500 Capacity	0.6 ha	✓			
	Regional/District Open Space	1000 Capacity	1.7 ha	✓			
	Regional Open Space	2000 Capacity	4.3 ha	✓			
	OPEN SPACE (LAWN)						
	Neighbourhood Open Lawn	30 x 50, 400 Capacity	1500 m^2	✓			All structures must be on slab footings, Light

FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
District Open Lawn	60 x 50, 800 Capacity	3000 m^2	✓			standards must be outside of SLZ
HARDSCAPE GATHERING SPACE (PLAZA)						
Urban Plaza	30 x 50, 400 Capacity	1500 m^2	✓			All structures must be on slab footings, Light standards must be outside of SLZ
Neighbourhood Plaza	30 x 50, 400 Capacity	1500 m^2	✓			
District Plaza	60 x 50, 800 Capacity	3000 m^2	✓			
SPORTS COURTS						
BASKETBALL COURT			**YES**	**NO**	**PARTIAL**	
Single Basketball Court	Unlit	26 x 17.5	✓			Basketball net post, must be on slab footing
Single Basketball Court	Lit	26 x 17.5			✓	Basketball net post, must be on slab footing, Light standards must be outside of SLZ
Double Basketball Court	Unlit	26 x 38			✓	Basketball net post, must be on slab footing
Double Basketball Court	Lit	26 x 38			✓	Basketball net post, must be on slab footing, Light standards must be outside of SLZ *
BEACH VOLLEYBALL COURT						
Beach Volleyball Court	Unlit	15 x 24	✓			Net posts must be on slab footing

FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
MULTI-USE COURT						
Half Multi-Use Court	Unlit	7.62 x 15.25	✓			Goal posts must be surface mounted
Multi-Use Court	Unlit	15.25 x 30.5	✓			
Multi-Use Court	Lit	15.25 x 30.5			✓	Goal posts must be surface mounted, Light standards must be outside of SLZ
TENNIS						
Double Tennis Court	Unlit	32.92 x 36.58		✓		
Double Tennis Court	Lit	32.92 x 36.58		✓		
Triple Tennis Court (w/ Pickle Ball)	Lit	40.16 x 36.58		✓		
Quadruple Tennis Court	Lit	54.77 x 36.58		✓		
PICKLEBALL						
Double Pickleball Court	Unlit	32.92 x 36.58		✓		
BOCCE COURT						
Triple Bocce Court	Unlit	28.2 x 15.2	✓			
Triple Bocce Court	Lit	28.2 x 15.2			✓	Lights must be located outside of SLZ
FITNESS FACILITIES						
FITNESS EQUIPMENT			**YES**	**NO**	**PARTIAL**	
Fitness Equipment	1 piece	45 m^2	✓			Sleeper or slab foundations only
Fitness Equipment	6 piece, 8 x 25	200 m^2	✓			
Fitness Equipment	Lit	200 m^2		✓		

	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER UG/SWMF			QUALIFICATION REQUIREMENTS
PLAYGROUNDS							
	PLAYGROUND (Junior and Senior)						
	Neighbourhood/ Urban Park Playground	23 x 31, Unlit	700 m^2	✓			Sleeper or slab foundations only
	District/Regional Playground	32.5 x 39, Unlit	1200 m^2	✓			
	WATER PLAY/SPLASH PAD						
	Urban Splash Pad	12.5 x 20	250 m^2		✓		
	Neighbourhood Splash Pad	12.5 x 20	250 m^2		✓		
	District Splash Pad	25 x 20	500 m^2		✓		
SPECIALTY FACILITIES							
	OUTDOOR RINK			**YES**	**NO**	**PARTIAL**	
	Outdoor Rink	20 x 50m	500 m^2	✓			Boards must be surface mounted, Light standards must be outside of SLZ
	SKATEBOARD						
	Skate Zone	22 x 14.5	320 m^2	✓			
	Skate Park	57 x 35	2000 m^2	✓			
PARK STRUCTURES							
	SHADE STRUCTURE			**YES**	**NO**	**PARTIAL**	
	Shade Structure/Shelter	Metal	7 x 7	✓			Slab footing only
	Picnic Shelter	15 Single Tables (90 Capacity)	8 x 14	✓			Slab footing only
	PARK BUILDING						
	Park Building	Washroom facility and picnic shelter area	30 x 11		✓		
* Assumption - Cover over UG/SWMF is less than 1.2m							

Figure 4: Soccer Field (Unlit) Overlay on SLZ / UG/SWMF – Base Condition

Source: Schollen & Company Inc.

Table 4: Suitability of Recreational Facilities within SLZ – Modified Condition

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
PATHS AND TRAILS							
	TRAILS			**YES**	**NO**	**PARTIAL**	
	Multi-use Asphalt (Unlit)	3-4 m Wide	1	✓			
	Multi-use Asphalt (Lit)	3-4 m Wide	1	✓			Additional depth of soil cover required
	Recreational Trail - Granular (Unlit)	1.5-2.5m Wide	1	✓			

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
	Nature Trail - Soft Surface (Unlit)	1.2-2.1m Wide	N/A	✓			
	Skating Track - Refrigerated (Lit)	3-5m Wide	1	✓			Additional depth of soil cover required and/or UF/SWMF customized to accept light standard footings
SPORTS FIELDS / PLAY FIELDS							
	BALL DIAMOND			**YES**	**NO**	**PARTIAL**	
	Ball Diamond (Junior/Softball/T-Ball)	60.96m Foul Line - Unlit	67 x 67	✓			Additional depth of soil cover required
	Ball Diamond (Senior)	102m Foul Line - Drainage & Unlit	112 x 112	✓			Additional depth of soil cover required
	Ball Diamond (Senior)	102m Foul Line - Drainage & Lit	112 x 112	✓			Additional depth of soil cover required and/or UF/SWMF customized to accept light standard footings
	Ball Diamond (Premium Senior)	111.96m Foul Line - Drainage, Close-out, Lit	131 x 131	✓			Additional depth of soil cover required and/or UF/SWMF customized to accept light standard footings

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
	CRICKET						
	Cricket Practice Cage/Pitch	1-Lane, Unlit	5 x 30	✓			Additional depth of soil cover required
	Cricket Practice Cages/Pitch	3-Lane, Unlit	15 x 30	✓			
	Cricket Practice Cages/Pitch	5-Lane, Unlit	25 x 30	✓			
	Cricket Field (Class C)	100m Dia - Unlit	100 x 100	✓			
	Cricket Field (Class B)	137m Dia - Unlit	110 x 127.5	✓			
	Cricket Field (Class A)	150m Dia - Unlit	150 x 168	✓			
	SOCCER						
	Mini-Mini Soccer	Unlit	35 x 50	✓			Additional depth of soil cover required unless goal posts are surface mounted
	Mini Soccer	Unlit	50 x 65	✓			
	Minor (9V9) Soccer	Unlit	56 x 83	✓			
	Major/Senior Soccer	Unlit	78 x 120	✓			
	Major/Senior Soccer	Lit	78 x 120	✓			Additional depth of soil cover required or UG/SWMF customized to accommodate light standard footings
	MULTI-PURPOSE FIELD						
	Multi-Purpose Field (Rugby)	Artificial, Lit	78 x 147	✓			Additional depth of soil cover required or UG/SWMF customized to accommodate

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
							light standard footings
	OFF LEASH PARK						
	Off Leash Park	126.5 x 79	1 ha	✓			
PLAZAS AND GATHERING SPACES							
	OPEN SPACE/PLAZAS			**YES**	**NO**	**PARTIAL**	
	Urban Open Space	24 x 23.5, 150 Capacity	559 m^2	✓			Additional depth of soil cover required to accommodate footings and/or UG/SWMF customized to address footings/ foundations
	Neighbourhood Open Space	24 x 23.5, 150 Capacity	560 m^2	✓			
	Neighbourhood/District Open Space	44 x 46, 250 Capacity	0.2 ha	✓			
	District Open Space	77 x 78, 500 Capacity	0.6 ha	✓			
	Regional/District Open Space	1000 Capacity	1.7 ha	✓			
	Regional Open Space	2000 Capacity	4.3 ha	✓			
	OPEN SPACE (LAWN)						
	Neighbourhood Open Lawn	30 x 50, 400 Capacity	1500 m^2	✓			Additional depth of soil cover required to accommodate footings and/or UG/SWMF customized to address footings/ foundations
	District Open Lawn	60 x 50, 800 Capacity	3000 m^2	✓			
	HARDSCAPE GATHERING SPACE (PLAZA)						
	Urban Plaza	30 x 50, 400 Capacity	1500 m^2	✓			Additional depth of soil cover required to

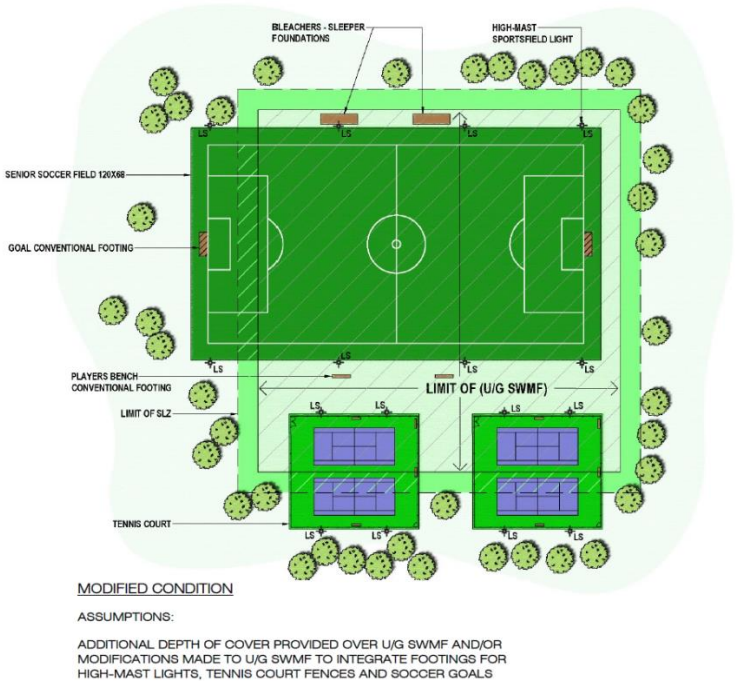
				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
	Neighbourhood Plaza	30 x 50, 400 Capacity	1500 m^2	✓			accommodate footings and/or UG/SWMF customized to address footings/ foundations
	District Plaza	60 x 50, 800 Capacity	3000 m^2	✓			
SPORTS COURTS							
	BASKETBALL COURT			**YES**	**NO**	**PARTIAL**	
	Single Basketball Court	Unlit	26 x 17.5	✓			Additional depth of soil cover required and/or UG/SWMF customized to accept light standard footings
	Single Basketball Court	Lit	26 x 17.5	✓			
	Double Basketball Court	Unlit	26 x 38	✓			
	Double Basketball Court	Lit	26 x 38	✓			
	BEACH VOLLEYBALL COURT						
	Beach Volleyball Court	Unlit	15 x 24	✓			Additional depth of soil cover required
	MULTI-USE COURT						
	Half Multi-Use Court	Unlit	7.62 x 15.25	✓			Additional depth of soil cover required and/or UG/SWMF customized to accept light standard footings
	Multi-Use Court	Unlit	15.25 x 30.5	✓			
	Multi-Use Court	Lit	15.25 x 30.5	✓			
	TENNIS						
	Double Tennis Court	Unlit	32.92 x 36.58	✓			Additional depth of soil cover required

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
	Double Tennis Court	Lit	32.92 x 36.58	✓			Additional depth of soil cover required and/or UG/SWMF customized to accept light standard footings
	Triple Tennis Court (w/ Pickle Ball)	Lit	40.16 x 36.58	✓			
	Quadruple Tennis Court	Lit	54.77 x 36.58	✓			
	PICKLEBALL						
	Double Pickleball Court	Unlit	32.92 x 36.58	✓			Additional depth of soil cover required
	BOCCE COURT						
	Triple Bocce Court	Unlit	28.2 x 15.2	✓			
	Triple Bocce Court	Lit	28.2 x 15.2	✓			Additional depth of soil cover required
FITNESS FACILITIES							
	FITNESS EQUIPMENT			**YES**	**NO**	**PARTIAL**	
	Fitness Equipment	1 piece	45 m^2	✓			Additional depth of soil cover required
	Fitness Equipment	6 piece, 8 x 25	200 m^2	✓			
	Fitness Equipment	Lit	200 m^2	✓			Additional depth of soil cover required and/or UG/SWMF customized to accept light standard footings

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
PLAYGROUNDS							
	PLAYGROUND (Junior and Senior)						
	Neighbourhood/ Urban Park Playground	23 x 31, Unlit	700 m^2	✓			Additional depth of soil cover required
	District/Regional Playground	32.5 x 39, Unlit	1200 m^2	✓			
	WATER PLAY/SPLASH PAD						
	Urban Splash Pad	12.5 x 20	250 m^2	✓			Additional depth of soil cover required
	Neighbourhood Splash Pad	12.5 x 20	250 m^2	✓			
	District Splash Pad	25 x 20	500 m^2	✓			
SPECIALTY FACILITIES							
	OUTDOOR RINK			**YES**	**NO**	**PARTIAL**	
	Outdoor Rink	20 x 50m	500 m^2	✓			Additional depth of soil cover required
	SKATEBOARD						
	Skate Zone	22 x 14.5	320 m^2	✓			
	Skate Park	57 x 35	2000 m^2	✓			
PARK STRUCTURES							
	SHADE STRUCTURE			**YES**	**NO**	**PARTIAL**	
	Shade Structure/Shelter	Metal	7 x 7	✓			Additional depth of soil cover required and/or UG/SWMF customized to accommodate footings
	Picnic Shelter	15 Single Tables (90 Capacity)	8 x 14	✓			

				MODIFIED CONDITION Increase in Soil Cover and/or Customization			
	FACILITY	DESCRIPTION / FEATURES	PLAY + PLAYOUT AREA DIMENSIONS (m)	ACCEPTABLE FOR STRATA LANDSCAPE OVER SWMF			QUALIFICATION REQUIREMENTS
	PARK BUILDING						
	Park Building	Washroom facility and picnic shelter area	30 x 11		✓		

Figure 5: Soccer Field (Unlit) Overlay on SLZ / UG/SWMF – Modified Condition



Source: Schollen & Company Inc.

Park Amenities

Park amenities comprise the furniture and other practical elements within parks and open spaces park amenities may include the following:

- Benches
- Bicycle racks/rings

- Picnic tables
- Waste and recycling receptacles
- Games tables
- Fitness equipment
- Play structures
- Drinking fountains
- Wayfinding, instructional and interpretive signs
- Bake ovens
- Furniture associated with sports fields, including players benches and spectator bleachers

A broad range of park amenities can be installed within the SLZ, contingent on the depth of soil cover over top of the UG/SWMF. In situations where the depth of soil cover is proposed to be 1.2m or greater, all of the amenities listed above can be accommodated within the SLZ. When the depth of soil cover is proposed to be less than 1.2m, alternative foundation methods will be required to facilitate the installation of park amenities, including the following:

- Concrete slab foundations
- Sleeper or stringer foundations

Fortunately, many of the manufacturers/suppliers of park amenities offer products that are fabricated to be installed on concrete slabs or sleepers/stringers. As a result, the SLZ does not pose any constraints to the installation of the majority of park amenities. However, drinking fountains should not be installed within the SLZ where the depth of soil cover is proposed to be less than 1.2m, due to the requirement for adequate cover over the water supply line to ensure frost protection.

Planting

Soft Landscaping

With respect to the composition of the vegetation community within the SLZ, a wide variety of plants and landscape types can be accommodated including the following:

- Turfgrass;
- Sports field turf (with irrigation and drainage);
- Meadow/prairie;

- Shrubs;
- Groundcovers;
- Micro-agriculture / community gardens; and,
- Horticultural displays.

However, consistent with Principle D (Future Environmental Implications), as set out above, trees are not to be planted within the SLZ owing to the fact that if rehabilitation/replacement of the UG/SWMF is required in the future, the removal of trees that have become established and semi-mature in size will result in loss of the canopy cover and may have other environmental implications. In addition, from a regulatory perspective, the requirement to remove trees may impose restrictions on the timing of rehabilitation/replacement work related to the Migratory Birds Convention Act, and potentially, the endangered Species Act (should a tree or trees provide habitat for Species At Risk (SAR)).

The planting of trees within the SLZ also poses concerns related to future loading of the structure. As a tree matures, it assumes more biomass and increases in weight and over decades a semi-mature tree can weigh in excess of 10 tonnes. Municipalities should work with the developers and tank manufacturers to ensure the tank is designed to withstand expected loads if trees will be planted above. There are also concerns related to the implications associated with the eventual failure of a tree that would be planted within the SLZ, including the following:

- Requirement for access by heavy machinery to remove the fallen tree/wood;
- Potential for damage to the UG/SWMF during the removal of the remnant stump; and,
- Implications of upturning of the root ball and displacement of soil over top of the UG/SWMF.

In addition to these issues, the requirement to remove semi-mature trees to facilitate future rehabilitation/replacement may be met with opposition from the public and other interest groups, which could complicate the process.

With the objective of sustaining the vegetation communities that are proposed within the SLZ, the following minimum planting media depths, as set out in the Canadian Landscape Standard – Second Edition (2020), are recommended.

Table 5: Minimum Depths of Growing Media

Application	Over Prepared Subgrade (which Retains "A" Horizon)	Over Prepared Subgrade where the Subsoil Drains Rapidly	Over Prepared Subgrade where the Subsoil Drains Poorly	Over Structures
Low Traffic Lawn Areas				
Irrigated	100mm (4in.)	150mm (6in.)	200mm (8in.)	200mm (8in.)
Non Irrigated	100mm (4in.)	150mm (6in.)	300mm (12in.)	300mm (12in.)
High Traffic Lawn Areas	100mm (4in.)	150mm (6in.)	300mm (12in.)	300mm (12in.)
Planting Aeras and Planters				
Ground Cover Areas	150mm (6in.)	300mm (12in.)	300mm (12in.)	300mm (12in.)
Small Shrubs	300mm (12in.)	450mm (18in.)	300mm (12in.)	450mm (18in.)
Large Shrubs	450mm (18in.)	600mm (24in.)	500mm (20in.)	500mm (20in.)

Parking Lots and Service Roads

Underground storage facilities can be designed to accommodate highway loading and are therefore ideally utilized below private or public parking areas and/or driveways. Most concrete precast systems are designed to CSA S6:19, the Canadian Highway Bridge Code as a base condition. The UG/SWMF can be designed to either work around or integrate stormwater inlets and light poles.

8.0 Rules/Responsibilities

Like traditional open stormwater management ponds, underground facilities come with rules and responsibilities for the City, the developer, and the ultimate owner (if this is not the City). This section outlines typical responsibilities for each party involved.

Typically, proposed stormwater management facilities are located at the topographic low point of a development, near existing watercourses or other available drainage outlets. At the early design stage, siting of a public park on top of an underground stormwater management facility will require consultation between the proponent's design team and municipal staff to ensure that community parkland facilities are conveniently located and situated to benefit the wider development area, and in some cases a proposed stormwater management facility location may not be suitable for public parkland in terms of placement, visibility, access or other community planning rationale.

It is envisioned that engineering design, review and municipal approvals for underground stormwater management systems located on public property/beneath public parks will follow the same protocols as the City's current process for open-air stormwater management ponds and facilities. Underground storage facilities should be considered municipal infrastructure and the City currently provides detailed engineering design, drawing and submission requirements within their standards documents for implementing such infrastructure where ownership of the facility is ultimately conveyed to the municipality. Proponents should refer to the City's Engineering Design Criteria & Standard Drawings (December 2020), Section 1.3, Stormwater Management System, for overall objectives of the stormwater strategy and facility criteria in support of development.

Similarly, during the construction and subsequent assumption process, underground stormwater management systems will follow the same City protocols for inspection, repairs, clean-out and maintenance criteria as typical municipal infrastructure or open-air stormwater managements ponds, prior to the ultimate conveyance of the facility ownership to the Municipality.

Developer

The intention to implement an underground stormwater management system within a development, situated beneath proposed public lands/parks, should be initially indicated by the Developer at the draft plan application stage through the submission of relevant supporting technical drawings and reports to the City.

The developer shall be generally responsible for:

- Siting the proposed dual-use underground stormwater management facility and public park and demonstrate the intended location is suitable for the dual-use purposes.
- Identify the proposed Block size based on stormwater management criteria identified within the City's Engineering Design Criteria & Standard Drawings (December 2002) and parkland amenity/facility fit requirements.
- Preparation of functional and detailed engineering design drawings, including general arrangement plans and manufacturer's shop drawings for the underground facility, all sealed by a P. Eng.
- In the case of a public park use above the UG/SWMF, preparation of a facility fit plan for the public park, including grading, landscaping, drainage, illumination and park amenity design layout.
- Provide an engineer's cost estimate based on the construction value of the underground facility and secure the full value of the proposed municipal infrastructure works with the Municipality.
- Securing Environmental Compliance Approval ("ECA") from the Ministry of the Environment, Conservation and Parks ("MECP") for the UG/SWMF.
- Funding and completing the construction of the UG/SWMF and provide full-time inspection by the responsible engineer(s); provide the municipality with certification letter(s) of general construction conformance, sealed by a P.Eng. and as-built drawings upon construction completion.
- Execute a Subdivision Agreement or Development Agreement with the municipality which shall include the developer's obligations and security requirements for the UG/SWMF.
- Undertake periodic inspection, monitoring, maintenance, repairs and/or clean-out of the facility up to municipal assumption of the facility, in accordance with municipal requirements, Development Agreement and MECP ECA certificate.
- Complete and submit documents to the MECP upon municipal assumption, transferring ownership and responsibility of the facility to the Municipality.

Municipality (City of Vaughan)

The City shall consider the UG/SWMF as municipal infrastructure, to be ultimately owned and operated by the City, and will follow similar design, approvals, construction, and assumption protocols as is currently applied by the City to development applications. The City shall be generally responsible for:

- Confirming at an early stage of the development application process the suitability of the proposed dual-use location for both a UG/SWMF and the above-ground use.
- Completing preliminary and detailed review of technical drawings and documents; including outsourcing for peer review of structural engineering design, if required, and issue engineering approvals.

- Preparation of the Subdivision or Development Agreement, including language accepting ultimate ownership of the infrastructure, confirming security requirements and outlining monitoring obligations.
- In the case of public parkland as an above-ground use over the UG/SWMF, review of the detailed design, landscape architecture and fund/administer the ultimate construction of the public parkland through conditions of development approval or the Development Agreement. Should the public park be constructed prior to assumption of the UF/SWMF, the City should circulate the detailed park design to the Developer and the City shall ensure no damage to the facility occurs as a result of the park construction.
- In the case of private ownership of the facility lands, administration of Development or Condominium Agreements to set out requirements and obligations for maintenance, typically found in commercial or higher density developments.
- Reducing and releasing securities at pre-established milestones.
- Issuing a letter to the MECP accepting ownership and responsibility of the UG/SWMF upon assumption.

9.0 Available Stormwater Infrastructure Products

The most common product materials used for UG/SWMF are concrete and polyvinyl chloride (PVC).

Underground stormwater management products and systems are available through numerous local manufacturers supplying Southern Ontario and product material may consist of concrete, polyvinyl chloride ("PVC"), corrugated metal pipe ("CMP") or granular clear stone. CMP is not commonly utilized for underground storage while granular clear stone may be suitable only for very small-scale storage applications, therefore the two most common product materials applicable to underground storage beneath public lands are concrete and PVC. It is increasingly recommended that PVC storage tanks are limited to use on private properties only due to the inherent structural benefits of concrete products.

The design engineer, in consultation with the municipality, should determine and select the desired material and product for the underground stormwater storage based on a variety of parameters such as cost, durability, life span, access, ease of installation, loading, and maintenance requirements.

Concrete

The majority of concrete underground stormwater management storage systems tend to be linear concrete box and circular storm sewers, also known as superpipe systems, which are usually located under roads and provide both stormwater conveyance and temporary storage. Superpipe systems, where storm sewers are oversized to create the required storage, are preferred where space for underground storage is limited.

Additionally, manufacturers also supply large concrete chamber systems specifically intended for large scale projects that are dedicated primarily to stormwater storage. These products can be referred to as end-of-pipe storage systems, similar to the function of a traditional open-air stormwater management pond. Smaller scale projects will benefit from concrete box or chamber storage with a modular design that allows for unique configurations to suit sites with space constraints. Generally, concrete products gain cost efficiencies over PVC products when large storage volumes are required.

Depending on the product supplier, concrete box or concrete chamber storage systems can be installed with an open bottom that allows for the infiltration of stormwater from

the chambers into the ground to meet additional stormwater criteria, such as water balance.

Figure 6: DECAST I-Storm Prototype

Source: DECAST

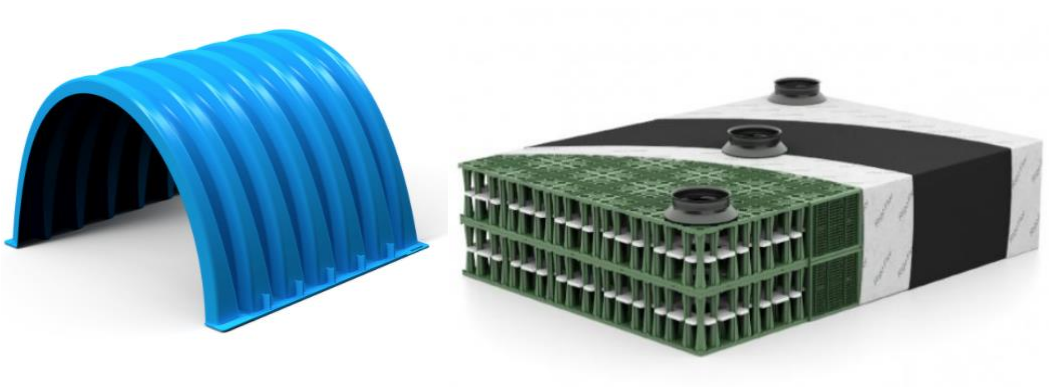
Notably, concrete products have a much longer lifespan in comparison to plastic products. Maintenance benefits are also associated with concrete facilities which are typically accessible to maintenance crews, unlike plastic UG/SWMF alternatives. Some facilities, like the I-Storm, can accommodate maintenance equipment inside, while most plastic systems are maintained via flushing and hydro-vac processes from the surface.

Polyvinyl Chloride

Underground stormwater management storage systems made of PVC (plastic) tend to be smaller in scale and are generally produced as arches or small cubic cells, however can also be used for larger applications. Generally, PVC stormwater management products are cost efficient for smaller scale projects, and if utilized for larger projects may require greater area than an equivalent concrete stormwater management system.

PVC storage arches are constructed as rows of an arched chamber system with manifolds that disperse stormwater across the chamber bed. Storage chambers may be constructed with an optional isolated containment row that pre-treats stormwater prior to entering the main storage chambers and can provide for the option of an open bottom to allow for infiltration of stormwater from the chambers into the ground below. Similar to concrete box storage systems, PVC cubic cells have a modular box design that allows for flexible installation configurations to suit site specific space constraints.

Figure 7: Sample PVC Prototypes



Source: StormCon

10.0 Examples of Existing Dual-Use Facilities

Dual use stormwater facilities have been successfully implemented in various locations and contexts through the Greater Toronto Area, including in the City of Vaughan. The following pages provide an overview and photos of select examples:

- *Nashville, City of Vaughan*
- *Pan Am Aquatic Centre, City of Toronto*
- *Amazon Fulfilment Centre, Town of Ajax*
- *Thornhill Green Park, City of Vaughan*
- *Bill Crothers Secondary School, City of Markham*
- *Uptown Markham, City of Markham*
- *Honda Canada Campus, City of Markham*

This section of the document provides some examples of Strata Landscapes over top UG/SWMFs. As noted, some of these projects have been approved and constructed within the City of Vaughan. These examples demonstrate the diversity of landscape types that can be implemented above UG/SWMFs without compromising the stormwater management functions or the aesthetic and visual components above grade.

Nashville, City of Vaughan

- Description: DECAST DE-CUBES were installed at this facility to provide the necessary detention volume for a 100-year storm event. The installatio included 350mm thick cast-in-place slab underneath the tank pieces, cast in sections and 136 total pieces with 5 different wall configurations. Grading, topsoil, and terraseeding have now been completed over the tanks.
- Date Installed: 2021
- Storage Capacity: 1,459m^3

Nashville, City of Vaughan

Source: DECAST

Pan Am Aquatic Centre, City of Toronto

- Description: Full-scale underground wet pond with stormwater detention, a forebay for grit removal, a baffle wall for oil and floatable trash removal. Two precast SWM tank systems were designed and installed around the foundation of the Pan Am Aquatics Centre, under green space and a parking lot, representing a true transfer of all the benefits of an above-ground pond underground.
- Date Installed: 2013-2014
- Storage Capacity: 1,742m^3 and 2,500m^3

Source: DECAST, Infrastructure Ontario

Amazon Fulfilment Centre, Town of Ajax

- Description: An underground SWM solution was mandatory for Amazon to select this location. This system features a hybrid design with precast structures (O-Series® system) with an underground SWM pond. Fully-loaded transport trucks frequently drive and park on top of the UG/SWMF demonstrating full dual use of the facility lands. The facility took less than a month to install.
- Date Installed: 2021
- Storage Capacity: 11,633m^3

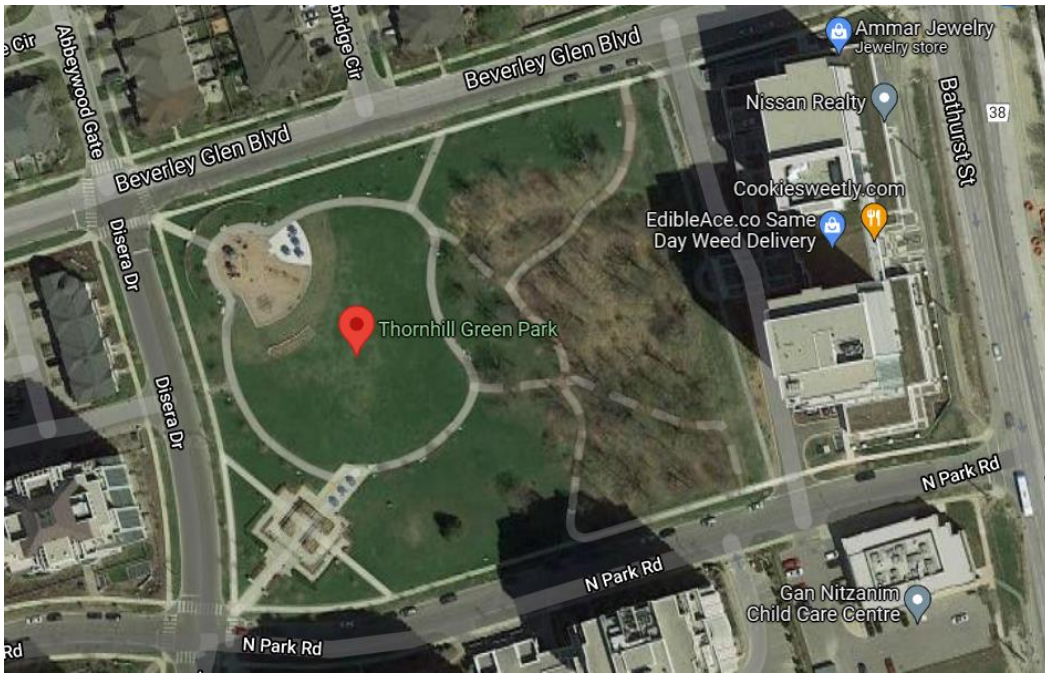
Amazon Fulfilment Centre, Town of Ajax

Source: DECAST

Thornhill Green Park, City of Vaughan

- Description: This neighbourhood park includes a passive play field, trails and a pavilion that are located over top of an UG/SWMF. The UG/SWMF comprises concrete tanks that are located below the passive open space area. The UG/SWMF provides both quality and quantity control.
- 5.0 acre municipal park with precast concrete stormwater tanks below
- Date Installed: 2008

Thornhill Green Park, City of Vaughan



Source: Schollen & Company Inc., Google Earth

Bill Crothers Secondary School, City of Markham

- Description: A 1,300m^3 stormwater storage tank located below the artificial turf practice area and Olympic caliber running track. The tank is located below the elevation of the groundwater table and includes an innovative weeper and pump system that supplies the tank using groundwater, in the event that the water level in the tank is depleted below a specified level. Stormwater that is collected within the storage tank is used to irrigate the natural turf sports fields, as well as to cool down the artificial turf field prior to each cycle of play during the summer months.
- Date Installed: 2004-2010
- Storage Capacity: 1,300m^3

Bill Crothers Secondary School, City of Markham

Source: Schollen & Company Inc.

Uptown Markham, City of Markham

- Description: Concrete quantity/erosion control tank under parkland
- Installed: 2015
- Pre-treatment with OGS and stone filtration/infiltration system

Source: SCS Consulting Group

Honda Canada Campus, City of Markham

- Description: The Honda Canada Campus was designed to reflect Honda's corporate vision for environmental efficiency and sustainability. Stormwater runoff is managed through and integrated system of LID technologies that include permeable pavement, biofilters, rain gardens and a rainwater storage and recycling system. The storage system comprises an 1,800m^3 storage tank that is overlain by a baseball field and trails. The tank stores water that is used for landscape irrigation throughout the campus.

Source: Schollen & Company

11.0 Conclusions & Recommendations

Many municipalities have adopted a dual-use approach to stormwater management in order to efficiently use land and optimize new developments. UG/SWMF are an innovative, cost-effective, and safe alternative to traditional SWM ponds and can be applied in various types of developments and areas, including both greenfield areas and built-up intensification areas. They provide benefits to the community by creating additional opportunities for usable parkland and recreational facilities and have been used successfully in municipalities throughout the Greater Toronto Area, including in the City of Vaughan.

Recommendations related to the application of UG/SWMF are presently being considered by the City of Markham (see Appendix C for proposed Council resolution) to initiate the process of approving UG/SWMF city-wide.

It is recommended that the City of Vaughan, in order to encourage and implement the use of UG/SWMF within new developments in the City, prepare City-wide engineering guidelines and/or standards to be used in the development planning process by City staff, developers and private consultants.

APPENDIX A

Letter from TRCA to DECAST dated October 18, 2021, Use of Underground Tanks for Stormwater Management

October 18, 2021

SENT BY E-MAIL (kseravalle@decastltd.com; aabbruscato@decastltd.com)

Katya Seravalle, PMP, Manager, New Products Development
Anthony Abbruscato, P.Eng., Technical Sales Engineer
DECAST
8807 County Road 56
Utopia, Ontario L0M 1T0

Dear Ms. Seravalle and Mr. Abbruscato:

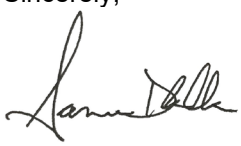
Thank you for meeting with TRCA to discuss the use of underground tanks for stormwater management (SWM). We appreciate the information provided and look forward to a future opportunity to monitor your system as part of TRCA's Sustainable Technologies Evaluation Program (www.sustainabletechnologies.ca). It appears that products listed within the DE-STORM group of stormwater management solutions can be used for various applications, to suit site-specific needs and adhere to various requirements.

As discussed, underground tanks and chambers have been an effective alternative to above ground stormwater ponds in TRCA's jurisdiction, particularly in high density urban areas. When located below parks they have the potential to significantly reduce the surface footprint of the developed area, allowing for greater conservation of natural lands and more efficient and compact land use planning. Monitoring of an underground tank in Unionville, Markham by the Sustainable Technologies Evaluation Program (STEP) showed that an appropriately designed underground tank provided similar water quality performance to that of "Enhanced Level" stormwater ponds, but with much cooler effluent temperatures (https://www.mdpi.com/2073-4441/8/5/211/htm). In addition to the land conservation and water quality benefits, underground tanks designed and sited appropriately can also effectively mitigate flooding and satisfy TRCA's criteria for both water quality and quantity as outlined in TRCA's Stormwater Criteria Document (https://trca.ca/conservation/stormwater-management/understand/). In addition, underground tanks with an open bottom can provide for infiltration of runoff, achieving TRCA criteria related to water balance and erosion.

The application of stormwater tanks is also described within both the Stormwater Management Planning and Design Manual (MOE 2003) and TRCA's Low Impact Development Stormwater Management Planning and Design Guide (https://wiki.sustainabletechnologies.ca/wiki/Main_Page). Both documents emphasize the importance of the treatment train approach, which suggests that the treatment of runoff at the source, enroute, and at end-of-pipe should be incorporated into every SWM strategy.

Stormwater Management Innovation combined with sound engineering and environmental principles will continue to be encouraged and accepted by TRCA provided that the necessary technical analyses, documentation, and approval from the municipality or SWM infrastructure owner are completed, and that these proposed works also satisfy all other applicable requirements and criteria, including provision for long term operations, monitoring and maintenance. We look forward to continuing to work with DECAST to achieve our shared objectives in stormwater management.

Sincerely,



Sameer Dhalla, P.Eng.
Director, Development and Engineering Services

T: 416.661.6600 | F: 416.661.6898 | info@trca.on.ca | 101 Exchange Avenue, Vaughan, ON L4K 5R6 | www.trca.ca

APPENDIX B

Letter from Concrete Durability Associates Inc. to DECAST dated March 12, 2021,
Service Life Predictions for Proposed Underground Precast Stormwater Storage Tanks

Concrete Durability Associates Inc.
41 Edgemore Drive, Toronto, Ontario, Canada, M8Y2N4

March 12, 2021

DECAST Ltd
8807 County Road 56, Utopia, ON
LOM 1T0
Attn: David Archer, P.Eng
darcher@decastltd.com

Service Life Predictions for Proposed Underground Precast Stormwater Storage Tanks

My Background

In addition to providing consulting services, I have been a Professor in the Department of Civil & Mineral Engineering at the University of Toronto since 1986 where my research focusses on concrete materials and durability. At the university, I hold the NSERC/CAC Senior Industrial Research Chair in Concrete Durability & Sustainability. I am also the current Chair of CSA Committee A23.1/A23.2 on Concrete Materials and methods of Concrete Construction & Concrete Test Methods, ASTM Committee C01 on Cements, and American Concrete Institute (ACI) Committee 201 on Concrete Durability. I am also member of ACI Committee 365 on Service Life Prediction.

The Project

It is my understanding that DECAST Ltd. is designing modular precast reinforced concrete units to be used to create vaults for temporarily storing stormwater, allowing for controlled releases and flood prevention.

The concrete units will be placed well below the frost line and therefore should not be exposed to freezing and thawing cycles. Regardless, it is planned to air entrain the concrete mixtures. Some of these underground vaults will be used to control runoff from sport fields, where there should be essentially no chlorides in the runoff water, but others maybe located beneath on-grade parking lots and therefore will be exposed to chlorides from de-icer salts so concrete mixtures will need to be designed to meet CSA A23.1 Exposure Class C-1 (i.e. minimum of 35 MPa at 56 days, air entrained and have a permeability index of less than 1500 Coulombs at 91 days). However, I understand that it is desired for the vaults to attain 100-year service life without requiring repairs due to corrosion of reinforcement, so they should be designed to meet CSA Exposure Class C-XL (i.e. minimum of 35 MPa at 56 days, air entrained and have a permeability index of less than 1000 Coulombs at 91 days).

Service Life Modelling

The Life-365 service life model, Version 2.2.2 was used to make time-to-corrosion predictions for four different concrete mixtures. This program was developed to assess highway bridges, parking garages and marine structures, therefore, the default values for the build up of chlorides in the concrete are not suitable. For the purposes of adapting the Life-365 model, it is assumed that on-grade parking slabs will more commonly plowed to remove snow rather than salted, but there will be some salt dripping from parked cars. Also, any salt in the runoff water from the parking lot will become highly diluted as melting snow and ice enters the underground vaults. As

well, the water stored in the tanks will only be there temporarily so chloride contents in the water will not likely build up to high values. Therefore, two different chloride exposure scenarios were modelled, (a) the chlorides in the concrete build up to 0.85% of concrete mass (the same as an urban bridge deck in Toronto), but instead of building to this value in 3.8 years, 100 years was used: this is still a very conservative assumption. (b) the chlorides in the concrete build up to a diluted value of only 0.20% of concrete mass (this assumes a conservative low dilution value of approximately 4x), and building up to this value over the first 25 years.

It is my understanding the clear cover depth to embedded reinforcement will be at least 50 mm. A base slab and wall thickness of 250 mm was used, based on preliminary drawings provided. Two potential concrete air-entrained mix designs were provided to me by DECAST Ltd.: Mix 158 with w/cm = 0.35 and 22% slag replacement of CSA Type GU portland cement, and Mix 336 with w/cm = 0.35 using 15% slag and 85% cement composed of ¾ Type GU cement and ¼ Type GUB8 SF cement (resulting in 2% silica fume in the total cementitious materials). In addition, two other mixtures were evaluated: a Modified Mix 158 with 35% slag, and a Modified Mix 336 with 6% silica fume (i.e. only using GUb8SF blended cement) and 25% slag, both at w/cm = 0.35.

Results

Prediction results are shown in the following tables with values rounded to whole numbers of years. In Life-365, after onset of rebar corrosion, a 6-year corrosion propagation period is assumed before repairs are required.

Chloride Exposure Scenario A: build up to 0.85% Chloride content over 100 years					
Mixture	w/cm	% Slag	% silica fume	Predicted time-to onset of corrosion	Predicted time-to-repair
158	0.35	22	0	54	60
Modified 158	0.35	35	0	70	76
336	0.35	15	2	58	64
Modified 336	0.35	25	6	106	112

Chloride Exposure Scenario B: build up to 0.20% Chloride over 25 years					
Mixture	w/cm	% Slag	% silica fume	Predicted time-to corrosion	Predicted time-to-repair
158	0.35	22	0	67	73
Modified 158	0.35	35	0	95	101
336	0.35	15	2	73	79
Modified 336	0.35	25	6	>150	>150

From the predictions, it can be seen that the assumptions made in selecting both the ultimate chloride content and the rate of chloride buildup have a large impact.

Also, with Mix 158, a 100-year service life is not attained in either exposure scenario but when the slag replacement of cement increased to 35%, the predicted service life by 16 to 28 years. And 100 years is predicted in Scenario B.

Similarly, for Mix 336 a 100-year service life is not attained in either exposure scenario but when the silica fume content is increased to 6% and the slag replacement of cement increased to 25%, predictions greater than 100 years are achieved in both scenarios.

Finally, it must be noted that all service life predictions are merely estimates and are best used to assess relative performance, so the actual years of service life should not be taken to be exact.

In this case, only corrosion of reinforcement due to chloride ingress was modelled. Also, for this analysis, there was no field data available to better define the actual exposure of these concrete vaults to chloride-contaminated water, the two chloride exposure values used were thought to be fairly conservative, so actual service lives could be longer.

Dr. R.D. Hooton, President
Concrete Durability Associates Inc.

APPENDIX C

City of Markham Development Services Committee Minutes dated June 7, 2021, Item 9.1, Recommendation re City of Markham Tanking Storm Ponds and Creating Parkland on Top

Electronic Development Services Committee Meeting Minutes

Meeting Number 13
June 7, 2021, 9:30 AM - 1:00 PM
Live streamed

Roll Call	Mayor Frank Scarpitti Deputy Mayor Don Hamilton Regional Councillor Jack Heath Regional Councillor Joe Li Regional Councillor Jim Jones Councillor Keith Irish Councillor Alan Ho	Councillor Reid McAlpine Councillor Karen Rea Councillor Andrew Keyes Councillor Amanda Collucci Councillor Khalid Usman Councillor Isa Lee
Staff	Andy Taylor, Chief Administrative Officer Claudia Storto, City Solicitor and Director of Human Resources Biju Karumanchery, Director, Planning & Urban Design Bryan Frois, Chief of Staff Ron Blake, Senior Development Manager, Planning & Urban Design Alain Cachola, Senior Manager, Infrastructure and Capital Projects Geoff Day, Senior Planner, Zoning & Special Projects Loy Cheah, Acting Director, Engineering Regan Hutcheson, Manager, Heritage Darryl Lyons, Manager, Policy Brad Roberts, Manager, Zoning and Special Projects	Laura Gold, Council/Committee Coordinator Mary-Jane Courchesne Morgan Jones, Commissioner of Community Services Adam Grant, Fire Chief Martha Pettit, Deputy Clerk Prathapan Kumar, Senior Manager of Infrastructure Nhat-Anh Nguyen, Senior Manager, Development & Environmental Engineer Victoria Chai, Assistant City Solicitor Kimberley Kitteringham, Director, Legislative Services & Communications Peter Wokral, Senior Heritage Planner

Alternate formats for this document are available upon request

Moved by Councillor Alan Ho
Seconded by Councillor Andrew Keyes

1. **That the deputations by Christiane Bergauer-Free, Ian Free, and Elizabeth Brown be received; and,**
2. That the report titled, "INFORMATION REPORT – PHASE 3B: New Comprehensive Zoning By-law Project, PR 13 128340" dated June 7, 2021, be received; and,
3. That the Development Services Committee authorize the scheduling of three non-statutory Open Houses and a Development Services Workshop, as outlined in this report; and further,
4. That staff be authorized and directed to do all things necessary to give effect to this resolution.

Carried

8.3 ITEMS TO BE SENT TO COUNCIL ON JUNE 8, 2021

Moved by Councillor Isa Lee
Seconded by Deputy Mayor Don Hamilton

That the Development Services Committee provide its consent for the following items to go to Council on June 8, 2021:

1) 7.2 – Designated Property Grant

2) 7.3 – Commercial Façade Improvement Grant Program for 2021

3) 7.4 – Heritage Easement Agreement

4) 7.5 – Garden Homes (Markham) Inc., 73 Main Street South, Proposed Draft Plan of Subdivision.

Carried

9. MOTIONS

9.1 CITY OF MARKHAM TANKING STORM PONDS AND CREATING PARKLAND ON TOP (5.0, 6.3)

Councillor Keith Irish assumed the Chair at 1:00 PM

Regional Councillor Jim Jones advised that it has been requested that the motion on the City of Markham Tanking Storm Ponds and Creating Parkland on Top be referred to staff for further analysis.

Committee provided the following feedback on the motion regarding the City of Markham tanking storm ponds and creating parkland on top:

- Suggested that Engineering Staff evaluate the mechanics, capital cost, and maintenance cost of tanking storm water ponds, and that Planning Staff evaluate the effectiveness of tanking storm water ponds to provide parkland ;
- Noted that the tanking storm ponds should be considered on a case by case basis, as sinking the tanks may be more appropriate in certain instances, such as in higher density communities;
- Requested that staff look at what additional policies may be required if storm water ponds were permitted to be tanked on private property;
- Requested that staff breakout the issues so that they can be considered separately.

Biju Karumanchery, Director of Planning & Urban Design, advised that Planning Staff will collaborate with Environmental Services Staff to conduct a cost benefit analysis on the tanking of storm water ponds. Mr. Karumanchery advised that staff will also breakout the issues in their analysis in order for Committee to consider each issue separately.

Moved by Councillor Andrew Keyes
Seconded by Councillor Reid McAlpine

That the motion on the "City of Markham Tanking Storm Ponds and Creating Parkland on Top" be referred to staff for further analysis; and,

That staff report back to the Development Services Committee at a future meeting.

Carried

Recommendation:

Whereas the City of Markham is considered a leader in Community Planning and Development; and,

Whereas the City of Markham recognizes that new Community Development should be premised on the efficient use of land for the benefit of the City and its residents; and,

Whereas the Robinson Glen Block and other areas in the future urban area represents an opportunity for the City to implement industry leading techniques and technologies to create more livable communities; and,

Whereas for example, the current stormwater pond located south of Sheridan Nurseries with a fence around it, should be tanked and parkland created on top as it is in a high density urban area and be financed by Kingdom Development because of their parkland deficiencies and they should be given a parkland credit; and,

Whereas the Langstaff Gateway has been approved for stormwater storage tanks 11 years ago and parkland will be created on top of the tank and Condor should be given a parkland credit; and,

Whereas the City of Markham's $40 million stormwater pond being created on the west side of Torbay Road should be tanked and parkland created on top (in this case a bubbled sports dome that creates the equivalent of two regulation soccer fields) and be classified as parkland and paid for by applicants who have parkland deficiencies in their development applications submitted; and,

Whereas the City of Markham needs to hire a civil engineering firm like SCS Consulting Group, Shaffer Consulting or Urbantech Engineering and engage B+H Architects to work on the Torbay Sports Fields Centre Concept; and,

Whereas when storm ponds are identified in complete destination Transit Oriented Community stations, they should be tanked and parkland created on top because it makes a more desirable urban public realm; and,

Whereas any storm ponds installed or being installed and requires fencing, indicates they are unsafe for the public, therefore tanking the storm ponds should be considered and parkland created on top; and,

Whereas storm ponds created in TOC communities, tanking the storm pond should be considered as they serve a dual purpose, 1st, as a stormwater storage tank, and 2nd, parkland on top of very expensive lands; and,

Whereas parkland cash-in-lieu is taken because the application doesn't have sufficient parkland contribution; and,

Whereas, parkland cash-in-lieu is worth approx $3,750,000 in Markham, but it is subject to a market value appraisal, Lands in Markland Centre, Langstaff

Gateway / Richmond Hill Centre and Vaughan Metropolitian Centre are valued between $13,000,000 to $25,000,000 per acre; and,

Whereas one such technique is to discontinue where possible, the practice of constructing traditional style land-consumptive open stormwater ponds; and,

Whereas it is recognized that open stormwater detention ponds are an undesirable inefficient use of land, collect unsightly garbage, are unsafe and dangerous to local residents and present a local breeding ground for disease carrying mosquitos; and,

Whereas the use of underground stormwater storage tanks will eliminate the undesirable impact of traditional stormwater detention ponds; and,

Whereas underground stormwater storage facilities create an opportunity for the City to develop more parkland for active and passive recreation for the benefit of the residents of the municipality; and,

Whereas the annual maintenance cost of underground stormwater detention facilities is significantly less, relative to the traditional stormwater detention ponds; and,

Whereas underground stormwater storage facilities meet or exceed stormwater management standards with a design life of 100 to 150 years and will only require minor maintenance during that period to extend beyond that period of time. Further, the total life cycle for the water storage tanks are up to 200 to 300 years, rendering the City's Alternative Infrastructure Policy unnecessary; and,

Whereas the City will peer review the detailed structural design of the underground tanks at the expense of the proponent; and,

Now Therefore Be It Resolved,

1. That the City of Markham endorse and approve the use of underground stormwater storage facilities in all residential, industrial and commercial developments as they are a benefit to the Community by providing opportunities for usable parkland, etc; and,

2. That the City of Markham not impose the Alternative Infrastructure Policy for the use of underground stormwater storage facilities; and,

3. That the City of Markham endorse and approve the use of underground stormwater storage facilities for the Torbay Properties in the Markham's Steeles-area to provide the required stormwater protection and resolve an existing on going flooding problem; and,

4. That the Chief Administrative Officer for the City be authorized to negotiate a fair parkland credit for the parkland created by the use of the underground stormwater storage facilities and come back with a stormwater storage tank and parkland on the top policy,

5. That the Commissioner of Development Services develop a stormwater management retrofit plan strategy and identify the storm ponds that could be converted to a water storage tank with parkland on top.

Be it further resolved that a copy of this resolution be sent to:

- Hon. Jeff Yurek, Minister of the Environment, Conservation and Parks;
- Hon. Steve Clark, Minister of Municipal Affairs and Housing;
- Hon. Laurie Scott, Minister of Infrastructure Ontario
- Hon. Victor Fedeli, Minister of Economic Development, Job Creation and Trade;
- Hon. Lisa MacLeod, Minister of Heritage, Sport, Tourism and Culture Industries;
- MPP Billy Pang, Parliamentary Assistant to the Minister of Tourism, Culture and Sport (Tourism);
- MPP Vincent Ke, Parliamentary Assistant to the Minister of Tourism, Culture and Sport (Culture and Sport)
- Debbie Low, President & CEO – Canadian Sport Institute Ontario
- John MacKenize, CEO, Toronto, and Region Conservation Authority.
- Chris Raynor, Regional Clerk, Regional Municipality of York;

Referred

9.2 RICHMOND HILL GO TRANSIT LINE - OPPORTUNITY FOR A TOC GO STATION AT GREEN LANE/JOHN STREET AREA (5.14)

Deputy Mayor Don Hamilton assumed the Chair at 1:18 PM.

Committee supported staff investigating the opportunity of having a GO Station at Green Lane and John Street on the Richmond Hill GO Transit Line.

Moved by Regional Councillor Jim Jones
Seconded by Councillor Keith Irish

Malone Given Parsons Ltd.
201- 140 Renfrew Drive
Markham Ontario
L3R 6B3 Canada

1-905-513-0170 **mgp.ca**

ATTACHMENT 2

MEMO

TO: Saad Yousaf, P.Eng., City of Vaughan

FROM: Steven Van Haren, P.Eng., WSP

SUBJECT: Peer Review of "Dual-Use Stormwater Facilities Policy Paper, Dec. 2021"

DATE: May 20, 2022

Executive Summary: A policy paper has been advanced by a group of private companies ("Policy Paper: Dual-Use Stormwater Facilities Policy Paper, prepared for: The City of Vaughan, ON, MGP Ltd., SCS Consulting Group Ltd., and Schollen & Company Inc., Dec. 2021") promoting an alternative to traditional wet ponds as a preferred Stormwater Management approach. WSP has peer reviewed the policy papers and made recommendations and observations related to it. A summary of the most relevant points is as follows:

- Traditional wet ponds are a common approach to addressing stormwater management requirements for new development, but require significant amount of developable land, and have issues with increasing temperatures in pond discharge, as well as some issues with how water quality treatment is provided.
- The steadily increasing value of land is driving innovation in the application of publicly owned and operated Stormwater Management Facilities, traditionally configured as wet ponds.
- Underground Stormwater Management Facilities (UGSWMF's) are promoted as an equivalent approach with some noted benefits above the traditional approaches such as thermal issues. Traditional approaches retain some benefits such as passive recreation opportunities.
- UGSWMF's can be installed below park land or other appropriate publicly owned lands to allow the previously separated land dedications to be combined into a single dedication as a "Dual-Use Stormwater Management Facility (DUSWMF)". This will lead to conservation of land for additional programming.
- Operation and Maintenance issues are not similar between traditional SWMF's and UGSWMF's or DUSWMF's.
- There are specific issues to address with UGSWMF's including odor control and water quality treatment. UGSWMF's should be configured to drain fully between storm events and provide an appropriately designed treatment train based water quality treatment approach upstream of the UGSWMF's.

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- UGSWMF's provide cooler runoff that would normally heat up in open water SWM ponds, particularly during the summer months. This will benefit receiving water systems, particularly those with endangered species often associated with cold water fisheries, such as red side dace systems.
- UGSWMF's should be configured with separate water quality treatment systems to avoid storing runoff underground between storm events. This will ensure that receiving water systems, such as creeks, are not impacted by water discharges with low dissolved oxygen concentrations.
- When configured appropriately, UGSWMF's and DUSWMF's may be considered an appropriate approach for addressing stormwater management issues associated with land development applications.

In summary, WSP recommends that the use of UGSWMF's and DUSWMF's may be considered as a valid Stormwater Management approach when considering land development applications. Any such strategy requires significant justification in the form of design documentation and review processes from an engineering and urban planning perspective,but do not require adjustments to the City's planning and development review processes. Significant issues remain to be addressed including specific risks associated with procurement, installation, operations and maintenance, but WSP has not identified any fundamental obstacles to consideration that place an undue burden on the City from consideration of such systems.

Yours sincerely,

Steven van Haren, P.Eng.
Manager, Land Development/Water Resources
Land Development and Muncipal Engineering

MEMO

TO: Saad Yousaf, P.Eng., City of Vaughan

FROM: Steven Van Haren, P.Eng., WSP

SUBJECT: **Peer Review of "Dual-Use Stormwater Facilities Policy Paper, Dec. 2021"**

DATE: **May 6, 2022**

Introduction & Objective: The City of Vaughan (the City) has retained WSP Canada Inc. (WSP) to provide peer review commentary on a policy paper ("Policy Paper: Dual-Use Stormwater Facilities Policy Paper, prepared for: The City of Vaughan, ON, MGP Ltd., SCS Consulting Group Ltd., and Schollen & Company Inc., Dec. 2021") submitted to the City detailing the perceived benefits of a new style of 'end of pipe' stormwater management facility (a "Dual-Use Stormwater Management Facility, DUSWMF"). These systems are conceived to combine the active storage performance of a traditional stormwater management approach for land development applications in an underground structural system specifically designed and constructed to contain the additional runoff created from the conversion of natural and pervious areas into relatively impermeable development areas. These Dual-Use facilities provide a compelling promise to remove impediments to conserving land by combining underground stormwater management functions with low loading surface uses (such as parks and recreational uses) and allow for more usable land that would otherwise be dedicated to one or both of those uses in a more 'traditional' approach. WSP notes that these systems cannot function identically to traditional stormwater management facilities such as wet ponds or constructed wetlands due to numerous considerations for how water quality treatment goals will be met and the hydraulic principles required in each system to provide the stormwater management functions. We also note that underground systems tend to improve on traditional stormwater management facilities in many ways, while they also face challenges in other areas, such as dissolved oxygen concentrations that are not associated with traditional facilities.

General Comments: In most areas, open water ponds (as part of a natural system, stormwater management facility, or otherwise) are not a common feature in the landscape. Areas of natural pond presence tend to be a result of glacial action, such as the numerous natural ponds and small lakes of the Oak Ridges Moraine (aka 'kettles'), or as a result of artesian groundwater pressure or streamflow collecting in shallow or deep surface depressions that have developed over a geologic time scale. It is actually more common to encounter open water areas that are a feature of a traditional stormwater

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management facility or flood control facility in the urban areas of the Greater Toronto Area than a natural pond. Secondly, open water areas were not present in traditional urban areas before the late 1970's when policies that addressed the additional runoff from development began to be a requirement for development approvals. It is understandable that the most common form of stormwater management facility implemented is the 'wet pond' as it tends to provide the required stormwater management functions in the smallest footprint for the smallest overall investment, resulting in numerous private and public wet ponds throughout the Greater Toronto Area. The City of Vaughan currently owns and operates approximately 150 stormwater management facilities, of which the majority are wet pond style. It is WSP's opinion that the Dual-Use Stormwater Management Facilities Policy Paper has been prepared to illustrate the perceived benefits of an 'innovation' to the wet pond approach that combines park land and stormwater management facility footprints into a single block, allowing for more development or other land uses, as appropriate. This approach is becoming financially feasible as land values continue to increase in the GTA, and the stormwater management facility footprint area that would normally be a requirement for approval of a subdivision application (or other land development application) becomes a larger cost item on the development project's overall budget that can be mitigated with this approach.

WSP is concerned about the potential for UGSWMF's configured with permanent pools (which provide a close to zero flow energy area where sediment will fall out of suspension) will introduce conditions where low dissolved oxygen concentrations are present. This situation is likely to produce noxious odors (such as hydrogen sulfide due to reductive chemistry present in low dissolved oxygen conditions) as well as facility discharge that reduces overall dissolved oxygen concentrations in the local receiving water system, which would impact fish and aquatic ecological communities. We recommend that any UGSWMF be configured to temporarily store runoff volumes to the level required by the relevant policies, but that the systems should be configured to drain fully between precipitation events. In addition, water quality treatment should be provided by upstream treatment-train based approaches that remove sediment into more easily accessible areas for removal during maintenance activities. An exception to this would be integrated water quality filtration or gravity-based removals that do not require the presence of a sustained underground pool of water (such as isolator rows in plastic hemispherical chamber systems).

The following are specific comments by WSP on the contents of the policy paper and should be read in conjunction with it. The bolded, underlined text below refers to the relevant section of the policy paper.

Executive Summary: The statements made in the policy paper's executive summary are generally factually correct, however the conclusions reflect the judgement of the authors instead of an independent analysis. In effect, there is a bias present for promotion of the Dual-Use Underground Stormwater Management Facilities in place of traditional stormwater management facilities. In addition, the purpose statement does not discuss the need to compare Dual-Use Stormwater Management Facilities to traditional Stormwater Management Facilities, which would arguably be of increased utility to City staff.

Section 2.0 Application of Dual-Use Stormwater Facilities in the City of Vaughan, Greenfield Development: The statement that surface based wet pond style SWMF's have no above-ground usability is misleading. The aesthetic benefits to local residents and contribution to a pastoral setting often associated with open spaces is an undervalued benefit that is generally not considered by a municipality when the wet pond is only considered as a City infrastructure component. These facilities do contribute to passive recreation and an attractive feature along active transportation routes. The discussion on the use of Regional Storm Control facilities stating that quality treatment could be provided in the underground components is not recommended by WSP. The statement should be revised. **Intensification Development**: WSP's position is that UGSWMF systems related to intensification development will typically be located on private property and the statement that dual-use facilities provide the opportunity to create parks and other benefits is unsupported as the presence of an UGSWMF will not impact any site planning actions. **Vaughan Metropolitan Centre (VMC) Development**: The discussion here is focussed on increasing the use of UGSWMF's in context to the VMC master plan to preserve or increase the number of parks and open space in the face of intensified development pressures above the original master plans. WSP agrees that UGSWMF's have potential to allow for increased density while maintaining the original proportion of open space and park areas, but caution is required due the additional potential to introduce infrastructure conflicts and encumbrances on park lands due to these systems.

Section 3.0 Benefits of Dual-Use Stormwater Facilities: Summary of Benefits: WSP finds these bulleted items to be of a general nature, and while not factually inaccurate, do not provide much context for how these benefits are provided. Most of these items are required of any SWMF and therefore do not provide much information on how Dual-Use systems are superior in this regard. **Land Utilization**: WSP agrees that the vertical walls of UGSWMF's allow for a reduced footprint while providing similar volumes of active storage, a major benefit of these systems. The remaining discussion in this section discusses the use of the area above the UGSWMF and its various options for configuration. Most of these will be affected by various Municipal policies related to urban planning. The statement that additional parkland or community gathering space seems out of place, as the premise of the policy paper is that space for parkland and traditional SWMF are combined to conserve land, presumably for additional development as evidenced by the cost estimate in Section 6.0 that describes the additional tax & development charge revenue realized by these systems, which cannot be generated from additional parkland. We note that the provided table does not include major repairs or replacement costs. These costs are a vital concern for a municipality to consider to ensure long-term operations and maintenance considerations are addressed. These tables should be revised to include these costs, but we recognize that various practices will continue to evolve in the future and their related costs will be approximate for the time being. **Safety**: WSP agrees that UGSWMF's provide improved safety compared to open water based SWMF's due to reduced probability of exposure to drowning hazards, particularly for special needs and other residents for whom warning signs may not be an effective deterrent. Fencing and other barriers to address this hazard near wet ponds are often ineffective or neglected over time and may only be effective in reducing liability rather than improving safety. In terms of mosquito larvae, WSP does not

believe that open water based SWMF's or UGSWMF's provide any significant contribution to mosquito-based disease vectors due to predation and shallow wave action that disturb the development of mosquito larvae. Larger open water bodies do not provide sufficient suitable habitat for the development of mosquito larvae, and public perceptions of SWMF's as contributing to West Nile Virus or other issues are overblown, if not incorrect. Any discussion on the benefits of UGSWMF's compared to traditional SWMF's is unsupportable on this issue. **Aesthetics**: WSP agrees that UGSWMF's provide a preferred approach to traditional open water based SWMF's in the vicinity of airfields due to the reduction in propensity to attract waterfowl or other avian hazards near flight paths. WSP does not support the shallow burial of access locations due to the propensity to lose track of their location as documentation processes evolve. WSP does not agree with the statement that parkland amenities with fewer safety risks (implying that UGSWMF's are preferred to traditional SWMF's in this issue) are preferable from a mental health perspective as the statement is subjective and unsupported. It also reveals a bias by the authors to the use of UGSWMF's over traditional SWMF's. **Thermal Impacts:** The statements in this section are generally supportable. The various techniques to mitigate thermal impacts from open water based traditional SWMF's are known to be inefficient and considered as 'band-aid' style solutions that do not fundamentally address the issue of thermal aggradation associated with these systems. UGSWMF's provide a subsurface tank in thermal equilibrium with native soils and groundwater, which acts as a thermal heat sink. In essence, the propensity for thermal aggradation is removed, addressing that specific issue in a comprehensive manner. This is superior to open water based surface SWMF's for which the water must be cooled after the fact, by systems with varying levels of efficiency. **Maintenance and Installation:** The statements in this section are generally supportable. However, WSP cautions that UGSWMF's may suffer from an "out of sight, out of mind" issue and municipal staff replacement over time may contribute to neglected maintenance or consideration of these systems compared to surface based SWMF's that are easily noticed and contemplated on visual inspection by newer employees.

4.0 Policy Framework and Rationale: WSP has reviewed the policy references provided and confirmed that the content of the policy paper has summarized the issues and remained true to the context of the referenced policy documents. Most references are direct extracts of text from the referenced documents, and those that aren't are correctly interpreted. In general, the conclusions related to the content of the Provincial Policy Statement (PPS) are supportable. We note that the PPS is silent on the issue of traditional vs. UGSWMF's but the PPS does clearly support innovation in SWMF implementation as referenced in section 1.6.6.7 f) in the use of "best practices". In addition, the text of section 1.6.6.7 c) charges the various levels of government to consider the impacts of climate change in water balance, for which UGSWMF's have considerable advantage over traditional SWMF's. The statements related to the York Region Official Plan appear supportable and in context to the relevant text. Lastly, the policy paper appears to have correctly interpreted the intent of the TRCA letter included in its appendix based on WSP's review and a personal conversation with the author of it, Sameer Dhalla, P.Eng.

5.0 Engineering Overview of Dual Use Stormwater Facilities: Groundwater Interaction: WSP finds the statements in this section factually accurate, but the discussion on floatation potential would be of increased utility if it referenced an appropriate "factor of safety" related to buoyancy resistance by the facility. WSP does not agree with the statement on UGSWMF's outfitted with a permanent pool as that is not a preferred configuration for this system due to issues with dissolved oxygen concentration. **SWM Facility Design Considerations**: WSP agrees with the first paragraph in this section, but does not agree that a permanent pool should be integrated into an underground SWMF. The 'alternative' arrangement is preferred over an underground permanent pool due to issues with environmental performance, maintenance of water quality treatment systems and other issues, as outlined in various portions of this document. **Outlet Design Considerations**: This section should include a discussion about the relative elevations of outlet controls due to the loss of available head from the presence of UGSWMF's. A traditional, gravity-based SWMF would be preferred over an UGSWMF that relies on a pumped solution for discharge due to operational costs and the need for easements for electrical service alone. **Erosion and Sediment Control During Construction**: No specific comments.

6.0 Maintenance, Installation, Life Cycle, and Costs: Specific commentary on this section is provided in the detailed answer to Q3 below.

7.0 Above Ground Uses: WSP does not offer specific comments on this section, as the issues are better addressed by municipal staff affiliated with urban planning and parks development. We generally support the discussion and conclusions of this section, and note these additional points:

- Recreational uses above UGSWMF's should not use items that require structural foundations, supports or other infrastructure when insufficient cover is available.
- The SLZ area is an additional requirement of UGSWMF's to facilitate repairs or rehabilitation / replacement.

Questions Raised by City of Vaughan Staff & Responses to Specific Issues

Q1: Does the intent / purpose of the policy paper report ensure it is operationally and financially feasible for the City to adapt to dual SWMFs? The answer to this question should be supported by a decision matrix based on the comparison of a dual-use SWMF with a conventional SWMF in terms of cost, social, environmental, constructability, and operational criteria

A1. The policy paper does not provide a direct answer to this question, but it is presenting and supporting underground stormwater management facilities as a valid and innovative alternative to traditional stormwater management facilities. The paper does not provide discussion on the relative pros and cons of traditional stormwater management facilities versus dual-use underground stormwater management facilities. To address this question, the following decision matrix has been prepared.

Assumptions. Proponents are responsible for procurement, construction, commissioning, and warranty of underground stormwater management facilities similar to traditional stormwater management facilities and assume that a constructed DU/SWMF will be provided in an identified block of property in a manner similar to current practices. Some of the items in the decision matrix below may be affected if the above process is modified.

PARAMETER	TRAD. SWMF	DU-U/G SWMF	NOTES: DARKER CIRCLES IMPLY IMPROVED PERFORMANCE
Cost			
Land Value	○	●	High land values favor U/G SWMF.
Capital Cost	●	○	Trad: Capital Costs nominal (earthworks). U/G: Capital costs 2 – 3x higher.
Maintenance	◑	◑	Trad: untidy, long restoration periods. U/G: offers quicker, outsourced maintenance.
Social			
Safety	◑	●	Trad: accessible open water. U/G: no open water areas.
Aesthetics	◕	◑	Trad: Ponds with open water. U/G: turf areas
Nuisance	○	◑	Trad: perceived as illness vectors (West Nile, unclear water). U/G: non-preferred habitat for vector biology.
Recreation	◕	◔	Trad: passive options. U/G: park related options only.
Environmental			
Thermal	○	●	Trad: thermal aggradation issues. U/G: acts as heat sink to cool discharges.
Water Quality	◕	●	Trad: has integrated treatment via gravity settling. U/G: off-line treatment with addt'l options for filtration.
Footprint	◑	●	Trad: pond sloping required. U/G: Vertical walls.
Erosion	◕	◕	Both options dependent on design

PARAMETER	TRAD. SWMF	DU-U/G SWMF	NOTES: DARKER CIRCLES IMPLY IMPROVED PERFORMANCE
Infiltration	○	◑	Trad: generally, not feasible. U/G: Infiltration feasible.
Constructability			
Complexity	◕	◔	Trad: open excavation, earthen composition. U/G: confined space entry, need for air displacement, structural analysis, etc.
Materials	◕	◔	Trad: Native materials with less concrete. U/G: Increase in imported concrete
Operations			
Simplicity	◑	◕	Trad: Batch-flow and plug-flow system dynamics. U/G: Offline treatment followed by storage.
Recovery	○	◕	Trad: Vegetation recovery slow with disturbed soils. U/G: Same-day recovery after maintenance.
Advantage	✗	✓	

To summarize, in terms of the major performance metrics, dual-use underground stormwater management facilities appear to be superior in most areas, while traditional stormwater management facilities have several advantages. In essence, had dual-use underground stormwater management facilities been available and sufficiently developed in 2003, it is my professional opinion that they would have been included in the 2003 Stormwater Management Planning and Design Manual in Chapters 3 and 4, where valid end of pipe stormwater management facilities are outlined and summarized. At that time, they would likely have been considered cost prohibitive. However, the rapidly increasing value of land convincingly shifts the discussion on the use of dual-use systems as a valid alternative that does not impose an excessive burden on the assuming municipality based on the analysis presented in this decision matrix.

Q2: Has the dual-use SWMFs policy paper fulsomely referenced the relevant legislation and Official Plan policies related to parks and stormwater management?

A2. WSP reviewed the specific references in the paper's Provincial Policy Framework, correlating the text entries to the source documents and found the references to be faithfully interpreted as they apply to the subject of underground stormwater management facilities. In most cases, the referenced text is either a direct extract of wording from the referenced documents or has been correctly interpreted in the paper's context. The papers conclusions on the relevance of the Provincial Policy statement are supportable. WSP notes that the Provincial Policy Statement is silent on issues of traditional vs. underground stormwater management facilities but does directly support innovation in stormwater management facilities through the use of "best practices". WSP's opinion is that underground stormwater management facilities meet the description of a best practice when it is demonstrated that the alternative facility can convincingly and defensibly address the required stormwater management policies through the relevant design documents that satisfy the affected Conservation Authority's and municipality's development related policies.

Q3: Is the comparison of conventional SWMF versus Dual-Use SWMF (underground storage tank below City Park) reasonable, in terms of?

a. sediment cleaning frequency
b. structural inspection / rehabilitation frequency of the concrete tank
c. overall life cycle cost
d. maintenance costs
e. capital cost

A3.

i) Sediment Cleaning Frequency: There is no typical straightforward comparison applicable here between the two options, as UGSWMF's should not be configured with inherent underground treatment capacity (like a submerged permanent pool for gravity based settling of suspended solids) due to concerns with low dissolved oxygen concentrations. Upstream treatment-train based measures may require more frequent cleaning as they tend to be smaller scale than sediment forebays and main cells in wet ponds, but have more defined clean-out processes that may be implemented quicker, with less reestablishment time. Clean-out frequencies on UGSWMF's outfitted with a permanent pool (not recommended) will be at least twice as frequent and significantly more expensive due to additional manpower requirements and confined space entry procedures. Sediment cleaning on treatment separated tank arrangements is expected to be similar, if slightly less, than a traditional stormwater management facility pond. Sediment removal from upstream treatment-train systems may be more frequent but less costly depending on the amount of upstream loadings.

ii) Structural Inspection / Rehabilitation Frequency of the Concrete Tank: The policy paper provides a well-conceived and described approach to structural and rehabilitation issues related to underground stormwater management facilities. It is difficult to establish a standardized structural inspection or rehabilitation frequency in the absence of site-specific design issues (such as upstream drainage area characteristics) but the inspection and rehabilitation frequencies included in the policy paper, based on a typical application, seem reasonable on review and within the "Order of Magnitude" consistent with normal SWM practices. Structural inspection frequency may be minimized by using approved precast systems that benefit from improved quality control processes at the factory compared to cast-in-place systems, but certain components (such as joint waterproofing, where required) cannot be applied prior to installation and may affect the inspection frequency depending on the quality of the construction and installation processes utilized.

iii) Overall Life Cycle Cost: The lifecycle cost breakdown presented in Section 6.0 of the policy paper seems reasonable based on the assumptions attached to it. It is not possible to account for all variables, and the analysis does not account for the time value of money, so projection to any specific case or site is not possible. However, from a comparison perspective, the analysis seems reasonable and sufficiently comprehensive to show essentially equivalent annualized costs between the two options. The additional tax revenue items at the bottom of

the table imply that securing the property that would normally be dedicated to either a surface stormwater management facility or a park for other uses is offsetting any cost considerations for underground systems is highly subjective and should be removed from the table as it skews the conclusions in a biased manner. It should be noted that given the relative infancy and limited number of examples of UGSWMFs implemented in municipalities at the moment, the overall lifecyle comparative costs between SWMFs and UGSWMFs are still yet to be accurately determined and can be considered highly variable depending on a number of factors including but not limited to the location, the size of the drainage area, major repairs, replacement costs, regulatory impacts, etc. It is recommended a full detailed analysis of life cycle costs between traditional SWMF's and UGSWMF's be included in future policy development.

iv) Maintenance Costs: The detailed assessment of maintenance costs takes a "straight line" approach to distributing low frequency, but high cost items such as pond clean out, inlet / outlet structure reconstruction, concrete rehabilitation, LID system replacement, etc. to estimate an annualized cost. This may skew the conclusion as those costs must consider an inflation rate or other approach to provide a reasonable annualized cost for future expenditures. If the intent of the assessment is to compare traditional stormwater management facilities to underground stormwater management facilities, the effect is minimized, but it diminishes the reasonableness of the future cost estimates when projecting likely future costs for those items. It may be more appropriate to consider these comparisons using a "net present value" approach based on appropriate inflation rates.

Capital Cost: Section 6.0 of the policy paper provides a capital cost summary section but the cost tables it references list maintenance costs, not capital expenditures. The policy paper does not discuss initial or ongoing capital costs to procure, install and commission underground stormwater management facilities versus traditional stormwater management facilities. However, it is assumed that initial capital expenditures will remain the responsibility of the developer or other project proponent and be relevant to the assuming municipality. WSP anticipates that capital costs for underground stormwater management facilities to be much higher (possibly 2 to 3 times higher) than a typical traditional stormwater management facility when the cost of land is excluded from the consideration, due to the much higher amount of precast items and infrastructure required. This will be an issue for consideration of replacement costs should the systems fail over time should replacement costs be considered in the overall life cycle cost analysis. WSP anticipates the probability of a failure requiring full replacment to be exceedingly low, but the cost comparison should account for likely replacement costs based on varying amounts of system repair (i.e. 10%, 25%, 50%, 75%, 90%, 100% replacements). As mentioned in the General Comments, underground stormwater management facilities are a response to increasing land values when this important consideration is accounted for. Traditional municipal approval approaches involving the dedication of separate surface-based stormwater management facilities and park blocks by the proponent will be under significant cost pressure for revision as land values increase

exponentially in urban or urban adjacent settings as the land values are expected to offset the higher capital costs of the underground stormwater management facility, resulting in less overall cost to the proponents when considering all cost related factors.

Q4: Is the anticipated service life of precast concrete / concrete and plastic underground storage storm system and any similar underground tank products realistic and reasonable?

A4. WSP finds that the statements made by the University of Toronto Civil Engineering professor on the service life of underground precast stormwater storage tanks to be reasonable and defensible. The argument is supported by fundamental analyses, the parameters used in the modelling results appear appropriate and the modelling software that was utilized is a well-known software package specifically created to address this issue. WSP notes that the concrete mixture utilized in the construction of the pre-cast units has an outsized impact on the anticipated service life, and that the "Modified 336" mixture delayed the onset of rebar corrosion by double the duration of a more common "158" mixture. WSP recommends that the anticipated concrete mixture be detailed in any proposal for the use of an underground stormwater management facility to ensure the service life estimate is consistent with the project subsurface conditions.

Q5: Have the potential development opportunities and limitations on top of the underground concrete tank been fully explored?

A5: It is not possible to state that potential development opportunities and limitations for land uses above the underground facilities have been exhaustively explored. The paper has outlined various potential uses as examples of appropriate applications above the underground systems in an attempt to showcase how parkland can be combined with stormwater management functions in a single facility footprint. All of the proposed uses above the tanks correlate with uses that do not require extensive foundation elements or servicing infrastructure that would presumably conflict with the relatively shallow depth of cover over them. As cover depth above the tank is rarely expected to exceed 1.2 m, it is reasonable to assume that cover materials will freeze solid in the wintertime due to advancing frost depth, so foundations or infrastructure in such a position would be at risk. While most underground storage systems have criteria to support AASTHO HS-20 or HS-25 loading criteria (meaning they could support standard live loads for highway bridge designs), the authors of the policy paper suggest that land use above the underground facilities be limited to recreational and park uses to ensure that actual loadings never approach the limits of them.

Q6: Has the structural review of the underground concrete tank including foundation requirements to minimize settling been properly assessed?

A6. The Dual-Use Stormwater Management Facility paper does not attempt to provide a comprehensive structural review or foundation requirements to minimize settling, as that would be a function of the specific soil properties in the individual site locations. The paper has demonstrated that structural concerns related to underground concrete installations are appropriate for typical settings within the acceptable range of native structural soils present in

locations with generally acceptable soil properties. However, modifications may be required in areas of poor or structurally inappropriate locations, which may increase the cost of such systems. Whether that will make the system prohibitively expensive compared to a traditional stormwater management facility will be dependent on the project site setting.

Q7: Has the Policy Paper provided sufficient empirical evidence from other public agencies for the effective use and implementation of underground SWMF systems?

A7. The question of sufficient empirical evidence is subjective to the reader of this peer review memorandum. However, the paper has documented the use, approval, and satisfactory performance of various types of underground stormwater management facilities in a multitude of local applications, both on private and public property. The ratio of underground SWMF's to traditional SWMF's is small but growing and additional empirical evidence will emerge over time. At this point, it is WSP's professional opinion that the amount of empirical evidence available supports the use of UGSWMF's as a valid alternative to a traditional SWMF's when configured properly and defensibly by the proponent. Each approach has its advantages in certain areas, but the weight of evidence suggests that both approaches will produce adequate performance in the areas of flow control, quality treatment and erosion control when appropriately designed and constructed. Water balance is a more complicated issue to address as that issue applies to the facility and its upstream catchment area, as well as the specific site setting, so a comment on that issue in context is not applicable.

Q8: Has the Policy Paper sufficiently explored the socio-economic impacts of conventional SWMF versus Dual-Use SWMF?

A8. The answer to this question is also subjective to the reader, however, a comprehensive socio-economic analysis has been provided that details numerous benefits from the combination of SWM and park blocks into a Dual-Use SWMF block. WSP finds the statements to be generally supportable and the reported benefits attractive from a stormwater management design perspective. Issues of open water liability to the municipality from residents' use of or exposure to open water systems have been discussed and highlighted, with the benefit clearly in favor of underground systems from a safety and liability perspective. However, under an assumption that the Dual-use facility would host the same recreational block as a traditional SWMF approach, the paper doesn't address the loss of aesthetic and passive recreation typically associated with open water based SWMF's. While most municipalities typically treat wet ponds and other surface based SWMF's as an infrastructure component, traditional facilities do provide pastoral settings and facultative wildlife benefits that are considered a 'bonus' to area residents that live in proximity to them, despite not being included in the municipality's natural heritage resources. As a result, it is difficult to account for the loss of those bonus features, or the municipality will be at risk of trying to "have it both ways."

Q9: The Consultant shall provide conclusions and recommendations to the City for next steps.

A9. The policy paper is focused on the example of the I-Storm system by DeCast for large scale underground storage systems intended to function similarly to the active storage component of traditional wet ponds. The City should request a discussion with the authors of the policy paper on the issue of dissolved oxygen concentrations in dual-use systems to ensure that downstream receiving waters do not experience negative impacts from the use of them. In addition, City policy should specify that UGSWMF's be limited to providing integrated flow attenuation, storage, and water balance functions (including groundwater recharge and infiltration) rather than providing integrated water quality treatment to avoid the use of permanent pools of water below ground, which WSP discourages. These permanent pool systems are likely to result in stagnant water that produces low dissolved oxygen discharge with the potential for hydrogen sulfide or other noxious odour issues. WSP recommends that the City develop policies that UGSWMF's should be designed to fully empty between storm events, save for small depths of water intended to infiltrate fully after an appropriate design interval to avoid the slow release of dissolved oxygen and development of stagnant water in difficult to access locations.

Q10: UGSWMFs will require frequent access due to maintenance activities such as inspections, sediment clean-out, repairs, and rehabilitation. Will this access be disruptive to the surface of the above ground amenity area?

A10. While it is possible that UGSWMF's experience this kind of maintenance activity, much of this can be performed with little to no disturbance of the above ground amenity areas if access points are sited correctly during detailed design stages. Much of the works described involve inspections which are likely minimally invasive, while cleaning, corrective maintenance, emergency spill response and other activities likely to involve major equipment and disturbance will be relatively rare events that, in most cases, can be planned to minimize disturbance and access impediments to the above ground amenities. Amenities above the UGSWMF may or may not be able to sustain truck and vehicle loading in a manner similar to amenities not associated with an UGSWMF. Inspection and maintenance would typically be performed through appropriately designed access hatches with facility specific Operations and Maintenance requirements. Therefore, there is no fundamental reason to associate amenity areas with repeated surface rehabilitation after a maintenance or inspection activity.

Q11: Open bottom UGSWMFs can provide opportunity for groundwater recharge, enhanced water quality, and runoff reduction. Are there any specific maintenance considerations for these systems?

A11. The maintenance of open bottom UGSWMF's with infiltration layers would follow similar procedures to the maintenance of permeable unit pavers or other LID systems that rely on the open permeability of surface layers in contact with runoff, assuming appropriately sized equipment can be mobilized inside the system. UGSWMF's with off-line water quality treatment (through upstream treatment-train based processes) can be assumed to have virtually sediment free runoff stored within them, which limits the rate that infiltration beds will become 'clogged'. Like

permeable paved surfaces, these surfaces do not tend to become clogged uniformly or quickly, but rather have a gradual reduction in permeability that can be restored with typical maintenance when designed with infiltration in mind. Each UGSWMF design should include specific O&M requirements to maintain their associated infiltration beds.

Q12: UGSWMFs do not generally have quality control functions comparable to stormwater management ponds so UGSWMFs often rely on upstream treatment-trains to provide suitable quality control. The Policy Paper speaks to the use of filter type pre-treatment units however, the City does not currently permit filter type pre-treatment units within the public right of way due maintenance considerations. Should the City reconsider this approach?

A12. WSP agrees that UGSWMF systems should not incorporate a permanent pool or other integrated water quality treatment system inside it, as any approach will accumulate sediment in an inconvenient (and expensive) location to remove. Water quality treatment should be provided upstream with a treatment-train based approach that removes sediment in a manner that is easier to access and maintain. WSP also agrees that pre-treatment filter units within the public ROW can be problematic, but still believes that filter units can be part of a treatment-train based approach if provided with appropriate pre-treatment approaches to remove gross particulates prior to filtration, such as provided by upstream gravity-based or hydrodynamic separation-based OGS units. Bioretention and other LID systems as pre-treatment systems upstream of a filter-based oil / grit separator unit may also be an applicable approach. Filtration is inherently superior to gravity-based settling in the area of fine particulate removal, which will be crucial to ensuring that UGSWMF's are not configured with integrated underground quality treatment functions or be susceptible to clogging of infiltration based functions.

Q14: Are UGSWMFs recognized under the Ministry of the Environment, Conservation and Parks' (MECP) Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA) as typical sewage infrastructure?

A14. WSP does not believe that the CLI ECA has considered Dual-Use UGSWMF's in its current form. The objective of the CLI ECA is to streamline processes for low-risk projects. Therefore, it is likely that initial installations of Dual-Use UGSWMF's will not qualify for the CLI ECA process but may require an Individual ECA process until the requirements for them meet the low-risk criteria. However, WSP anticipates that the risk associated with UGSWMF's does not exceed the risk associated with a traditional SWMF, so approval for UGSWMF's under the CLI ECA process should not be unduly postponed or onerous. That process will be specific to the conditions of the municipality's individual CLI ECA.

Q15: Do UGSWMFs contribute to odour or mosquito development and, if so, what are the recommended prevention and/or mitigation measures?

A15. The policy paper does not discuss these issues, but from a peer review perspective, it is anticipated that UGSWMF's should be configured to drain fully between storm events to avoid odour issues, thus obviating the need for odour control. The specific duration for emptying is not

relevant so long as water is not retained in the structure. As for mosquito development, the life cycle of mosquitos is dependent on an aquatic larval stage where the larvae's mouth parts form a floatation mechanism for air transfer in an undisturbed area that the adult mosquitos can access to deposit eggs. Thus, they prefer small, but sheltered standing pools of undisturbed water (such as tire swings, shaded puddles or similarly sheltered, but easily accessible locations by flying insects). UGSWMF's, when configured to empty fully between storm events, will not provide suitable habitat for the larvae development and thus are not anticipated to contribute to mosquito development in any significant manner.

Q16: Is burying access locations to UGSWMFs beneath shallow soil and vegetation cover, as suggested in the Policy Paper, recommended?

A16. WSP would recommend against burying access hatches beneath shallow soil and vegetation but does recommend associating hatches with maintenance or public roadways to facilitate maintenance that does not require surface restoration activities, if possible.

Q17: Is root intrusion a concern with respect to UGSWMFs?

A17. Root intrusion is not anticipated to be a significant concern for larger installations, while smaller systems may be affected where tree presence is dense in close proximity to them. WSP anticipates that root barriers such as those described here: https://www.deeproot.com/products/root-barrier/ can be effective in addressing this issue but should not be completely relied upon to warranty a system against tree root intrusion.

Q18: Inspection of the interior condition of UGSWMFs for concrete cracking and/or deterioration was flagged as a required maintenance activity. Is specialized equipment and/or personnel needed to carry out such inspections and, if so, what is the estimated cost for this work?

A18. WSP would recommend that visual inspection of cracking or other concrete deterioration is performed whenever a confined space entry is performed or by use of remote sensing equipment. Visual inspections of the tank system (by remote sensing or in rare conditions by qualified personnel during a confined space entry) are assumed to be required on a bi-annual basis in the initial years after commissioning with decreasing frequency on documentation of stable conditions with no required maintenance on a recurring basis year after year. As described above, certifications in confined space entry would be required for any entry, along with qualifications related to assessing the structural integrity of concrete structures, such as those possessed by bridge inspectors. Those costs will be variable, and we do not believe they have been included in the current annual expenditure estimate.

Q19: The Policy Paper suggested the need for corrective maintenance. What would trigger corrective maintenance and what equipment and/or personnel would be required to perform such maintenance? Is this maintenance included in the UGSWMF cost estimate?

A19. Corrective maintenance is assumed to be similar to maintenance for similar issues on other concrete structures, such as patching of spalled concrete and remedial repairs or grouting of

cracked concrete. In extreme cases, systems like the I-Storm system may be able to expose individual structural elements and replace them without the need for replacement of the entire structure. WSP assumes that equipment choices, procedures and qualifications / expertise of the required personnel will be determined based on the severity of the maintenance requirements. It is difficult to estimate or project costs beyond a standard allowance which we do not believe is included in the estimate.

Q20: The Policy Paper speaks to emergency spills. What kind of situation or spill would trigger an inspection of the tank?

A20. The policy paper suggests that an uncontrolled discharge of hydrocarbons from an accident or other situation would trigger an inspection. WSP believes the probability of such an incident to be low and that the severity would be minimized with appropriate upstream quality control systems configured to intercept such a discharge (via Oil / Grit Separators or other systems). Emergency spill response procedures should be included in the design and review process of such dual-use underground systems so that operational protocols on how to respond to such an event are documented and mitigation measures for the concerns outlined above are considered prior to installation and commissioning. Risks of amenity service disruption are likely minimized with sufficient documentation and training on specific procedures. While the risk of catastrophic failure and response are never zero, good records and designs will reduce the risk to a level that can be comfortably accommodated by City staff.

Q21: The Policy Paper speaks to excessive accumulation of hydrocarbons. Can the excessive accumulation of hydrocarbons be quantified as a trigger to initiate maintenance activities?

A21. The policy paper describes excessive accumulation as any visible sheen on the water surface indicating hydrocarbon discharge. If there is standing water in the tank with a visible sheen, then a maintenance activity must be immediately initiated and the contaminated water volume must be pumped to controlled tanks for treatment and disposal, like any spill response process. UGSWMF's configured to fully empty between storm events are unlikely to retain any visible sheen, however, it is anticipated that the upstream water quality treatment systems would intercept those discharges. Upstream oil/grit separators are typically configured for this purpose with reservoirs where floating hydrocarbons are intercepted and stored for subsequent removal during inspection and maintenance.

Q22: The Policy Paper speaks to the potential to fit other underground infrastructure (sanitary sewer, water main, hydro, etc.) in proximity to UGSWMFs. Does this pose a risk?

A22. The addition of other underground infrastructure in proximity to the UGSWMF should be discouraged. However, it does seem possible to envision an unavoidable situation where buried infrastructure must be placed in such a situation. In those situations, it is likely a requirement that the smaller infrastructure be positioned above the larger tank (provided there is sufficient cover and separation between systems to meet the specifics of the affected systems). As the UGSWMF tanks are anticipated to be structurally sufficient to meet HS-20 loadings, infrastructure

maintenance and repair on those affected systems is not likely to be overly encumbered by the presence of the tank system below it. In addition, the smaller footprint of UGSWMF's compared to traditional SWMF's is likely to create relatively fewer impediments to infrastructure deployment around them. Some impact to standard maintenance practices (such as open cut access) can be expected adjacent to an UGSWMF, but operational impacts or increased frequency of repair is not anticipated.

Q23: Should the bottom of UGSWMFs be moderately sloped (2% slope) towards to a sump area to facilitate sediment flushing and vacuuming?

A23. WSP feels that a 2% slope is likely too steep to facilitate the movement of contained water toward a sump or other discharge location. A 0.5% slope is likely the minimum required for such performance, although 0.35% may be considered in exceptional circumstances. A sump area is an advantageous configuration to maintain consistent pumping rates for maintenance activities.

Q24: Should UGSWMF be designed as watertight structures? If so, are there recommended repair methods in case of water intrusion?

A24. UGSWMF's can be configured as watertight structural elements, but it is likely that these systems will instead be typically configured as water intrusion resistant systems through the use of integrated gaskets between structural elements with optional waterproofing applied to joints after initial installation, per design specifications. The need for those elements will be dependent on the project setting and the relative elevation of groundwater resources. Minimal water intrusion resistance is anticipated to be required to prevent the tendency of an UGSWMF to function as a groundwater dewatering system. Repair of leakages observed during tank inspection likely require the exposure of the waterproofing application on the outside of the tank system (hence the need for a setback dimension as shown in the policy paper in Section 7.0) via temporary dewatering systems to provide sufficiently dry conditions for the procedure.

Q25: What are the effects of a high or low groundwater table on UGSWMFs and are there recommended anchoring systems for these applications?

A25. Detailed anchoring methods would be site and soil specific designs associated with the individual project and seem out of scope of the policy paper. However, it is standard practice to consider buoyancy effects on submerged systems that provide any significant submerged open volume. High and low groundwater tables would impact these considerations, but the use of an appropriate factor of safety should be incorporated to ensure that all conditions are accounted for.

Q26: Should remote monitoring and warning systems be installed to notify the City in the event of unexpected high water levels?

A26. These can be incorporated as required. However, when configured to empty fully between events, the probability of such a situation is anticipated to be very low. Remote monitoring and notification systems may be applicable and the cost of such systems may be sufficiently low that

they can be incorporated into a project's plans. The City will be required to supply the appropriate staff contacts or protocols for implementing such a system.

Q27: Should a flow bypass system be included to facilitate inspection and maintenance activities?

A27. Such a system can likely be accommodated, but inspection is likely to be of sufficiently short duration that scheduling it during periods of low precipitation via a weather forecast is likely to address the issue. Maintenance, particularly repair of structural elements is likely a longer process and may require a bypass approach so that the underground system where the repairs are taking place is considered 'off-line'. Numerous approaches to this issue are available, and best practices should be incorporated for all maintenance processes. It appears reasonable that smaller scale facilities should include an external bypass as they may fill in a 'flash flood' manner while larger facilities may be able to provide multiple internal flow pathways with removable flow restrictions at the outlet point to allow for bypassing of work areas without risk of worker exposure to incoming flows.

Q28: Is there a minimum setback to consider between UGSWMFs and adjacent properties to minimize the impact of potential tank leakage?

A28. WSP assumes the answer to this question is dependent on the site setting and soil properties at the project site. Minimum setbacks should be consistent with similar requirements for underground structures (such as basements) on neighboring properties. Tank leakage is minimized when the tank is configured to empty fully between storm events and in such a configuration, settling or impacts to adjacent properties should be obviated.

Q29: Traditional stormwater management ponds are designed with emergency overflows that can convey flows exceeding the designed storm. What storm event should the UGSWMFs' emergency outlet be sized to and what will happen in event that a storm exceeds the emergency outlet design storm?

A29. UGSWMF tanks can be configured to pass uncontrolled flows through them via careful outlet structure design like traditional SWMF's. Essentially, the outlet would be configured to pass a flow equal to the sum of full flow rates for any upstream pipes and/or surface openings. This is a fairly standard approach for civil engineers to implement. In the event of a storm exceeding that flow rate, it is anticipated that the upstream infrastructure will surcharge, and localized flooding is possible.

Q30: What is the level of risk associated with a blocked inlet?

A30. While inlet blockages can and do occur, it is unlikely that multiple inlets will all become blocked at the same time, so inlets in close proximity to each other are likely to provide some redundancy in accommodating such a situation.

Q31: Has the link between infiltration containing high salt content and tank deterioration been studied/explored as there was a mall parking lot failure fairly recently as a result of concrete deterioration due to chloride exposure.

A31. The letter contained in Appendix B of the policy paper addresses this subject with an analytical examination of the effect of chloride exposure to various concrete mixtures. In any event, salt application for ice maintenance should be discouraged wherever possible due to salination impacts on receiving water systems. In the event of parking lots associated with amenity areas as outlined in the policy paper, it may be assumed that traffic movements relative to shopping mall parking lots will be lower and therefore require less salt. In addition, commercial shopping plazas typically overapply salt to reduce ice buildup due to fear of liability or to avoid any impacts to customer experience, a condition that often leaves residual salt piles that can affect downstream conditions long after winter conditions have abated. While salt application concerns are valid for park and amenity parking lots, the anticipated lower use of the parking lots in winter suggests that plowing is a much more viable winter maintenance approach in these conditions, with consequently lower rates of salt application. In addition, underground tanks configured to fully empty between storm events are unlikely to retain salt laden runoff for sufficient amounts of time that such runoff would exacerbate the onset of rebar corrosion.

Q32: Is a flow modeling recommended as part of the tank design and review process to simulate the impact of various storm events?

A32. Flow dynamic modelling may be available if supported by the manufacturer of the UGSWMF systems, however, such modelling is not a standard submission item required by current development review processes, unless required by a site-specific concern. Again, if water quality treatment is provided by upstream, treatment-train based processes, it is unlikely that sufficient sediment or other suspended particulates will be present to significantly affect concrete erosion rates, particularly if concrete mixtures can be provided that provide specific resistance to this scenario. In addition, the lower levels of UGSWMF columns are the areas exposed to flowing water most frequently, and water is generally spread evenly across the floor of the system after it leaves the incoming pipe. Therefore, the unit velocity and exposure to sand / debris (if present) would be low on any particular column. Lastly, the typical capacity of the incoming and outgoing pipes suggest that water does not flow quickly in any part of the tank system as a general function. In the case of sustained inflows and outflows controlled by gravity and the typical designs of hydraulic orifices and weirs, the main body of the tank will fill uniformly to the various design water levels. The only anticipated areas of significant flow velocity will be at the inlets and outlets. The main tank volume will generally flow vertically as the system fills up and empties.

Q33: Are there any specific warranty considerations with respect to UGSWMFs?

A33. WSP anticipates that UGSWMF warranties would be consistent with relevant standards for similar structures, such as pre-cast culverts, bridges and other hydraulic structures. Warranty clauses would need to be discussed with the project proponents on a site-specific basis and may

be related to the construction or development companies involved in its design and construction. Specific warranty considerations should include precast components for substandard concrete depth over rebar, out of tolerance structural dimensions, improper installation by manufacturer supervised contractors, etc. Vegetation installations above UGSWMF's should be warrantied similarly to 3rd party constructed municipal assets. Clauses on who is responsible for maintenance and inspection are likely site specific and related to the type and frequency of previous installations of similar products. Products and their suppliers that are being introduced to the municipality for the first time can be reasonably expected to be responsible for maintenance and inspection for a longer period of time.