Matrix Solutions Inc.
A Montrose Environmental Company

HIDDEN VALLEY STORMWATER MANAGEMENT STRATEGY

Prepared for:
CITY OF KITCHENER

Prepared by:
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HIDDEN VALLEY STORMWATER SERVICING STRATEGY

prepared for City of Kitchener, December 2024

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1 Introduction

The City of Kitchener retained Matrix Solutions Inc., a Montrose Environmental Company, to complete the Hidden Valley Stormwater Management (SWM) Strategy project. The project has been prepared to support and inform the City's Secondary Planning process underway for the Hidden Valley area. This SWM strategy is being conducted to assess the potential for hydrologic impacts related to the development of the Hidden Valley Secondary Plan (HVSP) area, and to recommend associated mitigation strategies. The recommendations provided in this report are meant to outline management goals and guide the SWM strategy for the study area. Implementation specifics are subject to change as part of detailed development planning.

1.1 Study Area

The approximately 210 ha Hidden Valley Creek subwatershed, delineated on Figure 1, is located in southeast Kitchener. Much of the subwatershed headwaters are substantially development with medium to high-density residential and commercial across the north, industrial across the west, and major transportation corridors of Highway 8 and Fairway Road. There is some limited low-density residential in the southeast, downstream portion of the subwatershed.

Central to the subwatershed and largely undeveloped is the HVSP area. Bounded to the north and east by Fairway Road and Highway 8, to the west by Wabanaki Drive, and to the south generally by Hidden Valley Road, the Council-approved Hidden Valley Master Plan (Figure 2) includes potential development areas around the periphery of a large woodland/wetland complex that holds classifications as a Provincially Significant Wetland (PSW), Environmentally Sensitive Policy Area (ESPA), and Core Environmental Feature (CEF). Within the study area there are Regionally Significant Woodland and Significant Valley, species at risk habitat, a warmwater fishery, and a regionally significant groundwater recharge area. In addition to being an environmentally sensitive area, the Hidden Valley ESPA/PSW is the hydrologically dominant landscape feature in the subwatershed. Two defined watercourses, known as the north and west tributaries, convey flow across the HVSP area as the outlets from the developed headwater areas into the ESPA/PSW. The hydrology of the study area and wetland have been previously studied, with two recently completed hydrologic investigations conducted for the Hidden Valley subcatchment (WalterFedy 2016; Wood 2019) to be discussed in Section 2.

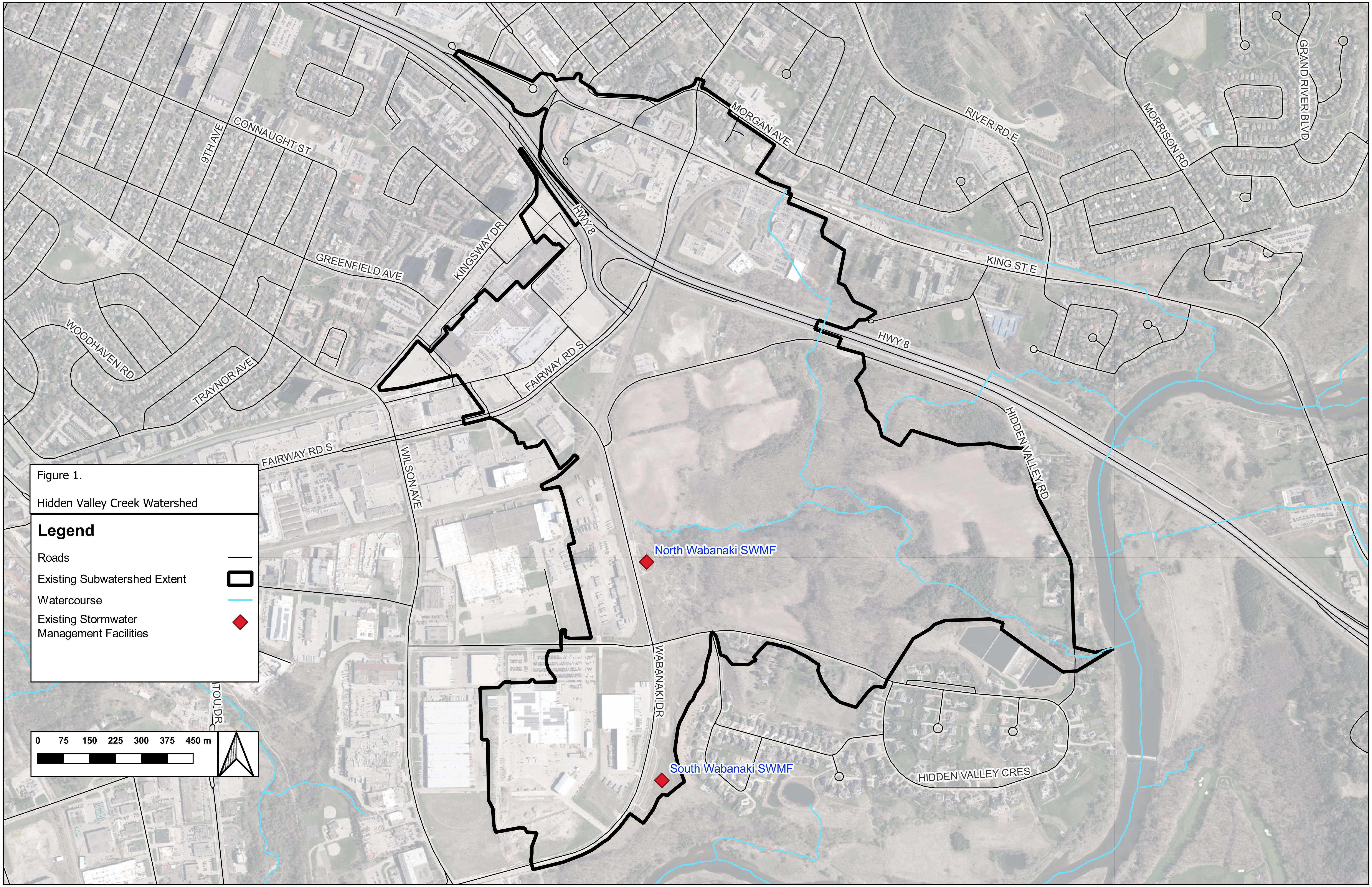
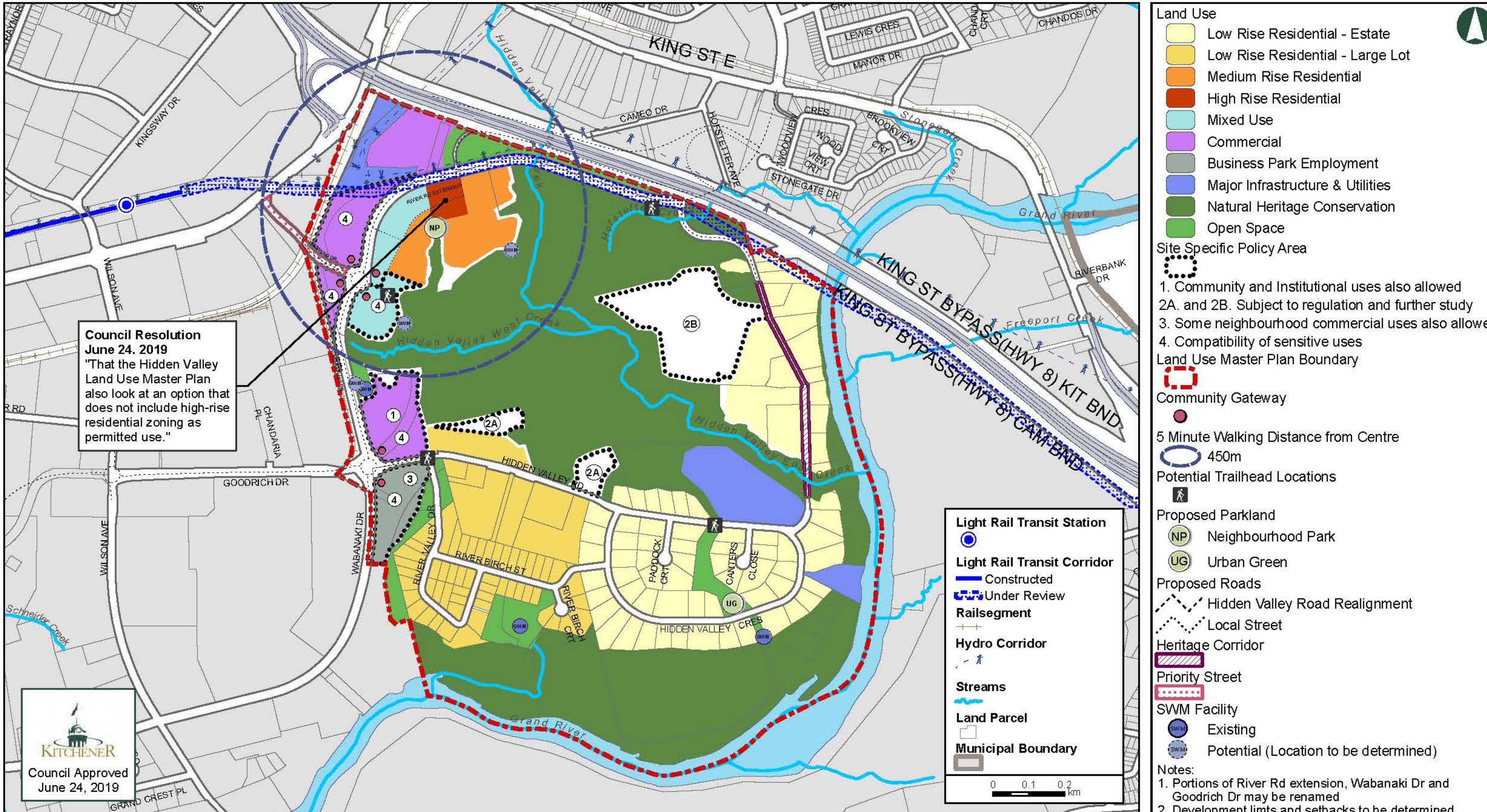


Figure 1.

Hidden Valley Creek Watershed

Hidden Valley Land Use Master Plan



The River Road Extension, currently in its final engineering design phases, will connect Highway 8 to Wabanaki Drive through the study area. Low-density to high-density residential, mixed, and commercial and use is planned around the new road alignment. Near the intersection of Wabanaki Drive and Hidden Valley Road there is planned commercial and Business Park development. Along Hidden Valley Road there is planned special use areas, “2A” and “2B”, which are still under discussion but will likely be developed into low-density to medium density residential land use.

The portion of Hidden Valley Creek downstream of the ESPA/PSW, through private property and under Hidden Valley Road, has experienced historic and existing flood and erosion impacts related to specific rainfall-runoff events and/or the release of natural debris-blockages (e.g., beaver dams or natural debris jams) within the wetland feature. Within a separate-but-related study Matrix has recently completed a Schedule “B” Municipal Class Environmental Assessment (EA) to address flooding and erosion conditions in/around the Hidden Valley Road crossing 2023 (Matrix 2023). The EA concluded that over controlling flows upstream of the wetland or within the wetland itself were not recommended, with the preferred approach instead involving simply increasing the capacity at the road crossing and isolated erosion spot repairs.

2 Background

Several studies have been reviewed to understand the existing hydrologic characteristics of the Hidden Valley subwatershed. These studies include, most notably, two key hydrologic investigations as prepared by WalterFedy in 2015 and Wood in 2019, which were subsequently used as the baseline models for the current study’s hydrologic analysis. These key background studies are summarized in the following sections.

2.1 IBI Group (2013) - Class Environmental Assessment River Road Extension – Stormwater Management Report

The River Road Extension program is a multi-phased extension of River Road from King Street to Manitou Drive to improve the east-west connection in south Kitchener, managed by The Regional Municipality of Waterloo (Region). IBI Group was retained by the Region to conduct a Class EA of the River Road Extension. The project involves the development of a new roadway north of the Hidden Valley ESPA/PSW, and an expansion of Wabanaki Drive to the west of the Hidden Valley ESPA/PSW.

The SWM Report produced by IBI was a supporting document to the Class EA, detailing the design of pipes and roadway grading to convey stormwater across River Road. Stormwater from west of the Highway 8 on-ramp and east of the proposed light rail corridor was proposed to be conveyed to a bioswale system, and ultimately to the Hidden Valley north tributary. Stormwater from west of the light rail corridor and north of the Hidden Valley Road and Wabanaki Drive intersection was to be conveyed to the North Wabanaki SWMF. This represents an increase to the subcatchment area draining to the Wabanaki North SWMF as compared to existing conditions, necessitating an associated expansion to accommodate the additional runoff produced by the improved transportation corridor.

2.2 WalterFedy (2015) - Hydrologic and Hydraulic Study

WalterFedy conducted a hydrologic and hydraulic study of the Hidden Valley Creek subwatershed in 2015, creating a hydrologic model for the entire subcatchment area using InfoSWMM, and a localized hydraulic HEC-RAS model for the reach of Hidden Valley Creek downstream of the ESPA/PSW. The goal of the study was to investigate the root causes of the existing erosion and flooding of the creek and gain insight into potential mitigation options. The objectives outlined included:

- Develop a calibrated hydrologic model.
- Determine the causes of existing erosion and summarize inundation levels downstream of the wetland.
- Evaluate the possible impacts of the proposed River Road development on the wetland.
- Determine if specific techniques to reduce the quantity and rate of runoff from the proposed River Road development were warranted.
- Provide suggestions on stormwater management criteria for future developments within the subwatershed.
- Examine the potential for collaborative channel erosion mitigation options that will address existing problems and future developments; and,
- Provide an analysis on the flow capacity of the existing culvert crossing at Hidden Valley Road.

In addition to hydrologic and hydraulic modelling of Hidden Valley Creek subwatershed, field monitoring was undertaken to measure flow at three locations. The flow monitoring stations were labelled SW1 (located downstream of Hidden Valley Road), SW2 (located along the west tributary), and SW3 (located along the north tributary; Figure 3).

Figure Date: August 9 2024

Watercourse
Flow Monitoring Locations

N

0 100 200 300 400 m

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Monitoring Station Locations

Fig. 3

2.2.1 Hydrologic Model

WalterFedy created a hydrologic model, using InfoSWMM, for both existing conditions and future conditions, as outlined in the Class EA River Road Extension, River Road Stormwater Report (Stantec 2013a). The existing model contained 60 subcatchments delineated through a combination of drainage infrastructure, site topography, field review, and land use mapping. Topographic and aerial maps were used to define subcatchment slope and imperviousness, respectively, and soil parameters were uniformly applied to all subcatchments based on the average soil class of "gravelly loam." Subcatchments within the northwestern and southwestern areas of the study area were of primarily industrial and commercial land use, while subcatchments to the southeast were of low-density residential land use. Recent aerial photography indicates that additional development in the south and west areas of the subcatchment (south of Hidden Valley Road) have occurred since this study. The hydrology of the Region was modelled in response to the 25 mm, 1:2-year through 1:100-year return period, and the Regional Storm.

Two storm pond facilities were included in this study and the wetland feature was represented as a storage node, with a coarse stage-storage relationship developed through analysis of the topographic information. A beaver dam was noted in the wetland and assumed to be the primary hydraulic control for the wetland. WalterFedy questioned the stability and reliability of the dam to provide stormwater attenuation, speculating that the natural sedimentation process would reduce active storage volume over time. Inspection from aerial imagery indicates the dam may have drained since the investigation, with visual water recession observed after 2016.

Precise calibration of the wetland feature was not a goal of this study and, not unexpectedly, there remained significant variability between modelled and observed hydrograph results downstream of the Hidden Valley ESPA/PSW.

Three proposed conditions scenarios were created by WalterFedy to assess the impacts of upstream development with and without stormwater control:

1. River Road development conditions
2. River Road and future development around the road extension with SWM pond control
3. River Road and future development around the road extension with SWM pond and LID control

The results of the study indicated that implementation of the River Road Extension without accompanying SWM controls would increase peak flows entering the west and north tributaries. From an event-based water balance, the incremental increases in flow volumes were not expected to have detrimental impacts on the hydroperiod of the wetland. Minimal changes were expected to the water levels within the wetland, due to the large surface area available for storage.

To mitigate the impacts of increase runoff rates / match existing flows, two new end-of-pipe SWM facilities were proposed and upsizing of the North Wabanaki SWMF was recommended. It was also concluded that implementing LID controls reduced the quality and quantity control requirements on the SWM facilities and increased the infiltration of stormwater, thus improving Regional water balance.

2.2.2 Hydraulic Assessment

An existing conditions hydraulic model was established for the Hidden Valley Creek system downstream of the ESPA/PSW to the Grand River, based on surveyed cross-sections. The purpose of the hydraulic modelling was to assess inundation and the hydraulic capacity of Hidden Valley Road and its associated infrastructure. The driveway culverts at 735 Hidden Valley Road, immediately upstream of the road crossing, and the Hidden Valley Road crossing itself were observed to create a backwater effect by restricting conveyance for all design storm events. It was determined that backwater at the Hidden Valley Road culvert does not extend to the building at 735 Hidden Valley Road and is not the cause of the flooding at that location. Assuming existing development conditions in the contributing catchment, and a beaver dam remaining in place and attenuating flows, a box culvert of span 2.5 m and rise 1.0 m was determined to meet MTO criteria for an arterial road, conveying a maximum flow of 12.8 m^3/s. Without beaver dam attenuation, the maximum flow would be 14.8 m^3/s (based on the uncalibrated hydrology model) and would require a 3.8 m span box culvert to provide sufficient conveyance.

Varying scenarios of peak flow rates were also tested to determine if increased development upstream of the wetland complex would influence flooding downstream at Hidden Valley Road. Pre-existing flows, assuming conditions preceding the Kitchener Operations Facility and Best Buy development in 2008, were compared to existing conditions, and it was determined that there was negligible difference to the flood extents within the Hidden Valley Corridor. These results indicated that flooding downstream of the wetland was not a result of increased upstream development. Additionally, a scenario of ultimate development considering the River Road Extension plans was tested and it was concluded that the proposed development would also not influence inundation at Hidden Valley Road, as the proposed SWM controls would reduce post-development flows to pre-development levels. Historic flooding experienced downstream of the ESPA/PSW was speculated to be a result of a repeated failures of the beaver dam(s).

2.2.3 Erosion Hazards

During the survey of the site by WalterFedy in 2015 major bank erosion was identified along the channel and undercutting of both CSP culverts. The remains of a blown-out culvert were observed 50 m upstream of the 735 Hidden Valley Road property during the survey. The soil texture class (sandy and gravely loam) and relatively steep slope of the channel were noted as promoting high velocities and potential for further erosion.

Two potential solutions were evaluated to remediate the erosion hazards, including protecting the creek bed and banks and creating a geomorphically stable system. Armour stone or riprap were suggested to harden the banks and prevent further erosion. Velocity dissipation devices such as grade control structures would reduce velocities within the channel, slowing potential erosion. Alternatively, naturalization of the channel and widening the floodplain would mitigate erosion and stabilize the creek.

2.3 Wood (2019) - Flow Monitoring, Calibration, and Hydrologic Study for New Secondary Plan

Wood conducted a hydrologic investigation in 2019 with the goal of calibrating the Hidden Valley EPSA/PSW represented in the WalterFedy hydrology model and understanding the impact of the proposed development upstream of the feature.

2.3.1 Flow Monitoring

Flow monitoring data was collected by Wood at the same locations as the WalterFedy (2015) study and used to complement the 2015 dataset. Water level data was collected using level-loggers, and a rating curve developed using flow rates measured with an acoustic doppler. As rating curve data was not available for the full range of monitored water levels, a rating curve was developed for each station in HEC-RAS by adjusting channel and bank roughness to match the measured stream stage and discharge.

Rainfall data from both the nearest rainfall gauging station (City of Kitchener’s Operation Facility [131 Goodrich Dr.]) and the nearest Environment Canada gauge (Region of Waterloo International Airport, ID 6144239) were used to relate streamflow to precipitation events.

The period in which streamflow was monitored (2017) was atypically dry compared to the climate normal for the Region. As such, the calibration process suffered for only measuring low flow events.

Data from the flow monitoring stations (refer to Figure 3 for locations) indicated that SW1 and SW3 show more muted responses to precipitation events than SW2, with the latter also exhibiting the highest rate of baseflow. Anomalies in the data, such as SW3 exhibiting dry weather diurnal flow are unexplained. The rating curve fits for the three stations were good for low flows but lacked any high flow points to allow for proper calibration of a rating curve. Comparison between measured and modelled flow at SW2 showed a very poor fit, which attests to the limited reliability of the measured flows.

Due to the lack of high flow data, supplemental data from Stantec (2011-2017; refer to Section 2.6) was used to provide a more comprehensive dataset. The location of the Stantec monitoring was close but not at the exact location as the Wood installed sites (+/- 10 m). The Stantec measured flow data, used for rating curve development, also only included low flow events and, therefore, did not improve the rating curve for high flow events.

2.3.2 Hydrologic Model Calibration

A total of 15 precipitation events were used to calibrate the existing condition hydrologic model. Calibration used post-2014 hydrometric data obtained from the City of Kitchener operations facility rain gauge. Rainfall data prior to 2014 (from Environment Canada rain gauges) had significant gaps. A storage-discharge relationship was developed for the wetland but overestimated streamflow with a relatively low coefficient of determination (R^2) between simulated and observed streamflow.

A sensitivity analysis was performed for various hydrologic parameters including soil hydraulic conductivity, subcatchment directly connected imperviousness, wetland storage volume, and wetland discharge rate. Subcatchment width/length, overland flow roughness, and depression storage were excluded from the analysis. Changes to the soil parameters and directly connected imperviousness improved the fit to the estimated runoff at flow locations SW2 and SW3.

Modifications to the wetland storage node, including the wetland feature and beaver dam, were less successful. The wetland node was calibrated solely against SW1 and with changes to initial depth, seepage rate, and outlet discharge relationships. Initial depth and seepage rate were calibrated according to the received model and information from the Stage 1 Hydrogeology Study, River Road Extension (Stantec 2013b), and deemed to be relatively insensitive for long-term simulations. It is unclear whether the structures are based on empirical relationships or represent the physical outlet configuration of the wetland. While the discharge relationship of the wetland had the greatest impact on results, given the absence of physical information on the outlet and minimal high flow calibration events, Wood felt there was no justification to alter the relationship.

While the results of the calibration process, including the modelling of three large storm events that led to improved hydrograph fit and volume, showed some improvement significant disparity remained between modelled and measured flows, most notably at the downstream SW1 location. The GRCA accepted the fit for the SW2 and SW3 stations but expressed concern regarding the calibration fit for SW1 as not able to meet the definition of “engineered” for the purposes of deriving Regulatory floodlines. It was concluded that, while the updated calibration was considered sufficient for the 2019 study, additional and improved calibration would be required if the model was to be considered for these purposes in the future.

2.3.3 Hydrologic Results

The updated Wood hydrologic model was used to model existing and proposed development conditions. The inclusion and absence of stormwater controls, LIDs, and attenuation from the wetland were considered. The proposed development scenarios were created based on the Hidden Valley Master Land Use Plan (the City 2018), the River Road Extension Environmental Assessment (IBI 2013, 2014), and the hydrologic and hydraulic study (WalterFedy 2015). Due to the lack of detailed grading and lot information for the new developments and road alignments, Wood had considered the stormwater controls described by WalterFedy as adequate. Changes were made to subcatchment areas for the proposed development along Hidden Valley Road as well as the River Road alignment in accordance with the updated Land Use Plan and River Road Extension Report. Storm sewers along the River Road Extension were not included in the model.

The hydrologic model was also used to assess a high-level annual water balance (no separation of infiltration and evapotranspiration) and to determine exceedance of erosion thresholds by running a continuous simulation. The continuous simulation was run for a period of 50 years (1962 – 2011) using climate data from compiled from the Guelph OAC, Arboretum, and Turfgrass stations. The continuous simulation results indicated that, under existing conditions, the average annual water balance includes 837 mm of rainfall, 167 mm of runoff, and 666 mm of infiltration and evaporation. Under a future development scenario without SWM controls, average annual runoff was estimated to increase by 59%, as compared to existing conditions. Implementing LIDs and end-of-pipe stormwater quantity controls to control the developed subcatchments increased infiltration rates to allow for similar average annual runoff to existing conditions (172 mm, 3% increase over existing conditions).

Erosion thresholds are exceeded for 1,522 hours (0.35% of full period), and 834 hours (0.19% of full period) under existing conditions, and for 2,304 hours (0.53% of full period), and 815 hours (0.19% of full period) under future, uncontrolled conditions, along the west and north tributaries respectively. Applying stormwater quantity controls and LIDs to the future, controlled conditions scenario allows for closer representation of existing conditions, 1,556 hours (0.36% of full period), and 815 hours (0.19% of full period) along the west and north tributaries, respectively.

2.4 City of Kitchener, 2019 - Hidden Valley Master Plan

The City of Kitchener's Council-approved Hidden Valley Land Use Master Plan (2019) describes the anticipated development within the study area. The Land Use Plan includes the proposed development of low-, medium- and high-rise residential, mixed-use, commercial, and business park uses, in addition to major transportation infrastructure elements such as the River Road Extension and the light rail transit corridor. The type and locations of the proposed developments are illustrated in Figure 2. Since the Council approval of the Land Use Plan in 2019 there has been further delineation of the boundaries of development around the Hidden Valley ESPA/PSW. The current limits of development are further explored in Section 4.2.

Development of the existing pervious area within the subwatershed will have impacts on the hydrology of the Hidden Valley Creek subwatershed. The replacement of naturally pervious area with impervious coverage reduces natural infiltration and evapotranspiration, while increasing runoff volumes and rates. The effects of increased impervious area can be mitigated by using stormwater controls such as recharge-oriented LID techniques and stormwater ponds. A fundamental objective of the stormwater planning process is mitigating the hydrologic impacts of the proposed development.

2.5 WSP, 2021 - River Road Extension from Manitou Drive to King Street Stormwater Management and Hydraulics Report

WSP was retained by the Region of Waterloo to carry out the detailed design of the River Road Extension from Manitou Drive westerly to King Street. WSP identified the proposed stormwater design for the roadway extension and the North Wabanaki SWMF.

WSP identified the subcatchment area draining to the North Wabanaki SWMF under existing and future conditions. The subcatchment area delineated by WSP differs from that delineated by IBI (2013) and Wood (2019). Most notably, the area around the proposed Wabanaki Drive and future River Road (north roundabout) assumes a different future grading and subcatchment delineation than that assumed by IBI in 2013.

2.6 Stantec, 2011-2022 – Flow Monitoring

Stantec conducted a Stage 1 Hydrogeology Study (2013) and Pre-Construction Groundwater and Surface Water Monitoring (2014) in support of the proposed River Road Extension on behalf of the Region of Waterloo. As part of these projects Stantec captured water level data along the west and north tributaries, as well as directly upstream of the Hidden Valley Road from December 2011 to December 2021 at a resolution of 1 measurement every 15 minutes. Stantec also collected instantaneous flow data at these locations to relate location of the water level to flow rate. Typically, observed instantaneous flow data is used to relate measured water surface elevations to derive a rating curve for a given location. Unfortunately, the measured instantaneous flow does not capture high flow events at any of the three locations; therefore, the rating curve developed by Stantec is not applicable for calibration.

2.7 Husson, 2018 – Stormwater Management Report – 2960 Kingsway Drive

Husson was retained to design the stormwater management system for the Fairview Mall in 2018. The design includes a proposed drainage delineation for the Fairview Mall and underground storages and infiltration galleries to attenuate and infiltrate flow. The Husson design includes 4,002 m^3 of retention volume, to infiltrate and attenuate 25 mm of runoff from the portion of the subcatchment draining to Hidden Valley Creek. Husson determined that the addition of the underground storage and infiltration galleries would reduce peak flow rates below existing conditions, and thus additional quantity control measures were not needed.

Quality control for the Fairview Mall is provided through the use of four Oil Grit Separator Units (OGS), which would provide approximately 80% removal of total suspended solids.

3 Existing Conditions

3.1 General Catchment Characterization

The Hidden Valley Creek watershed drains approximately 210 ha to its outlet at the Grand River (Figure 1). The HVSP area (Figure 2) generally comprises the central and downstream half of the watershed, receiving flows from approximately 120 ha of drainage from areas to the west of Wabanaki Drive and north of Fairway Road S. and Highway 8. Land uses in these external areas include relatively intense urban development, with highly impervious contributing catchments, much of which pre-dates the adoption of stormwater management controls. Along Hidden Valley Road there are several large lot residential units draining directly to the ESPA/PSW.

3.1.1 Surface Water Hydrology and Hydrogeology

As described above, most of the contributing headwater areas drain directly to the Hidden Valley ESPA/PSW through two headwater drainage features, known as the north and west tributaries.

The north tributary originates at King St. E., immediately north of Highway 8, and bisects the Heffner Toyota site. At the Hidden Valley Road crossing just inside the HVSP, the watercourse carries drainage from approximately 45 ha of predominantly commercial and medium/high-density residential land uses to the north and northeast. Downstream of the Hidden Valley Road crossing it transitions from a single-thread, defined bed and bank characteristic into the wetland feature of the ESPA/PSW.

The west tributary starts at the culvert outlet discharging from the east side of Wabanaki Drive and flows east within a well-defined channel before dissipating into the open water/cattail marsh, wherein defined bed and bank characteristics cease. The west tributary receives untreated and treated storm drainage from approximately 67 ha of predominantly commercial and industrial land uses located to the north and west of the HVSP area. The North Wabanaki SWM Facility, located immediately to the south of the watercourse on the east side of Wabanaki Drive, treats drainage for roughly 10% of the total area contributing to the west tributary.

A third small tributary known as Hofstetter Creek drains northerly from the northeast portion of the study area, conveying drainage from existing natural areas across Hidden Valley Road and Highway 8 before winding its way to the Grand River along the rear of residential properties fronting onto Stonegate Drive. As there are no land use or drainage changes anticipated for this area, no further discussion is warranted herein.

Surface water flow monitoring completed on the west and north tributaries over approximately the last 10 years (Stantec 2014) identified that hydrologic characteristics of these watercourses are largely reflective of highly urbanized headwater drainage areas – largely dry or under minimal baseflow conditions during dry weather conditions, but exhibiting short, peaky runoff responses following rainfall or snowmelt events in the headwater areas.

As described above, flow in these defined watercourses transitions into the ESPA/PSW wetland receiver, with a large (i.e., ± 9 ha) open water area. The extent of the open water is variable, controlled to some extent by seasonal and/or event-driven fluctuations in precipitation and runoff, but primarily by beaver dam(s) that have been observed in the ESPA/PSW through aerial imagery (Kitchener, 2016-2021), drone imagery (Kitchener 2023) and field investigations (Stantec 2013, Matrix 2023). The storage effects introduced by the beaver dam and associated head pond serve to significantly dampen any precipitation event-related surface water hydrologic response through reaches of Hidden Valley Creek downstream. Monitoring did note increases in flows through reaches downstream of the beaver dam "during the early winter snow melt in January 2013 and the spring melt in early March 2013" (Stantec 2013) which should be expected given the larger runoff volumes in such events and reduced infiltration capacity at that time of year.

It is understood that the beaver dam(s) have failed and been rebuilt at least once in the past decade, creating inconsistent storage/backwater/recharge conditions, hampering calibration of hydrologic models. Wood (2019) noted that calibration was unable to be achieved downstream of the dam and Matrix (2023) were likewise unable to create an inflow-outflow rating relationship using surface water monitoring data. While it would be desirable to gain an improved understanding of the hydrodynamics of the ESPA/PSW, the fact that the proposed development and associated SWM controls are located upstream of the Hidden Valley ESPA/PSW reduces the necessity of developing a wetland stage-storage-outflow relationship as there should be no impacts downstream of the feature. In other words, by limiting hydrologic changes upstream of the ESPA/PSW, it is reasonable to expect that the feature will continue to function as per current conditions and that the hydrology of the downstream reaches will not be negatively impacted. For the purposes of the current report, the hydrologic characteristics of the Hidden Valley ESPA/PSW have been kept consistent with the Wood (2019) model.

There are two existing SWMF upstream of the ESPA/PSW, both located along Wabanaki Drive. The South Wabanaki SWMF, located east of Wabanaki Drive approximately 375 m south of Hidden Valley Road, receives flow from approximately 19.2 ha of industrial lands to the west of Wabanaki Drive. The North Wabanaki SWMF, located on the east side of Wabanaki Drive approximately 225 m north of Hidden Valley Road, receives flow from approximately 6.8 ha of industrial lands to the west and the Wabanaki Drive right-of-way. Both facilities are represented in the hydrologic model.

The hydrogeology of the study area is complex and the subject of multiple previous and ongoing studies; the Region continues to undertake hydrogeologic assessment work in the area as such is of notable relevance to nearby surface water and groundwater supply sources (e.g., Parkway Well Field). Stantec (2013/2014) includes the most up-to-date and comprehensive understanding of the local area hydrogeology. In summary, some of the key aspects of relevance to the current study include:

- Across most of the study area there are multiple geologic units comprising the stratigraphic sequence, including both aquifer and aquitard layers.
- Given relatively coarse surficial geology across much of the study area and the upland areas above the low-lying ESPA/PSW feature specifically, it is understood that much of the incident precipitation not lost to evapotranspiration is converted to infiltration.
- That portion of upland infiltration that remains in the shallow groundwater layers by virtue of intervening aquitard layers migrates laterally and emerges as groundwater discharge supporting the ESPA/PSW.
- Within the ESPA/PSW feature and the esker forming a ridge along its southern limits, Stantec 2013/2014 noted the significant thinning and/or absence of aquitards and postulated the existence of a hydraulic “window” into the deeper aquifer system with significant recharge to deeper aquifers.
- The beaver dam(s) and associated head pond are understood to have <u>significant</u> impact on both groundwater flow/recharge and stream discharge conditions, increasing the former and moderating the latter. Stantec (2013) completed an assessment of the relative importance of the beaver dam on local groundwater recharge through the comparison of two scenarios, (1) with the dam in place and recharge occurring within the extent of the associated ponded area, and (2) beaver dam absent and recharge only occurring below the creek corridor itself. Though the analysis should be considered relatively “high-level”, it highlighted that the difference in local recharge could be close to 200,000 m^3/year (40 × more with dam in place than absent).

In short, in addition to being a significant environmentally sensitive area, the approximately 34 ha ESPA/PSW is the hydrologically/hydrogeologically dominant landscape feature in the subwatershed, with a complex and dynamic surface water / groundwater relationship that is significantly impacted by the presence and activities of beaver throughout the area. With loam and sandy loam over gravel dominating the surficial soil and high groundwater table, surface water/groundwater exchange plays a large role in the water balance of the wetland.

Downstream of the ESPA/PSW, the open water/cattail characteristic transitions back to a well-defined, single-thread channel officially known as Hidden Valley Creek that flows east/ southeast across a couple private properties before its at Hidden Valley Road, and discharge to the Grand River. Flows through this reach of the system are controlled by the beaver dam and supplemented to a minor extent through groundwater discharge. Calibration of the inflow-outflow relationship of the wetland is difficult given its variable hydrologic characteristics (e.g., ever-changing beaver dam conditions) and complex connection with the groundwater systems.

3.1.2 Existing Conditions Updates

WalterFedy created a hydrologic InfoSWMM model in 2016 which represented existing and future development conditions. Wood updated the existing condition and future condition scenarios in 2019 to reflect the varying soil types within the subcatchment and calibrated against available data from three flow monitoring locations.

Matrix imported the Wood model into PCSWMM and modified it to reflect existing land use conditions as of 2024, including updates to subcatchment area, imperviousness, and lengths. The methodology for updates is described below:

- Subcatchment areas were re-delineated based on improved base information such as provincial LiDAR (2018) and/or re-discretized to align with anticipated future development catchments for easier results comparison (e.g., peak flow comparison at common flow nodes).
- Subcatchment length was measured for pervious subcatchments (<20% impervious area), and calculated for impervious subcatchments using the formula Area (m^2) = $(1.5*\text{Length(m)})^2$.
- Slope was measured for subcatchments. New subcatchment slopes were established using the formula S= (max elev. - min elev.)/length.
- Imperviousness was measured using aerial imagery (2019-2023).

A comparison of the Wood (2019) and Matrix (2024) total subcatchment areas, highlighting areas of change between the two models, is presented in Figure 4.

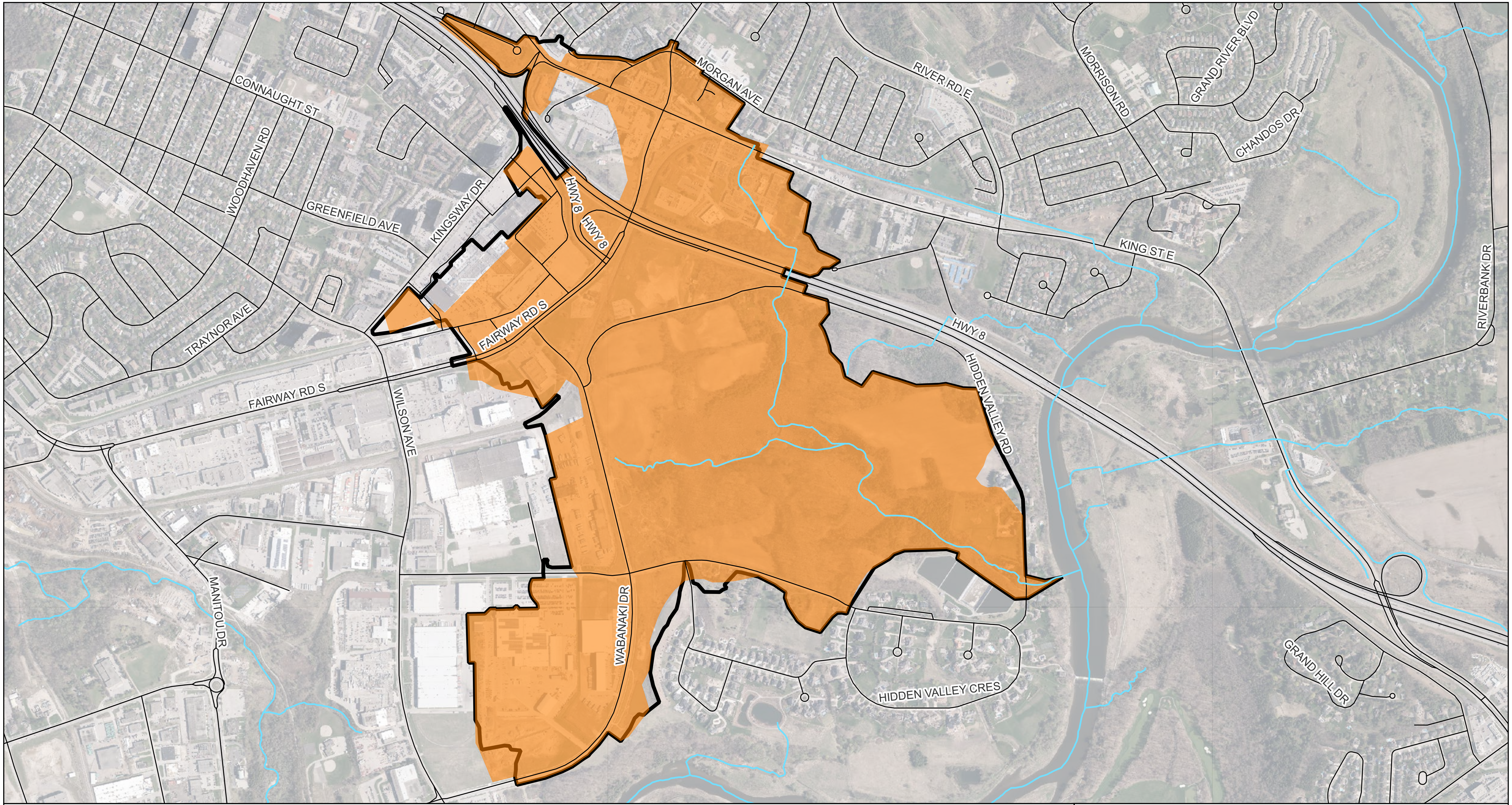

Figure Date: August 9 2024

Roads
Watercourse
Matrix (2024) Existing Subwatershed Extent
Wood (2019) Existing Subwatershed Extent

This drawing must be used in conjuction with the attached memorandum, and is subject to the same limitations and conditions stated in the memorandum.

N

0 250 500 m

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Project #: 31809

Comparison of Existing Wood (2019) and Matrix (2024) subwatershed Extents

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M.L.

Fig. 4

Several key areas have changed since the development of the 2019 hydrologic model. The most prominent changes are described below:

1. Drainage area limits adjusted to accommodate the Hidden Hills Estates subdivision southeast of the Hidden Valley Road/River Valley Drive intersection, as designed by MTE (2019). The imperviousness and slope for this area was assigned 40% and 4% respectively, to represent low-rise (estate) residential land use.

2. An additional 1.3 ha subcatchment west of Wabanaki Drive, immediately south of the rail line which was observed to drain to the West Hidden Valley Creek, was added to the model.

3. The Fairview Mall subcatchment area was re-delineated and a private storage system was added based on Husson SWM (2018) report, as described above. The storage was modified to replicate the maximum storage and peak 5-year and 100-year outflow reported in the Husson SWM report.

4. A 5.6 ha subcatchment north of Highway 8, generally between Kingsbury Road and Fairway Road S., that drains to the storm sewer on King Street East, was added to the model.

5. The spill elevation of the North Wabanaki SWM pond was updated in the model. The pond maximum depth was described as 2 m in the Conestoga-Rovers (2002) and WalterFedy (2016) reports, but modelled as 3 m deep in the Wood model and report (2019). The provincial LiDAR shows the pond crest at an elevation of 321.1 m, which would imply a maximum pond depth of 2.6 m. The pond crest and maximum depth were modified in the model to align with the provincial LiDAR.

6. The channel lengths leading into the Hidden Valley ESPA/PSW from the north and west tributaries were updated in the model. The channel lengths between the most downstream tributary nodes and the wetland storage node have been shortened to 50 m to improve model stability. The original model had lengths of 740 m for the west and north tributaries which represented very gentle slopes of approximately 0.1% and allowed for significant backwatering effects in the channel within the modelling. While such effects may actually occur under elevated flow conditions, within the modelling they translate into unrealistic hydrograph micro-peaking (rapidly rising and falling in the span of seconds) at the north and west tributary nodes, and erroneously reducing the total flow from the tributaries into the ESPA/PSW. Removing the backwatering impact into the upstream channel allows for comparison of incoming flows, separate from the complexities of the wetland hydrology, and reduces erroneous micro-peaking in inflow hydrographs. Additionally, the full extent of the

ponding within the wetland feature varies by year and season, at elevated storage levels, standing water can be observed as close as 50 m downstream of the north and west tributary nodes, so a reach length of 50 m is not unrealistic.

7. Three topographic depression storages have been included in the model. The two depression storage features are located south of the main ESPA/PSW feature but north of Hidden Valley Road, at the outlets of the proposed 2A lands, and one is located north of the proposed 2B lands. Runoff from the depression north of the 2B lands would drain through the 2B lands at the spill elevation of 315.4 m, but preliminary modelling shows that spill does not occur during the 1:2 year through Regulatory events. The topographical depression volumes were measured using GIS software and the provincial LiDAR.

3.1.3 Subsurface Representation

Evapotranspiration from soils can represent 60% (or greater) of annual precipitation losses (Sanderson 1998), so accurately capturing this process in the modelling is important for water balance analysis. The default evaporation process in PCSWMM does not allow for transpiration from soils/plants and only represents surface evaporation, which vastly underestimates total evapotranspiration. To better represent evapotranspiration losses, soil layers were added to subcatchments using the “Low Impact Development” (LID) feature in PCSWMM. Typical LIDs are at-source SWM controls (e.g., rain gardens, grassy swales, and pervious pavement) and are often designed and implemented to encourage groundwater recharge across the landscape, better mimicking natural water balance. The LID calculations implemented in PCSWMM allow for the parameterization of a soil layer, simulating soil storage and evapotranspiration more effectively than the default PCSWMM subcatchment characterization. LID features were added to existing subcatchments as a modelling “workaround” to represent dynamic storage and evapotranspiration processes from existing soil units within the subcatchment areas.

Each subcatchment was subdivided into pervious and impervious subcomponents, with an LID feature added to all pervious subcomponents. The LID features contain two layers, a “surface layer” which adopted the surface parametrization of the subcatchment itself, including width, area, and depression storage, and the “soil layer” which was parameterized according to the dominant soil type of the Region. The general physiography of the Region is gravelly loam to fine sandy loam (Wood 2019; Stantec 2013b), and was modelled as sandy loam as such represents the best approximation to the coarse loamy soils of the Region. The soil parameters applied to the LID features are shown in Table 1.

Table 1 Soil Parameters

Parameter	Value	Source
Soil Type	Sandy Loam	Hydrogeological Study River Road Extension (WSP, 2013)
Porosity	0.412	Table 1 United States Department of Agriculture Soil Types (Rawls et. al 1983).
Field Capacity	0.19	Table 3-12 City of Calgary Stormwater Guidelines (City of Calgary 2011)
Wilting Point	0.085	Table 3-12 City of Calgary Stormwater Guidelines (City of Calgary 2011)
Conductivity	10.9 mm/hr	Table 1 United States Department of Agriculture Soil Types (Rawls et. al 1983).
Conduct Slope	40	Stormwater Management Model Reference Manual, Volume 1 Hydrology Revised (Rossman et al. 2015)
Suction Head	110.1 mm	Table 1 United States Department of Agriculture Soil Types (Rawls et. al 1983).
Initial deficit	0.246	Handbook of Hydrology (Maidment, et al. 1993)
Soil thickness	200 mm	Calibrated to match annual actual evapotranspiration (AET) (Sanderson 1998, Stats Canada 2017)

Within the PCSWMM modelling, soil thickness was determined by iteratively calibrating modelled annual AET against reported annual AET, estimated at 500 mm per year for Kitchener (Sanderson 1998, Stats Canada 2017), based on reported results for similar land use types (agricultural). Situated between the future River Road alignment and the ESPA/PSW (Figure 5), subcatchment SUB2010 was selected as the representative agricultural subcatchment of similar land use to the source comparison subcatchments. The calibration period was 30 years (1980 to 2010).

Soil conductivity was adjusted on a seasonal basis to replicate slower infiltration during winter months when soils are frozen and less permeable. Monthly soil conductivity adjustment factors were applied based on “Guelph Turf Grass Institute - Updated Water Balance Modelling Approach and Results” (Matrix 2018). Table 2 shows the month-by-moth infiltration modification factor.

Table 2 Monthly Soil Conductivity Adjustment

Month	Soil Conductivity adjustment
January	0.1
February	0.1
March	0.5
April	0.6
May	1
June	1
July	1
August	1
September	1
October	0.6
November	0.5
December	0.1

For the pre-to-post-development water balance comparison, soil storages were only added to subcatchment areas anticipated to undergo a change in land use, as highlighted in Figure 5. The parameters for these subcatchments are presented in Table 3. Note: these parameters represent the full subcatchment before they are subdivided into impervious and pervious components. Soil parameters for subcatchments not impacted by future development were maintained from the Wood (2019) model.

Table 3 Existing Catchment Parameters (Refer to Figure 5)

Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Impervious (%)	Depression Storage Impervious (mm)	Depression Storage Pervious (mm)
SUB2001	3.2	322.5	100.0	6.0	8.0	2.0	5.0
SUB2005	4.5	171.0	263.1	7.5	0.0	2.0	5.0
SUB2008	3.8	254.1	151.0	9.8	0.0	2.0	5.0
SUB2009	3.7	146.6	255.0	2.5	0.0	2.0	5.0
SUB2010	5.0	242.7	207.0	7.0	0.0	2.0	5.0
SUB2101	1.2	83.9	138.0	0.8	0.0	2.0	5.0
SUB2103	1.5	151.3	100.8	2.0	77.0	2.0	5.0
SUB2104	0.6	98.5	65.7	2.0	60.0	2.0	5.0
SUB2108	0.5	89.1	59.4	2.4	72.6	2.0	5.0
SUB2111	0.7	80.0	91.0	7.4	22.0	2.0	5.0
SUB2146	2.9	210.3	140.0	6.3	0.0	2.0	5.0
SUB3001	1.5	364.2	41.0	6.4	0.0	2.0	5.0
SUB3005	0.7	100.5	67.0	1.5	85.0	2.0	5.0
SUB3010	4.6	170.0	270.0	5.6	12.6	2.0	5.0
SUB3011	1.2	175.5	67.0	5.7	10.8	2.0	5.0
SUB3012	1.4	190.5	73.0	13.9	16.1	2.0	5.0
SUB3013	0.7	40.9	168.0	2.4	85.0	2.0	5.0
SUB3020	1.6	92.6	172.0	2.0	0.0	2.0	5.0
SUB3022	8.7	298.4	290.0	3.4	0.0	2.0	5.0

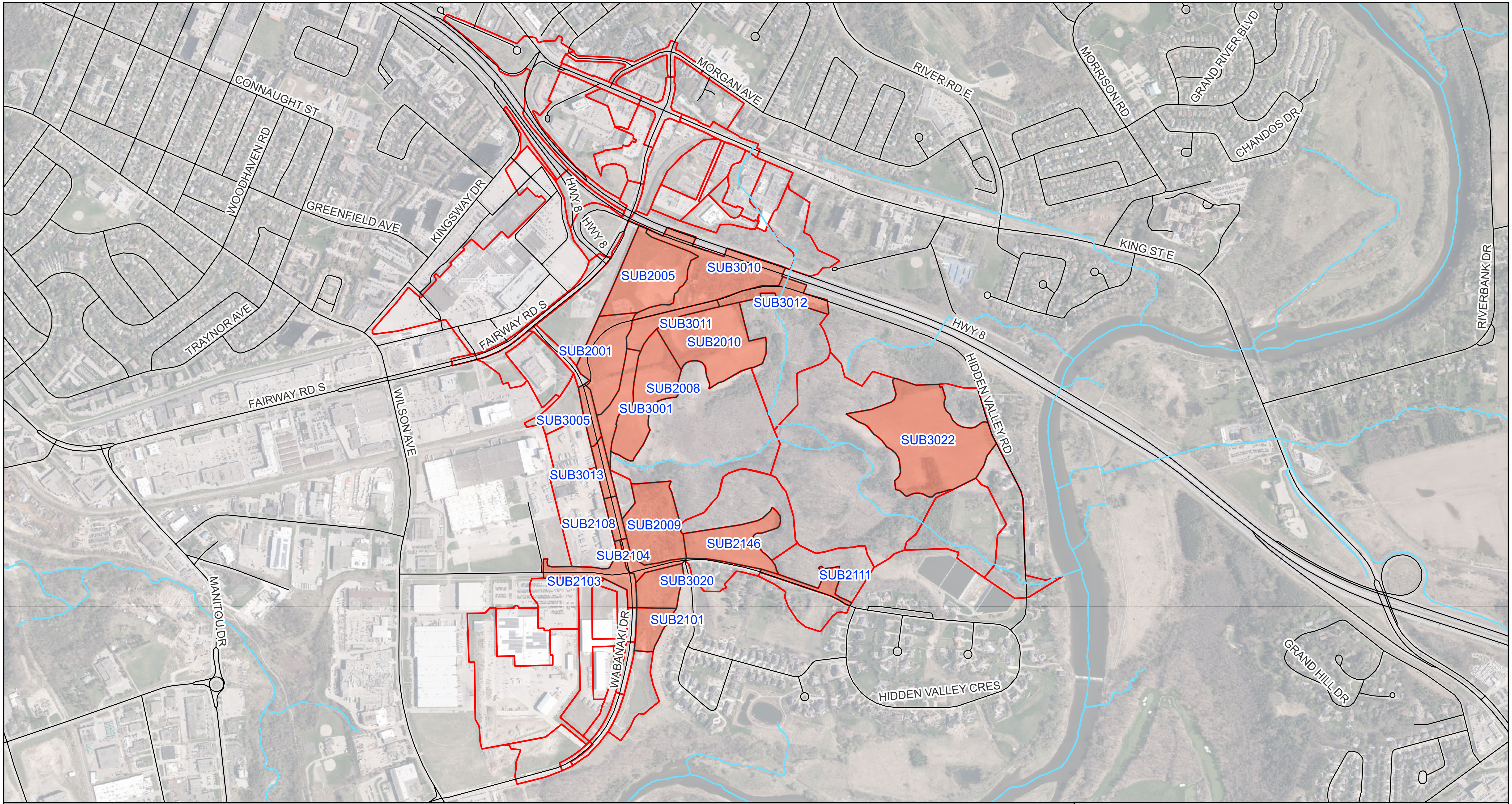

Figure Date: August 8 2024

Legend	
Existing Conditions Subcatchments	
Catchments Impacted by Future Development	
Roads	
Watercourse	

0 250 500 m

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Existing Conditions Subcatchments

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M.L.

Fig. 5

3.1.4 Stormwater Management Controls

There are two end-of-pipe SWM ponds located within the existing Hidden Valley Creek catchment area, known as the North Wabanaki SWMF and South Wabanaki SWMF. Both facilities act as quality and quantity control features for their respective subcatchments.

The North Wabanaki SWMF is located east of Wabanaki Drive, approximately 225 m north of the Hidden Valley Road south connection. The total subcatchment area draining to the North Wabanaki SWMF is 6.8 ha. As described in the North Wabanaki SWMF SWM Report (Conestoga-Rovers 2002), the SWM facility has two outlets inside a vertical riser. A low flow 75 mm orifice outlet at the elevation of the permanent pool (319.5 m) provides extended detention for water quality treatment and erosion control. A second, 375 mm diameter PVC riser pipe with a 350 mm orifice plate mounted at 319.65 m provides control for discharge of larger storm events. Both pipes are inside a 2,100 mm perforated CSP vertical riser structure, and discharge to the west tributary via a 300 mm diameter PVC outlet pipe.

The existing South Wabanaki SWMF is located east of Wabanaki Drive and approximately 375 m south of Hidden Valley Road. The pond receives inflow from a 19.2 ha subcatchment via an 825 mm diameter storm sewer pipe from the south and discharges to a 675 mm pipe with a 130 mm orifice plate to the north. Outflow is conveyed under Wabanaki Drive and discharges directly to the west tributary. The pond has an overflow pipe bypass at 321.7 m (depth of 2.2 m) which allows flow to enter the Wabanaki Drive storm system.

Additional local stormwater controls are implemented on a site-by-site basis. The industrial lot on the west side of Wabanaki Drive, the Fairview Mall, and the car dealership complex south of King Street East have private stormwater controls. All private stormwater controls from the Wood (2019) model have been maintained in the Matrix updated model, with the exception of the Fairview Mall storage which has been updated with respect to the Husson (2019) report.

3.2 Calibration

Extensive calibration efforts of the hydrologic model were undertaken by Wood in 2019, utilizing flow data from three flow monitoring locations, collected between 2011 and 2021. Flow monitoring data sources and periods are shown in Table 4.

Table 4 Flow Monitoring Data Collection Periods

Consultant	Data Collection Period
Stantec	2011-2021
WalterFedy	2014
Wood	2017

Wood achieved reasonable calibration at two of the locations, namely the west and north tributaries, upstream of the ESPA/PSW. As there have been changes to the subcatchment area since the 2019 study, previous calibration efforts do not translate to the existing modelling. Ideally, further calibration would be completed to adjust parameters to the existing (2024) conditions. To this end, Matrix requested the rating curves for the associated flow monitoring data used in the Wood (2019) study, but this information was not available. Without rating curves for the collected water level data, it is not possible to derive accurate flow estimates.

Notwithstanding the above, for the purposes of the SWM strategy development, the calibration of the tributaries is deemed to be unnecessary. All proposed development is upstream of the wetland and the west and north tributaries. The stormwater planning undertaken as part of the study is focused on comparing the hydrologic characteristics of existing and future land use conditions, and the effectiveness of SWM controls at mitigating potential negative changes. These objectives can be accomplished by analyzing relative flows and volumes, without determining absolute values via intensive calibration efforts.

3.3 Peak Flow Assessment

The 1:2-year through 1:100-year design storms were developed using the City of Kitchener Intensity-Duration-Frequency (IDF) Parameters (City of Kitchener 2021). The IDF parameters used for analysis are summarized in Table 5. A Storm duration of 3 hours was used in the hydrologic assessment in accordance with City of Kitchener design standards.

Table 5 City of Kitchener Design Storm IDF Parameters (2021)

Design Storm	A	B	C	Duration (hours)
1:2-year	743	6	0.7989	3
1:5-year	1593	11	0.8789	3
1:10-year	2221	12	0.9080	3
1:25-year	3158	15	0.9355	3
1:50-year	3886	16	0.9495	3
1:100-year	4688	17	0.9624	3

Table 6 provides a comparison of existing conditions peak flows between the as-received Wood (2019) model and the updated Matrix existing conditions model. There is a general decrease in peak flow to the western tributary is due to the attenuation provided by the Fairview Mall stormwater storage system that has now been incorporated. Flow increases in the north tributary due to the more conservative model parameterization.

Peak flows to the ESPA/PSW show increases due to the correction of the instabilities within the original model, as discussed in Section 3.1.2. To reiterate, channel lengths and slopes into the wetland were reduced in the Matrix model to eliminate model instabilities and address erroneous peak flow reductions caused by backwatering from the wetland. As shown in Table 6, the original modelling predicted lower total peak flow rates into the ESPA/PSW than from either the west or north tributaries individually, an obviously questionable result. Matrix's updates have increased the slope of the channels for the north and west tributaries into the wetland, largely eliminating the impacts of the backwatered condition from the model. The resultant peak flows, described as Existing Conditions in Table 6, more realistically estimate the peak flows into the ESPA/PSW as arithmetic sums of the main incoming tributaries plus some additional direct inputs to the feature.

Table 6 Comparison of Wood (2019) to Matrix (2024) Existing Conditions Model Results

	Original Wood Model (m^3/s)			Existing Conditions (m^3/s)			Difference (%)		
	West	North	ESPA/PSW	West	North	ESPA/PSW	West	North	ESPA/PSW
Node	574	564	STRG4	574	564	STRG4	574	564	STRG4
1:2-yr	4.1	2.5	1.4	2.9	3.2	5.8	-28%	30%	307%
1:5-yr	6.1	3.8	2.6	4.3	3.8	8.3	-29%	0%	216%
1:10-yr	6.9	4.3	3.7	5.7	4.5	11.0	-17%	4%	197%
1:25-yr	7.4	4.9	4.8	7.2	5.1	14.1	-4%	5%	197%
1:50-yr	7.9	5.4	5.1	8.4	5.7	17.0	6%	6%	237%
1:100-yr	8.7	5.9	5.5	9.5	6.2	19.7	10%	5%	260%
						Average	**-10%**	**8%**	**236%**

Peak flows from individual subcatchments generally increase within the Matrix model due to the expanded subcatchment area and updated hydrologic parameters. The Matrix model measures impervious using aerial imagery to provide a more accurate estimate of impervious land coverage. Average impervious area draining to the wetland increases in the Matrix model, with a total combined impervious area of 72.8 ha in the Matrix updated model, as compared to 52.4 ha in the Wood (2019) model. Increases to impervious area result in higher peak flow rates on average.

3.3.1 Stormwater Pond Performance

Under existing conditions, the North Wabanaki SWMF has a maximum active storage depth of 2.39 m (320.86 m). The pond spillway is not activated during any of the design storm events, and the maximum outflow from the pond is 0.29 m^3/s during the 1:100-year event.

The South Wabanaki SWMF has a maximum active storage depth of 2.21 m (321.71 m). The highest piped outlet is activated by the 1:100-year storm and above, which spills into the Wabanaki Drive storm sewer. The emergency spillway is not activated during any design storm event and the maximum outflow from the pond is 0.03 m^3/s during the 1:100-year event.

3.4 Water Balance

A continuous simulation was run for the 30-year period between 1980 and 2010. Hourly precipitation data was adopted from the Wood model, which compiled data from Guelph OAC/Arboretum/Turfgrass stations (Climate IDs: 6143083/6143069/ 6143090) and fills gaps with data from the Waterloo Airport monitoring station (ID: 6149387).

3.4.1 Climate Information

Evapotranspiration

Monthly average evapotranspiration was calculated used the Hargreaves and Samani methodology, an approach that has been shown to be more accurate in the prediction of monthly evapotranspiration than similar temperature-based methods (Metcalfe et al. 2019). The evaporation coefficient was varied monthly in accordance with the results of Metcalfe et al. (2019). Daily temperature data from the Waterloo Airport (Climate ID: 6149387) was used to calculate daily evapotranspiration rates and averaged from 1980 to 2010 (the period of continuous modelling) to produce monthly evapotranspiration rates. Table 7 shows the monthly adjusted evaporation coefficients (kHS) and Table 8 shows the calculated monthly potential evapotranspiration rates.

Table 7 Monthly Hargreaves and Samani Evaporation Coefficients

Month	Hargreaves and Samani Monthly Evaporation Coefficient (kHS)
January	0.0021
February	0.0021
March	0.0021
April	0.0025
May	0.0022
June	0.0020
July	0.0020
August	0.0020
September	0.0020
October	0.0022
November	0.0021
December	0.0021

Table 8 Monthly Potential Evapotranspiration Rates

Month	mm/month	mm/day
January	3	0.08
February	4	0.14
March	22	0.71
April	79	2.64
May	110	3.54
June	132	4.41
July	141	4.54
August	120	3.86
September	82	2.73
October	45	1.45
November	16	0.54
December	4	0.14
Sum	**758**	

A "LID Control" feature was added to each subcatchment to represent the soil storage and infiltration. Flow from the pervious areas of a subcatchment is directed to the LID control which has its own surface and storage parameters. See Section 3.1.3 for greater detail on the soil modelling approach.

Snowmelt

Snowmelt is not accounted for in the continuous modelling simulations. Proper snowmelt and snowpack characterization requires calibration of melt factors and rain-on-snow temperature thresholds, as well as hourly resolved temperature data, which are outside the scope of this study. Removing snowpack from the modelling reduces spring freshet flows but increases midwinter flows. For the sake of annual water balance, this omission will have a minimal impact on results.

3.4.2 Results

The existing conditions water balance results for the subcatchments of interest, i.e., those which will be impacted by future development, are shown in Table 9. Evapotranspiration makes up an average of 57% of annual losses, the largest portion of losses for most subcatchments. Infiltration represents an average of 33% of annual losses, the second highest source of losses. Many of the proposed development subcatchments have low imperviousness and highly conductive soils, so runoff represents the smallest portion of annual losses (average of 10%). Runoff is substantially higher in a select few subcatchments, such as SUB2103, SUB2104, SUB2108, SUB3005, and SUB3013 as these subcatchments contain the existing Wabanaki Drive and have a higher imperviousness, and thus lower infiltration and evapotranspiration potential.

Table 9 Existing Water Balance Results (Refer to Figure 5)

Subcatchment	Area (ha)	Precipitation (mm/yr)	Evapotranspiration (mm/yr)	Infiltration (mm/yr)	Runoff Depth (mm/yr)
SUB2001	3.2	824	473	274	76
SUB2005	4.5	824	497	298	28
SUB2008	3.8	824	497	298	29
SUB2009	3.7	824	497	299	28
SUB2010	5.0	824	497	298	28
SUB2101	1.2	824	497	298	28
SUB2103	1.5	824	273	68	484
SUB2104	0.6	824	321	119	384
SUB2108	0.5	824	284	82	459
SUB2111	0.7	824	432	232	159
SUB2146	2.9	824	497	298	29
SUB3001	1.5	824	496	297	29
SUB3005	0.7	824	249	45	532
SUB3010	4.6	824	461	261	102
SUB3011	1.2	824	465	265	93
SUB3012	1.4	824	455	256	112
SUB3013	0.7	824	251	45	529
SUB3020	1.6	824	497	298	28
SUB3022	8.7	824	497	298	28
Average:		824	470	271	83

4 Proposed Conditions and Stormwater Management Planning

Development of the proposed conditions modelling, including assumptions regarding reasonable subcatchment areas, impervious coverages and breakdowns (e.g., roofs versus roads/parking), anticipated drainage strategies (e.g., direction of discharge), and conceptual SWM approach and facility locations was completed in coordination with the City of Kitchener as well as the sources noted in Section 2. Since planning and design of development lands remain in various stages of completion, several assumptions regarding the ultimate drainage patterns within the study area were incorporated. These assumptions were developed in consultation with City staff and resources, with the local development community, and with the

Region and their consultant as it relates to the River Road Extension. A summary of related assumptions includes the following:

- The ultimate drainage plans for the area to the south of Hidden Valley Road and east of River Valley Drive (SUB3003) are adopted from the Hidden Hills Estates Stormwater Management Plan (MTE 2020). It is assumed that the minor flows (1:5-year event) from this subcatchment will be directed to a proposed stormwater pipe along Hidden Valley Road and conveyed north to the North Wabanaki SWMF, while major flows will be conveyed southward, away from the Hidden Valley subcatchment. Future conditions design storm modelling removes SUB3003 and applies a constant 1:5-year peak flow of 0.124 m^3/s to the storm sewer system along Wabanaki Drive, based on City/WSP email correspondence - July 2, 2024). For continuous modelling, SUB3003 is maintained using MTE delineation and assumed to be low-rise residential land use. Under this continuous scenario, major flow is not diverted from SUB3003. This will have marginal impact on water balance results as the vast majority of runoff is from small (<25 mm) events.

- The "2A" and "2B" areas marked on the City's Land Use Master Plan (2019) are modelled as low-rise residential land use to match surrounding land use, but the ultimate land use for these areas is still undecided. Consideration for alternate scenarios where these parcels have been developed for medium density residential land use are considered in Section 4.2.5.

- Proposed "2A" development lands are two, relatively small parcels that lie to the north of Hidden Valley Road that remain as "site-specific policy area" with no official designation in municipal planning documentation as of the time of writing. Drainage from most of these areas is effectively isolated from the remainder of the HVSP land, draining instead to topographic depressions on the south side of the main esker ridge that forms the south limits of the ESPA/PSW. Based on an analysis of the storage volume available within the topographic depressions (56,500 m^3 and 16,500 m^3 for those receiving drainage from SUB2146 and SUB2111, respectively), all drainage from these lands is infiltrated before entering the wetland under existing conditions, conditions that will require mimicking under proposed conditions. Storage nodes are used in the PCSWMM model to represent these topographic depressions.

- For the proposed business park lands located southeast of the intersection of Hidden Valley Road and Wabanaki Drive, the southern portion (SUB2101) will be directed to the South Wabanaki SWMF while the north half (SUB3020) will be controlled using an underground storage tank to match post-development peak flow rates to existing peak flow rates.

Per a City request, Matrix completed a high-level assessment of whether major flow from the entire parcel could be diverted to the South Wabanaki SWM facility for quantity control. Based on existing grading, it was determined to be impractical for surface flow from this parcel to be conveyed south. Additionally, Matrix have compared the 100-year runoff volume less the 1:5-year minor flow volume (1,050 m^3) from the business park subcatchment to available capacity (814 m^3) remaining in the South Wabanaki SWMF, as reported by the City (2024-03-20), and found that it would likely not have sufficient capacity. Therefore, only half of the drainage will be directed to the South Wabanaki SWMF.

- The existing lands to the north of the proposed River Road Extension drain in two directions, either east to the north tributary or west to the railway and storm sewer on Wabanaki Drive. This area (SUB2005) is proposed to be developed as commercial and utility corridor land use. Based on the grading of the area, Matrix assumes flow from this area will all drain to a common stormwater facility (SWMF 3) north of the River Road alignment.

- The Pearl Valley Development - Conceptual Servicing/SWM Strategy technical memorandum (MTE 2024) identified a potential development area denoted as “7” on Figure 3.3 – Conceptual Storm / SWM Plan, located along the south side of the future River Road just east of the north tributary. Per discussion with the City, development of this area has not been considered within the current analysis.

- Proposed drainage plans for the commercial parcels located to the north and south of the proposed emergency access road connection between Fairway Road and the roundabout on River Road (SUB2143, SUB3005, and SUB2001) were provided by the City on May 31, 2024. The drainage strategy has the north parcel (SUB2001) conveyed to the North Wabanaki SWMF unattenuated, while the orphaned triangular parcel and to-be-removed road segment (SUB2143 and SUB3005) will be controlled to the post-development 5-year peak flow rate using onsite controls before routing to the North Wabanaki SWMF.

- Matrix has assumed the new River Road alignment drainage delineation provided by WSP (2021) and MTE (2024) for sections north of North Wabanaki SWMF, as they are more recent than IBI (2013) and are reasonable. The road has a drainage divide approximately 160 m north of roundabout, where runoff to the north will enter SWMF 2 and runoff to the south will go to North Wabanaki SWMF.

- The proposed development areas south of River Road and between the west and north tributaries (SUB2008 and SUB2010) will be split based on existing topography and drain to two separate SWM facilities. Based on the steep grade of the existing terrain, it would be questionably feasible to drain the entirety of SUB2010 to SUB2006, to a common facility. Drainage from the area has been assumed split into roughly equal sections based on the existing topography.

- The subcatchment denoted SUB3022 includes lands labelled as “2B” on the Master Plan and select parcels immediately to the south. Development of this area is assumed as “Low-Rise – Estate” in keeping with the neighbouring existing uses. The northern tip of the “2B” area currently drains north. To have a consistent drainage catchment between existing and proposed conditions, this portion of the parcel has been disregarded from, capture within the ultimate SWM facility (SWMF-4), assuming that it will be backyards and pervious surface cover similar to existing conditions.

- Exact drainage details for the south roundabout (Goodrich Drive / Wabanaki Drive / Hidden Valley Road) remain unavailable at the time of writing. Subcatchment delineations have been based upon previous designs (Wood [2019] and WSP [2021]) and include the majority of the road rights-of-way leading into the roundabout from all four directions, as defined on Figure 6 and Figure 7. Drainage from these subcatchments is directed to the North Wabanaki SWMF.

- The roadway from Wabanaki North SWMF to the south roundabout (SUB2108) has been updated to 85% imperviousness to represent the proposed 4-lane roadway.

- In addition to the new end-of-pipe controls, The North Wabanaki SWMF will be expanded to accommodate additional inflow from new development and the River Road Realignment.

4.1 Stormwater Management Implementation Plan

The conceptual stormwater management planning for the HVSP area has been completed in accordance with guiding documents including, but not limited to, the City of Kitchener Development Manual (2021) and the Stormwater Management Planning and Design Manual (MOE 2004). The primary goals and components of the stormwater strategy include:

- Infiltration – maintain or increase existing infiltration volume.

- Water Quality – Enhanced protection, equivalent to 80% long-term total suspended solids (TSS) removal.

- Erosion (flow-duration) – maintain existing erosion regime in the west and north tributaries.

- Peak Flow Rates and Flood Mitigation – match proposed development peak flow rates to existing conditions peak flow rates in total discharge to ESPA/PSW.

Per provincial guidance and typical approach, the SWM strategy should meet the above objectives through the implementation of a multi-component, “treatment train” approach that includes SWM measures distributed across the landscape including at-source and at end-of-pipe. At-source controls have become more-or-less synonymous with Low Impact Development (LID), and are designed and operated with the aim of reducing surface runoff volumes and rates, and encouraging infiltration of clean water across the developing landscape, more closely mimicking existing conditions and aiding in water quality control. More traditional end-of-pipe controls such as stormwater ponds provide quality control through sediment settling within a permanent pool and extended detention of “first flush” storm events, and post-to-pre- quantity control through the use of active storage and peak flow restricting outlet structures. Both at-source and end-of-pipe components help to reduce erosion threshold exceedance risk in downstream receiving water systems.

Catchments impacted by future land use changes are shown in Figure 6 with their respective potential land use types. The limits of development around the Hidden Valley ESPA/PSW have changed since the 2019 Land Use Master Plan, according to the proposed limits of development by NRSI (2024). The subcatchment boundaries are representative of the current development limits as of June 2024. The specifics of implementation stormwater strategy presented in Section 4.1 are subject change following detailed land use planning. The goals of this report are to inform the control targets for quality, quantity, and erosion control. The strategy presented herein represents one reasonable implementation strategy to meet the targeted goals. There is currently substantial uncertainty with regards to land use type and the development limits within the study area, so it is expected that changes to the strategy will be necessary in the future. Regardless of the ultimate study area land use or stormwater control configuration, the goals for water quality, quantity and erosion control outlined in this report should be followed. I.e., stormwater controls can be repositioned, combined, or take another form, so long as the provide the same (or greater) level of control as those outlined in this report.

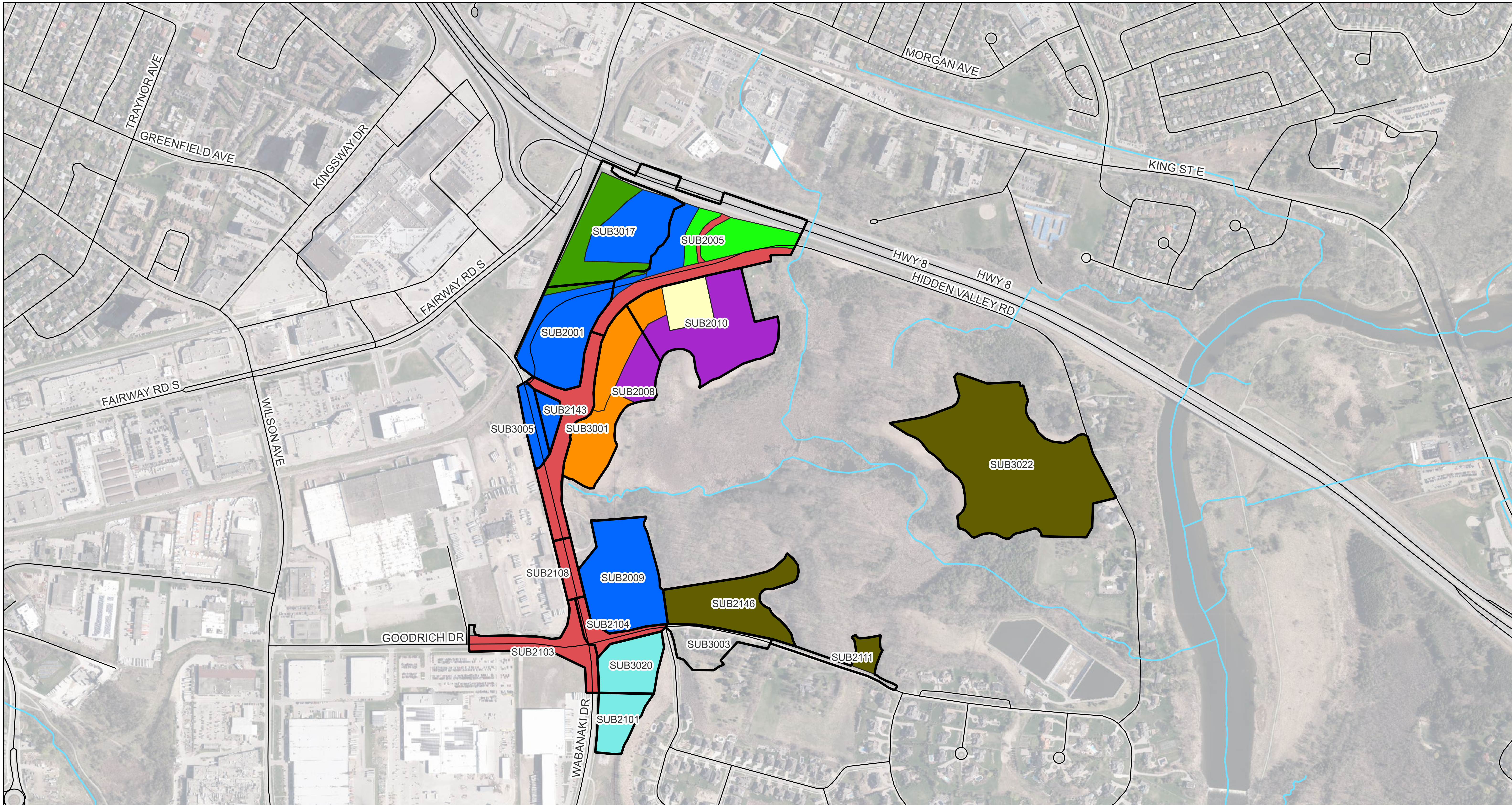

Figure Date: August 9 2024

Future Land Use

- Buisness Park Employment
- Commercial
- High Rise Residential
- Major Infrastructure and Utilities
- Medium Rise Residential
- Mixed Use
- Open Space
- Roadway
- Undecided
- Roads
- Watercourse
- Impacted Subcatchments

This drawing must be used in conjuction with the attached memorandum, and is subject to the same limitations and conditions stated in the memorandum.

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Future Development Land Use

M.L.

Fig. 6

4.1.1 At-Source Control

At-source controls aim to reduce runoff volume and flow rates at the source and can provide quality control for the benefit of downstream areas. Typical at-source controls include infiltration trenches, vegetated swales, pervious pavements, rainwater harvesting tanks, and rain gardens.

Infiltration Targets

As identified in the City's Integrated Stormwater Management Master Plan – Implementation Report (Aquafor Beech 2016), the targets for the "East Side" catchment area, of which the subject lands are a part, is that "a water balance is required". At the same time, there is a general City-wide requirement that the first 12.5 mm of runoff from all surfaces be retained onsite whether through infiltration, evapotranspiration or rain water re-use. Further, given the source water protection zones covering much of the site, the infiltration of stormwater should target "clean" runoff sources such as that from roofs or other pervious areas to limit the infiltration of chloride and other contaminants into groundwater systems.

Given the above, the recharge target for the proposed Hidden Valley development area, established to ensure a post-to-pre balance from developing lands upgradient of the ESPA/PSW, is the at-source capture and infiltration of the first 25 mm of precipitation from all "clean" sources including rooftops and pervious, landscaped areas.

Within the primary developing area, roofs are estimated to be 50% of all impervious area for all future land uses from which "clean" runoff can be collected and directly infiltrated.
Major infrastructure development such as the "utility corridor" as well as open space areas will remain largely pervious. Conversely, roadway corridors will consist of entirely "unclean" impervious area.

Beyond the purpose-built at-source infiltration measures, substantial groundwater recharge is expected to continue to occur within the ESPA/PSW area within which a "hydraulic window" has been previously identified, representing a conduit to the deeper groundwater systems and, importantly, the capture zone associated with the Region's Parkway Wellfield.

Quality Control

Enhanced at-source controls are recommended to provide quality control where "wet" end-of-pipe quality controls cannot reasonably be implemented. For example, site-specific policy areas "2A" are isolated from other development areas in a drainage sense, and achieve quantity controls through other means (i.e., 100% capture and recharge/evapotranspiration in existing depressions) and are not of sufficient drainage area to support a wet facility. In such instances, adopting at-source quality controls such as oil grit separators (OGS) as part of a multi-component “treatment train” with other measures such as bioswales and catch basin filters should suffice to clean the runoff to a level that future maintenance needs within the receiving natural depression areas will be unnecessary or at least minimized. Detailed assessment of the potential for development in these areas and any ecologic characteristics of these depressions requiring consideration prior to approval are beyond the scope of the current work.

4.1.2 End-of-Pipe Controls

End-of-pipe controls represent larger storage facilities, implemented at the downstream end of a subcatchment, with the purpose of treating water from a large area. End-of-pipe controls can take a variety of forms but typically include wet ponds, constructed wetlands, hybrid wet pond/ wetlands, dry ponds, or underground storage. Wet facilities with a permanent pool and forebay are typically considered most efficient at providing water quality treatment ponds through the settlement of suspended solids and the resistance to subsequent scour and resuspension. Dry ponds and underground storages do not provide the same level of quality control but can offer other advantages such as reducing at-surface land requirements.

Quantity Control

Four new end-of-pipe SWMF facilities (wet ponds/wetlands), two local onsite-storages, one underground storage, and an enhancement to the existing North Wabanaki SWMF are proposed to provide quantity control for proposed future development. The active storage characteristics for the end-of-pipe SWMF (SWMF 1 to 4 and North Wabanaki SWMF) controls have been developed based on simplified storage-discharge curves using dual orifice controls to provide a post-to-pre matching of peak flows for the 1:5-year and 1:100-year storm events. The proposed “local onsite-storages" have been designed to attenuate post-development 1:100-year storm event peak flow rates to post-development 1:5-year storm event peak flow rates.

The conceptual locations of stormwater ponds and a schematic representation of which subcatchment areas are associated with each pond are shown in Figure 7. Table 10 shows the anticipated active storage volumes required for attenuation of the 1:100-year event, assuming a maximum active storage depth of 1.5 m.

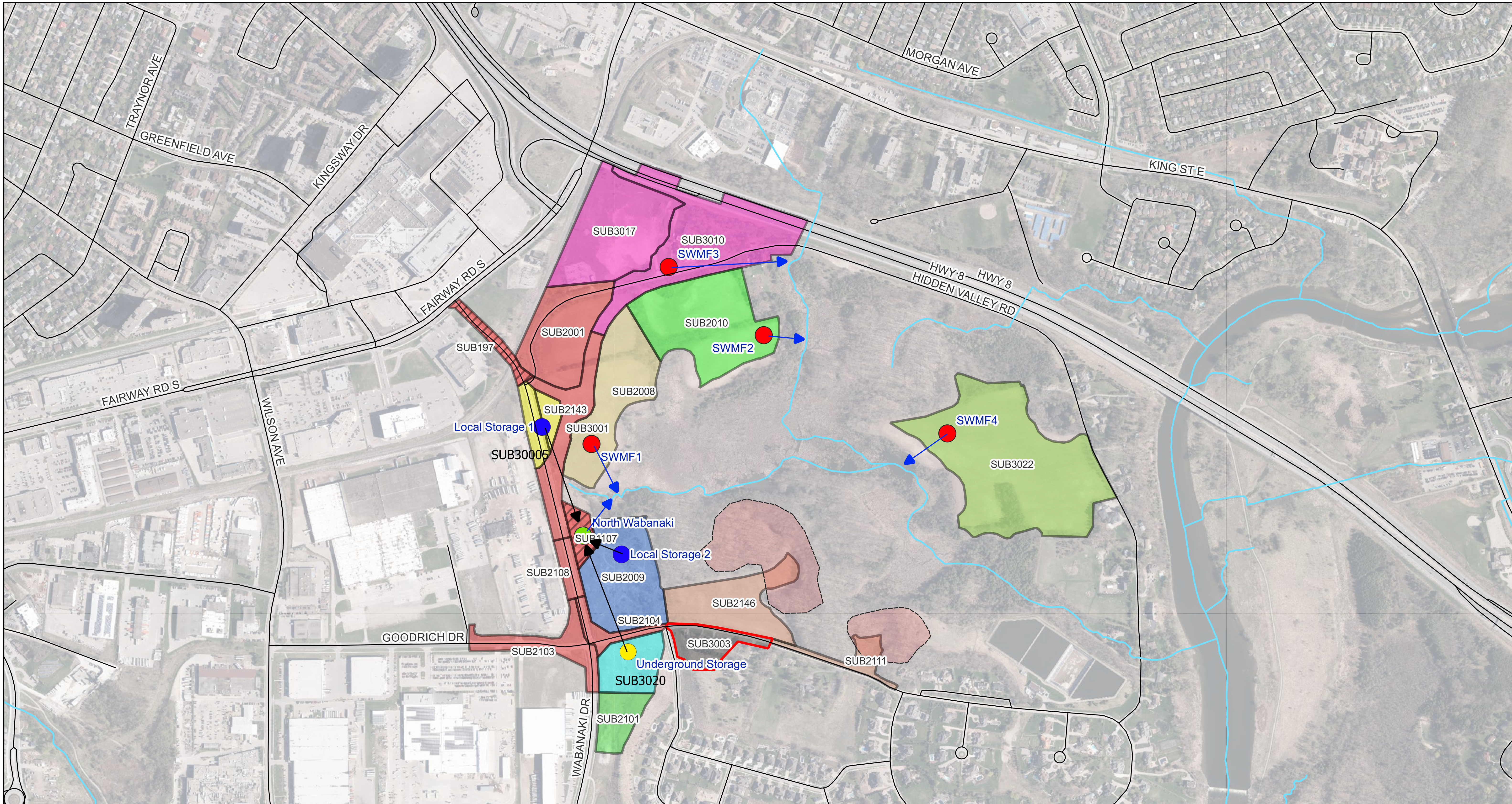

Figure Date: November 25 2024

Catchment Outlet Location

- Depression
- Local Storage 1
- Local Storage 2
- SWMF 1
- SWMF 2
- SWMF 3
- SWMF 4
- Underground Storage
- Wabanaki North
- Wabanaki South
- Unchanged - Wabanaki North
- Redirected

Stormwater Controls

- New
- Upsize
- Underground Storage
- Local Storage
- Roads
- Watercourse
- Depression Storages

0 250 500 m

N

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Stormwater Management Pond Locations and Subcatchment Contributions

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Fig. 7

Table 10 End-of-Pipe SWM Facility 100-Year Active Control Volumes (Refer to Figure 7)

Stormwater Facility	Contributing Subcatchments	Contributing Drainage Area (ha)	Active Storage for the 1:100-year event (m^3)
SWMF 1	SUB2008	3.8	1,664
SWMF 2	SUB2010	5.0	1,795
SWMF 3	SUB3010, SUB3017	10.4	1,025
SWMF 4	SUB3022	9.6	2,033
Underground Business Park Storage	SUB3020	1.6	656
North Wabanaki SWMF	SUB1107, SUB197, SUB2001, SUB2009, SUB2103, SUB2104, SUB2108, SUB2143, SUB3001, SUB3003, SUB3005, SUB3020	16.94	3,300

Quality and Erosion Control

Based on the requirements of the Stormwater Management Planning and Design Manual (SWMPD Manual; MOE 2003), "Enhanced" protection will be achieved by targeting a TSS removal rate of 80%. The proposed new and enhanced wet pond facilities will provide quality control to outflows through the use of a permanent pool. Table 11, reproduced from Table 3.1 of MOE SWMPD Manual, summarizes the storage volume requirements for different types of quality control storage facilities. Of the MOE-specified water quality volumes for wet facilities, 40 m^3/ha is extended detention, while the remainder represents the permanent pool.

Table 11 Enhanced Water Quality Storage Requirements Based on Receiving Waters (MOE SWMPD Manual, March 2003)

Protection Level	SWMP Type	Storage Volume (m^3/ha) for Impervious Level			
		35%	55%	70%	85%
Enhanced 80% long-term TSS removal	Wetlands	80	105	120	140
	Hybrid Wet Pond/ Wetland	110	150	175	195
	Wet Pond	140	190	225	250

Further, in place of the MOE-specified 40 m^3/ha of active quality storage, many jurisdictions adopt a more conservative design criterion that includes extend detention (24 – 48 hours) of the runoff associated with a 25 mm storm event, that also serves to limit downstream erosion potential.

Recommended quality and erosion control criteria and preliminary sizing aspects for the proposed facilities are summarized in Table 12.

Table 12 Quality and Erosion Control Targets for Stormwater Facilities (Assumes Wet Ponds)

Parameter	SWMF 1	SWMF 2	SWMF 3	SWMF 4	North Wabanaki SWMF
Quality Control Goal	Enhanced Quality Control, removal of 80% TSS				
Contributing Area (ha)[1]	1.6	1.9	2.2	1.9	11.8
Unit Area Storage Volume Requirements for Permanent Pool (m^3/ha)[2]	235	235	235	235	235
Required Permanent Pool Volume (m^3)	304	365	419	376	2,305
Extended Detention / Erosion Control (m^3)[3]	359	431	497	444	1,160
Drawdown time for Extended Detention Volume	24-48 hours				

1. For the purposes of water quality sizing, contributing drainage area to a given SWM facility excludes roofs and landscaped areas associated with proposed development as runoff from these areas is to be captured within at-source infiltration facilities. The remaining areas, comprised of roads, parking, and other at-surface impervious coverage is assumed to be 100% impervious.
2. Storage volume required per Table 11 (from MOE, 2003) includes extrapolation to 100% impervious coverage, for a total required of 275 m^3/ha.
3. Extended detention volumes within end-of-pipe water quality facilities are based on runoff volumes from the 25 mm, 4-hour storm event as modelled in PCSWMM.

4.2 Hydrologic Analysis

Three model scenarios were developed and assessed as part of the current work including:

1. **Proposed conditions without any stormwater controls**. This scenario assumes proposed development with no at-source or traditional end-of-pipe stormwater controls. Stormwater generally drains in the same direction as under existing conditions.

2. **Proposed conditions with at-source retention only**. At-source retention was designed to retain the first 25 mm of runoff from “clean” sources, such as roofs and landscaped areas. The percentage of roof area is estimated as 50% of the total impervious area of a given catchment, and the total impervious area is estimated based on proposed land uses within each subcatchment. Stormwater drains in the same direction as under existing conditions.

3. **Proposed conditions with at-source and end-of-pipe SWM controls**. This scenario assumes the addition of four additional SWM ponds, an underground storage facility, the upsizing of the North Wabanaki SWMF, all of which are design to control post-to-pre peak flows for the full range of return period storm event, and two at-source storage systems designed to attenuate the 1:100-year post-development flows to 1:5-year post-development flows. Post-development flow is directed to future stormwater management systems according to Figure 7.

The objective of the first two model scenarios was to assess the potential for hydrologic impacts on the receiving systems and, by association, the need for dedicated control facilities prior to discharge.

4.2.1 Hydrologic Model Updates

Hydrologic model updates were completed to represent proposed development upstream of the Hidden Valley ESPA/PSW based on planning discussions coordinated with the City, the Region, private development interests and their consultants, as described in Section 4.
The subcatchment areas impacted by the proposed development are shown in Figure 7 and proposed future land use changes are shown in Figure 6. Proposed development subcatchments were updated as follows:

- Catchment areas were defined based on the Master Plan (2019) adjusted to the limits of development, as derived in NRSI (2024). Subcatchments were modelled to be as consistent with the size and configuration of existing subcatchments as possible and areas which could reasonably drain to the same location with future grading.

- Catchment area length parameters were determined based on the formula "Area = 1.5*Length^2" for all impervious and developed subcatchment areas. Similar to existing conditions, pervious subcatchments (<20% impervious area) length was measured.

- Slope parameters for the proposed development subcatchment areas were assigned as standard values based on proposed land use type. Slope values are adopted from Wood (2019) to be consistent with previous stormwater planning. Slopes are assigned as follows:

    - Low-Rise Residential – Estate, Open Space= 4%

    - Mixed-Use, Medium Density residential and Business Park Employment = 3%

    - High-Rise Residential, Commercial, Roads, and Major Infrastructure/Utilities = 2%

- Roughness is assigned as 0.014 for impervious surfaces and 0.24 for pervious areas.
- Imperviousness for development subcatchments were based on the values used by Wood (2019), as summarized in Table 13.

Table 13 Future Land Use Imperviousness (Wood 2019)

Land Use Category	Impervious Values (%)
Business Park Employment	80
Commercial	80
Low-Rise Residential – Estate	40
Low-Rise Residential – Large Lot	50
Major Infrastructure and Utilities	25
Medium-Rise Residential	70
Mixed-Use	85
Open Space	0
Road	85

- Existing pipe sizes are maintained through future conditions, with the exception of the minor system along southern Wabanaki Drive which was upsized from a 300 mm pipe to a 900 mm diameter pipe, Since there is no overland flow route running parallel to this pipe, it is expected to require replacement to account for the additional flow of proposed development. For pipes north of the North Wabanaki SWMF, the dual drainage network conveys minor flow to the same discharge location (North Wabanaki SWMF) as major flow along Wabanaki Drive.
- For the purposes of modelling the various SWM components (e.g., at-source infiltration), developing subcatchments are subdivided into three components: landscaped areas, roof impervious area ("clean" runoff), and road/parking impervious areas.

  The landscaped subcomponent is characterized similar to existing conditions, with an LID feature added to represent the surface and soil storage layers. The depression storage within the surface layer is increased to 25 mm to represent the retention of 25 mm from landscaped areas.

  A storage node (with evaporation turned off) is added to the outlet of the roof subcomponents, with a total volume equal to 25 mm multiplied by the total roof area. Roof area is assumed to be 50% of the total impervious area for all proposed land uses, with the exception of roadways (0% clean) and utility corridors (100% clean). The roof storage nodes use the Green-Ampt infiltration methodology, with parameters typical of sandy loam soils.

The road/parking components of a given catchment, plus any overflow in exceedance of at-source control volumes, are directed to the same outlet, typically an end-of-pipe stormwater facility.

Updated subcatchment parameters for the developed subcatchments are presented in Table 14. Note these parameters represent the full subcatchment, before they are subdivided into landscaped, roof, and road components.

Table 14 Proposed Development Subcatchment Parameters (Figure 7)

Name	Area (ha)	Width (m)	Flow Length (m)	Slope (%)	Impervious (%)	Depression storage Impervious(mm)	Depression storage Pervious (mm)	Percent Clean Impervious
SUB2001	3.2	219	146	3.0	76	2	5	53
SUB2008	3.8	240	160	3.0	81	2	5	50
SUB2009	3.7	237	158	3.0	80	2	5	50
SUB2010	5.0	274	183	2.8	74	2	5	50
SUB2101	1.1	131	88	3.0	80	2	5	50
SUB2103	1.5	152	101	2.0	85	2	5	0
SUB2104	0.6	99	66	2.0	85	2	5	0
SUB2108	0.5	89	59	2.4	85	2	5	0
SUB2111	0.7	104	70	3.2	58	2	5	30
SUB2143	0.4	79	53	3.0	80	2	5	50
SUB2146	2.9	210	140	4.0	40	2	5	50
SUB3001	2.2	181	121	2.0	84	2	5	0
SUB3005	0.7	101	67	3.0	80	2	5	50
SUB3010	5.8	296	197	2.8	55	2	5	42
SUB3017	4.6	262	175	2.6	50	2	5	76
SUB3020	1.6	155	103	3.0	80	2	5	50
SUB3022	9.6	380	254	4.0	40	2	5	50
SUB3003(1)	1.3	139	93	4.0	40	2	5	50

1) SUB3003 is unchanged from existing conditions and is only included in the continuous model scenarios. For design storm scenarios, a constant flow rate is applied representing the 1:5 year flow rate from SUB3003, as per the City's request. See Section 4 for more information.

4.2.2 Proposed Scenarios – Peak Flow Comparison

The 1:2-year through 1:100-year design storms with 3-hour Chicago distributions were used to determine hydrologic output results for all scenarios. Peak flow rates and inflow volumes were compared along the west tributary (PCSWMM Node:574), the north tributary (PCSWMM Node:564), and within the wetland storage node (PCSWMM Node:STRG4) in order to assess the overall hydrologic impacts of changes in land use under the three modelling scenarios described in Section 4.2.1.

Proposed Conditions – No-Control Scenario

Table 15 summarizes the peak flow rates from the future conditions scenario without any SWM controls. Under such a scenario, peak flow rates increase by an average of 38% in the west tributary, 8% in the north tributary, and 28% into the wetland. Increased peak flow rates are due to an increase in impervious area for proposed development subcatchment areas. Peak flow from each subcatchment is higher under future uncontrolled conditions as compared to existing conditions, with the exception of subcatchments SUB2146 and SUB2111 which drain to, and are contained within, topographic depressions for all events up to an including the 1:100-year storm.

Additionally, the Regional peak flow rate is marginally lower in the north tributary under proposed conditions, due to a slightly reduced catchment size (portion of River Road drainage to be directed east) and a more rapid discharge from the proposed developments, resulting in an offset to the hydrograph peak timing.

Table 15 Peak Flow Comparison Existing and Future Uncontrolled Conditions

Peak Flow Comparison	Existing Conditions (m^3/s)			Future Conditions (No SWM or At-Source) (m^3/s)			Difference (%)		
	West	North	Wetland	West	North	Wetland	West	North	Wetland
PCSWMM Node	574	564	STRG4	574	564	STRG4	574	564	STRG4
2-year	2.9	3.2	5.8	4.6	3.5	7.9	58%	10%	36%
5-year	4.3	3.9	8.3	6.7	4.3	11.8	53%	11%	41%
10-year	5.7	4.5	11.0	8.5	5.0	15.1	49%	11%	38%
25-year	7.2	5.3	14.1	9.9	5.8	18.4	39%	9%	30%
50-year	8.4	5.9	17.0	11.1	6.4	21.3	32%	9%	25%
100-year	9.5	6.4	19.7	12.1	7.0	24.1	27%	9%	22%
Regional	9.5	6.0	19.5	10.0	5.8	20.1	6%	-3%	3%
Average							38%	8%	28%

In the absence of purpose-built quantity control measures for the proposed developing areas, peak flow rates to the west and north tributaries, as well as directly to the Hidden Valley ESPA/PSW, would experience significant increases. While it is possible the ESPA/PSW could attenuate the additional flow, the uncertainty surrounding the hydrologic functionality of the feature makes this alternative difficult to support. The storage-discharge relationship for the wetland is unknown and likely shifts according to groundwater patterns and the configuration of beaver dams or blockages within the wetland itself. Relying on the wetland to provide quantity control would create uncertainty with respect to the expected flow regime downstream. Additionally, an increase to peak flow rates from the developments during major storm events would increase the erosion potential in the north and west tributaries. It is, therefore, advised that quantity control be implemented to control post-development peak flow rates to existing conditions magnitudes.

Proposed Conditions – At-Source Control Scenario

Table 16 summarizes the peak flow rates from the proposed conditions scenario with at-source controls but no end-of-pipe stormwater management controls. Under a proposed at-source controlled scenario, peak flow rates increase by an average of 22% in the west tributary, 3% in the north tributary, and 15% into the wetland. Average peak flow rates are reduced as compared to a “no-control” scenario but are still greater than existing conditions. Peak flow increases to the west tributary are attributable to the large increase in unclean impervious area, especially the River Road Extension. Peak flows to the north tributary more closely align with existing conditions as a significant portion of the developing area is utility corridor and open space, from which much of the low flows are infiltrated.

Table 16 Peak Flow Comparison Existing and Future Conditions with At-Source Controls

Peak Flow Comparison	Existing Conditions (m^3/s)			Future Conditions – with At-Source Controls			Difference (%)		
	West	North	Wetland	West	North	Wetland	West	North	Wetland
PCSWMM Node	574	564	STRG4	574	564	STRG4	574	564	STRG4
2-year	2.9	3.2	5.8	3.9	3.3	6.7	34%	2%	16%
5-year	4.3	3.9	8.3	5.2	4.1	9.7	20%	6%	17%
10-year	5.7	4.5	11.0	7.2	4.8	13.1	26%	6%	20%
25-year	7.2	5.3	14.1	9.0	5.5	16.7	26%	4%	18%
50-year	8.4	5.9	17.0	10.2	6.1	19.6	23%	3%	15%
100-year	9.5	6.4	19.7	11.6	6.6	22.7	21%	3%	15%
Regional	9.5	6.0	19.5	9.9	5.8	20.0	5%	-3%	3%
Average							22%	3%	15%

The at-source controls provide some quantity control to the developing subcatchments but are not wholly adequate to match existing conditions flow rates.

Proposed Conditions – At-Source and SWMF Controls Scenario

SWM facilities incorporated into this proposed condition scenario were designed based on simplified storage and dual orifice outlet structures. A low flow outlet is designed to attenuate and control the 1:5-year flow while a larger office controls the 1:100-year flow. Table 17 summarizes a comparison of the peak flow rates from the proposed stormwater facilities as compared to their respective subcatchment areas under existing conditions.

Table 17 Peak Outflow Comparison Between Existing Catchments and Proposed End-of-Pipe Controls

SWMF (Figure 7)/ Catchment (Figure 5)	Existing			Proposed Controlled			Difference (m^3/s)		
	5-yr	25-yr	100-yr	5-yr	25-yr	100-yr	5-yr	25-yr	100-yr
SWMF 4 / SUB3022	0.06	0.2	0.64	0.06	0.1	0.61	0.00	0.00	-0.03
Northern Business Park (U/G storage) / SUB3020	0.02	0.0	0.14	0.02	0.0	0.14	0.00	0.00	-0.01
SWMF 1 / SUB2008	0.08	0.2	0.65	0.06	0.1	0.65	-0.02	0.00	0.00
SWMF 2 / SUB2010	0.07	0.4	0.63	0.07	0.3	0.59	-0.01	0.00	-0.04
North Wabanaki SWMF	0.20	0.3	0.29	0.20	0.2	0.29	0.00	0.00	0.00
SWMF 3 / PCSWMM Node 608 (lateral inflow)	0.21	0.6	0.96	0.20	0.5	0.92	-0.02	0.00	-0.04

All proposed SWMF are able to accommodate the 1:100-year event without overtopping. While not necessarily requiring post-to-pre peak flow control, the maximum volume of storage required in each of the proposed SWM facilities is marginally greater during the Regional Event than the 1:100 year event. Future designs of the proposed facilities should be designed to accommodate (i.e. pass) the Regional Event with spillways implemented to allow for discharge of flow in excess of the 1:100 year event.

The South Wabanaki SWMF, which receives new flow from SUB2101, is not overtopped during the 1:100 year or Regional Storm events. The maximum elevation in the South Wabanaki SMWF is 321.74 m during the 1:100-year event and 322.13 m during the Regional Event, below the spill threshold of 322.3 m. Outflow from the South Wabanaki SWMF increases marginally for the design storm events by a maximum of 0.02 m^3/s during the 1:100 year event but does not have an impact on the ultimate outflow to the west tributary.

Both topographic depressions north of the “2A” areas (SUB2146 and SUB2111) have sufficient storage available such that they are not overtopped and retain/infiltrate all inflow from the return-period and Regional Storm events.

Table 18 summarizes the peak flow rates in the receiving systems from the proposed conditions scenario with at-source and end-of pipe SWMF facility controls. Under controlled future conditions, peak flow rates decrease by an average of 16%, 2%, and 10% in the west tributary, north tributary, and wetland, respectively.

While the flow rates from the respective subcatchments are matched under existing and proposed conditions, as summarized in Table 17 above, differences in the peak hydrograph timing result in overall decreases to the tributary and wetland inflow.

Table 18 Peak Flow Comparison Existing Conditions and Future Conditions with At-Source and SWMF Controls

Peak Flow Comparison	Existing Conditions (m^3/s)			Future Conditions with At-Source and SWMF Controls			Difference (%)		
	West	North	Wetland	West	North	Wetland	West	North	Wetland
PCSWMM Node	574	564	STRG4	574	564	STRG4	574	564	STRG4
2-year	2.9	3.2	5.8	2.6	3.2	5.6	-10%	0%	-3%
5-year	4.3	3.9	8.3	3.8	3.8	7.6	-14%	-2%	-9%
10-year	5.7	4.5	11.0	4.7	4.4	9.5	-18%	-4%	-14%
25-year	7.2	5.3	14.1	5.7	5.3	12.2	-20%	-1%	-14%
50-year	8.4	5.9	17.0	7.0	5.9	15.1	-16%	0%	-11%
100-year	9.5	6.4	19.7	8.0	6.3	17.5	-16%	-2%	-11%
Regional	9.5	6.0	19.5	7.9	5.9	17.7	-17%	-2%	-9%
						Average	-16%	-2%	-10%

4.2.3 Water Balance Results

Tables 19 shows the average annual water balance under proposed conditions, and Tables 20 to 23 provide a comparison of the average annual water balance, 25 mm event runoff volume, 5-year event runoff volume, and 100-year event runoff volume, respectively, between existing and proposed conditions. Annual water balance is averaged across a 30-year simulation period and design storm events are simulated for a period of 3 days to allow for full discharge of storm rainfall. Only subcatchments impacted by the proposed development are considered, as those subcatchments have been modified within PCSWMM to include a soil layer, a necessary approach in order to separate evapotranspiration and infiltration components. Subcatchments are compared based on location. Some subcatchments are split or combined under proposed conditions, in which case the water balance volumes are area-weighted. Total runoff volumes do not sum to exactly zero, as there are minor changes to the total catchment area under proposed conditions.

The water balance assessment shows that under proposed development conditions there is a general increase in annual runoff, an unsurprising result given the conversion of pervious to impervious surface area, from which the runoff is not encouraged for direct infiltration (i.e., roads and parking areas). The road / parking areas of proposed subcatchments typically discharge significantly more volume than the total area of undeveloped existing subcatchments. Therefore, even if the proposed SWM controls captured all water from clean sources, there will still be an increase in net runoff. The corollary to this is that any reduction in road, parking, or other at-surface impervious surfaces that can be achieved through site design (e.g., reduced at-surface parking, reduced internal road widths, etc.) will inherently reduce the runoff volumes directed to the ESPA/PSW.

Roads, parking and other at-surface impervious areas are ultimately conveyed to the ESPA/PSW where substantial groundwater recharge is expected to continue to occur owing to a “hydraulic window” representing a conduit to the deeper groundwater systems and, importantly, the capture zone associated with the Region’s Parkway Wellfield. While additional infiltration would likely be feasible at the outlets from end-of-pipe SWMFs through measures such as infiltration trenches, whether seasonally operated or otherwise, to partially compensate for the increase in runoff volumes, the potential cost-benefit of such an approach is questionable given the recharge characteristics of the ESPA/PSW itself.

Under proposed conditions there is approximately 75,000 m^3 of additional runoff being directed to and infiltrated within the ESPA/PSW on an annual basis. For single storm events, 2,730 to 9,840 m^3 additional volume enters the wetland under proposed conditions.

This represents a relatively minimal increase in depth of 0.02, 0.05 m to 0.07 m for the 25 mm, 1:5-year and 1:100-year events, respectively, assuming the volume is conveyed to the wetland without losses and that runoff can access the entire existing open water area of the wetland. This is a conservative estimate in that it assumes there will be no channel losses and that all incoming water will be held indefinitely within the wetland feature when, in fact, there will be flow through the ESPA/PSW in response to such large, infrequent rainfall-runoff events.

Existing annual infiltration volumes on the developing parcels are effectively matched under proposed conditions due to the at-source “clean” water retention facilities. The at-source facilities capture greater volumes of water per unit area than the existing natural soils, offsetting reductions in infiltration from road, parking, and at-surface impervious areas. The fast runoff response from impervious areas, whether to at-source infiltration or to end-of-pipe, and the lack of vegetation significantly reduces evapotranspiration.

Notable outlier subcatchments include (proposed) SUB3017, SUB2103, SUB2104, SUB2111, SUB2146, SUB3005, and SUB3010.

- SUB3017 has a net increase in infiltration over existing conditions, as the majority of the subcatchment is proposed utility corridor which has low imperviousness and allows for high infiltration through at-source controls.

- Infiltration on SUB2103 and SUB2104 does not change substantially as they are already of similar impervious (road) land use. SUB2104 has a small increase in infiltration due to the high imperviousness of existing conditions and the future pervious area allowing for greater infiltration with at-source retention.

- SUB2111 and SUB2146 have increased runoff and lower infiltration on a subcatchment scale but will ultimately drain to topographic depressions. As no flow was observed to leave either depression storage in the 30-year model period, the functional runoff for these subcatchments is zero in both existing and proposed conditions.

- SUB3005 has an increase in infiltration over existing conditions as the existing land use is already highly impervious (road) and is proposed to be replaced by commercial land use with high potential for at-source infiltration controls.

- SUB3010 has increased infiltration under future conditions due to the large portion of greenspace proposed within the developing area which creates the potential for high capacity at-source controls.

Table 19 Proposed Conditions Water Balance Results

Subcatchment	Area (ha)	Precipitation (mm/yr)	Evapotranspiration (mm/yr)	Infiltration (mm/yr)	Runoff Depth (mm/yr)
SUB2001	3.2	824	278	281	266
SUB2008	3.8	824	262	265	298
SUB2009	3.7	824	265	265	294
SUB2010	5.0	824	282	268	274
SUB2101	1.1	824	264	266	295
SUB2103	1.5	824	273	72	480
SUB2104	0.6	824	249	47	530
SUB2108	0.5	824	248	47	530
SUB2111	0.7	824	327	217	281
SUB2143	0.4	824	263	266	296
SUB2146	2.9	824	382	288	153
SUB3001	2.2	824	252	49	524
SUB3005	0.7	824	263	264	298
SUB3010	5.8	824	339	279	205
SUB3017	4.6	824	224	481	119
SUB3020	1.6	824	264	265	295
SUB3022	9.6	824	383	288	153
Average:		824	303	273	248

Table 20 Subcatchment Water Balance Comparison – 30-year

Subcatchments		Annual Difference (mm)		
Existing Catchment(s) (Refer to Figure 5)	Proposed Catchment(s) (Refer to Figure 7)	ET	Infiltration	Runoff
SUB2001	SUB2001, SUB2143	-197	5	194
SUB2005	SUB3017	-273	183	91
SUB2008	SUB2008	-235	-33	269
SUB2009	SUB2009	-231	-34	266
SUB2010	SUB2010	-214	-30	246
SUB2101	SUB2101	-233	-33	268
SUB2103	SUB2103	0.7	3	-4
SUB2104	SUB2104	-73	-72	146
SUB2108	SUB2108	-36	-35	71
SUB2111	SUB2111	-105	-16	121
SUB2146	SUB2146	-115	-10	125
SUB3001, SUB3013	SUB3001	-167	-169	337
SUB3022	SUB3022	-114	-10	125
SUB3005	SUB3005	91	235	-327
SUB3010, SUB3011, SUB3012	SUB3010	-236	221	17
SUB3020	SUB3020	-233	-33	267
Average annual difference for developing subcatchments (mm)		-165	4	169
Average annual difference for developing subcatchments (m^3)		-75,577	1,728	75,445
Average annual difference for developing subcatchments (%)		-33%	1%	199%
Difference as a percent of entire catchment (%)				18%

*Runoff totals do not include SUB2146 and SUB2111 as runoff from these subcatchments do not reach the wetland

Table 21 Subcatchment Runoff Volume Comparison – 25 mm Event

Subcatchments		Runoff total (mm/m³)					
Existing Catchment(s) (Refer to Figure 5)	Proposed Catchment(s) (Refer to Figure 7)	Existing		Proposed		Difference	
		mm	m³	mm	m³	mm	m³
SUB2001	SUB2001, SUB2143	2	59	8	298	6	239
SUB2005	SUB3017	0	0	3	127	3	127
SUB2008	SUB2008	0	0	9	359	9	359
SUB2009	SUB2009	0	0	9	345	9	345
SUB2010	SUB2010	0	0	9	431	9	431
SUB2101	SUB2101	0	0	9	106	9	106
SUB2103	SUB2103	18	271	18	271	0	0
SUB2104	SUB2104	14	89	20	127	6	38
SUB2108	SUB2108	17	89	20	104	3	15
SUB2111	SUB2111	5	37	9	69	4	32
SUB2146	SUB2146	0	0	5	136	5	136
SUB3001, SUB3013	SUB3001	6	135	19	424	13	289
SUB3022	SUB3022	0	0	5	444	5	444
SUB3005	SUB3005	20	132	6	370	-14	238
SUB3010, SUB3011, SUB3012	SUB3010	3	207	3	127	0	-80
SUB3020	SUB3020	0	0	9	147	9	147
Average difference for developing subcatchments (mm)						6	
Total difference for developing subcatchments (m³)						2,730	
Average difference for developing subcatchments (%)						275%	
Difference as a percent of entire catchment (%)						18%	

*Runoff totals do not include SUB2146 and SUB2111 as runoff from these subcatchments do not reach the wetland

Table 22 Subcatchment Runoff Volume Comparison – 5-year

Subcatchments		Runoff total (mm)					
Existing Catchment(s) (Refer to Figure 5)	Proposed Catchment(s) (Refer to Figure 7)	Existing		Proposed		Difference	
		mm	m^3	mm	m^3	mm	m^3
SUB2001	SUB2001, SUB2143	6	182	25	903	19	720
SUB2005	SUB3017	2	74	14	622	12	548
SUB2008	SUB2008	3	104	27	1044	24	940
SUB2009	SUB2009	1	41	27	1003	26	962
SUB2010	SUB2010	2	97	25	1253	23	1156
SUB2101	SUB2101	1	13	27	309	26	295
SUB2103	SUB2103	36	544	35	533	-1	-11
SUB2104	SUB2104	29	187	38	249	10	62
SUB2108	SUB2108	34	180	39	204	5	24
SUB2111	SUB2111	13	92	22	163	10	71
SUB2146	SUB2146	2	73	13	396	11	323
SUB3001, SUB3013	SUB3001	16	340	38	832	23	492
SUB3022	SUB3022	1	96	13	1292	12	1196
SUB3005	SUB3005	39	264	18	1076	-21	812
SUB3010, SUB3011, SUB3012	SUB3010	8	568	14	622	6	54
SUB3020	SUB3020	1	22	27	428	25	406
Average difference for developing subcatchments (mm)						16	
Total difference for developing subcatchments (m^3)						7,500	
Average difference for developing subcatchments (%)						265%	
Difference as a percent of entire catchment (%)						21%	

*Runoff totals do not include SUB2146 and SUB2111 as runoff from these subcatchments do not reach the wetland

Table 23 Subcatchment Runoff Volume Comparison – 100-year

Subcatchments		Runoff total (mm)					
Existing Catchment(s) (Refer to Figure 5)	Proposed Catchment(s) (Refer to Figure 7)	Existing		Proposed		Difference	
		mm	m^3	mm	m^3	mm	m^3
SUB2001	SUB2001, SUB2143	32	1028	57	2064	25	1036
SUB2005	SUB3017	25	1104	42	1912	17	808
SUB2008	SUB2008	29	1128	61	2330	31	1203
SUB2009	SUB2009	20	761	60	2244	40	1483
SUB2010	SUB2010	26	1314	56	2822	30	1508
SUB2101	SUB2101	21	240	61	696	40	456
SUB2103	SUB2103	72	1100	67	1030	-5	-70
SUB2104	SUB2104	64	415	74	477	10	62
SUB2108	SUB2108	70	373	74	391	3	18
SUB2111	SUB2111	43	315	50	364	7	49
SUB2146	SUB2146	28	839	34	1006	6	167
SUB3001, SUB3013	SUB3001	47	1035	73	1589	26	554
SUB3022	SUB3022	21	1781	42	4053	21	2272
SUB3005	SUB3005	77	519	43	2518	-34	1999
SUB3010, SUB3011, SUB3012	SUB3010	35	2497	42	1912	7	-585
SUB3020	SUB3020	23	362	60	962	38	600
Average difference for developing subcatchments (mm)						21	
Total difference for developing subcatchments (m^3)						9,840	
Average difference for developing subcatchments (%)						68%	
Difference as a percent of entire catchment (%)						10%	

*Runoff totals do not include SUB2146 and SUB2111 as runoff from these subcatchments do not reach the wetland

A site-specific, feature based water balance assessment and scoped Environmental impact Study (EIS) will need to be completed and submitted to the GRCA at the draft plan of subdivision or site plan stage.

4.2.4 Erosion Threshold Analysis

A flow-duration erosion threshold analysis was completed using the PCSWMM models and conceptual SWMF outlet curves (1:5 year and 1:100-year control only, with no accounting for extended detention of smaller, more frequent storms) to compare the extent of time that the west and north tributaries might be expected to be encountering erosive flows. Threshold values used for comparison are based on the Wood (2019) analysis which determined flows of 0.18 m^3/s and 0.25 m^3/s for the north and west tributaries, respectively. The Wood (2019) erosion threshold values were calculated by AquaLogic Consulting in 2017 based on visual inspections as well as cross sectional and profile measurements at the monitoring station locations SW2 and SW3. The threshold exceedance for the existing and future conditions scenarios are presented in Table 24.

Under future controlled conditions, erosion thresholds are exceeded annually in the north and west tributaries by an additional 14 hours (0.16% difference) and 5 hours (0.06% difference), respectively. The minor increases to erosion threshold exceedance under future conditions is considered relatively insignificant.

Table 24 Erosion Threshold Analysis

West Tributary Annual Exceedance (hrs)			North Tributary Annual Exceedance (hrs)		
Existing	Proposed	Difference	Existing	Proposed	Difference
40	53	13	29	34	5

4.2.5 Alternate Land Use Scenarios

The proposed land uses within the “2A” (SUB2146, SUB2111) and “2B” (SUB3022) special policy areas, as shown in the Master Plan (2019), have yet to be firmly established. As part of the process for determining effective SWM strategy for these parcels, the City requested that a second scenario wherein the parcels are developed as medium density residential as opposed to low-density residential be assessed. This involved changing the imperviousness of the subcatchments from 40%, as described above, to 70%.

SUB2111 and SUB2146 (Areas 2A)

Changing the land use from low-rise residential to medium density residential for subcatchments SUB2111 and SUB2146 does not result in significant changes to water quantity control or water balance. Under both existing and future conditions runoff from these catchments drains to topographic depressions which retain and infiltrate all incoming water. Under a future conditions scenario with medium density residential land use, runoff volumes to the topographic depression would increase, but the overall water balance for the area would remain the same.

From a quality control perspective, increasing imperviousness of SUB2111 and SUB2146 would likely result in an increase in “dirty” runoff, depending on related increases in roads, parking, and other at-surface impervious areas. Onsite quality control features may need adjustment (expansion) as compared to a low-density use, to accommodate.

SUB3022 (Area 2B)

SUB3022, generally encompassing Area 2B as well as some adjacent lands that are expected to be potentially brought into the development concept, is located east of the ESPA/PSW and drains directly to the feature under existing conditions. As outlined above, the proposed SWM strategy for this parcel is typical of the broader strategy and includes at-source controls retaining and infiltrating the first 25 mm from landscaped and roof (clean impervious) areas, and end-of-pipe controls providing water quality control and attenuating peak flows to match existing conditions. Increasing imperviousness of this subcatchment would result in greater need for both at-source and end-of-pipe controls.

Under a scenario of medium density residential land use, the end-of-pipe SWMF for SUB3022 (SWMF 4) would need to increase in size to accommodate the additional runoff volumes for both quality and quantity control. The active storage in the facility would increase to approximately 3,750 m^3 to contain the 1:100-year storm and match pre-development peak flow rates. The permanent pool volume would increase to 741 m^3, with 874 m^3 extended detention storage.

The at-source controls would also need to be expanded to receive runoff from new clean impervious area.

Table 25 provides a comparison of water balance results for SUB3022 (Area 2B). Medium density land use has a slightly lower annual infiltration, lower annual ET, and greater annual runoff volume as there is increased “unclean” impervious area.

Table 25 Area 2B Land Use Water Balance Comparison

Area 2B Land Use	ET (mm/year)	Infiltration (mm/year)	Runoff Depth (mm/year)
Low-Rise Residential	383	288	153
Med Density Residential	296	271	258
Difference	-87 mm or -8,382 m^3/yr	-17 mm or -1,675 m^3/yr	105 mm or 10,147 m^3/yr

5 Conclusions

Despite substantial historic urbanization in the headwaters of the 210 ha subwatershed, much of which preceded the adoption modern SWM practices and, therefore, included little in the way of hydrologic impact mitigation, the Hidden Valley ESPA/PSW feature that is central to the HVSP area and receives all of the associated drainage remains one of the most ecologically important landscape features in the City. Beyond natural heritage aspects, the feature is also hydrologically significant as it relates to impacting instream flow / flood conditions through the receiving Hidden Valley Creek system, and as a key groundwater recharge area within the Region’s municipal water supply system. As such, it is important that changes in hydrology typically associated with the development of land from a rural to urbanized landscape incorporate measures to mitigate potential negative impacts on the receiving natural or anthropogenic systems.

As part of this work, Matrix has reviewed many related background studies available for the area and, using this information and an understanding of anticipated potential development plans as a starting point, assessed the existing and proposed conditions hydrology using an updated PCSWMM model to develop a SWM strategy that should serve to limit negative impacts associated with the land use changes. SWM strategies were developed with a focus on maintaining quality and quantity characteristics for both the surface water and groundwater receiving systems.

The conceptual stormwater management planning for the HVSP area has been completed in accordance with industry-standard guiding documents including, but not limited to, the City of Kitchener Development Manual (2021) and the SWMPD Manual (MOE 2004). The primary goals and components of the stormwater strategy include:

- Infiltration – maintain or increase existing infiltration volume upstream of the ESPA/PSW.
- Water Quality – Enhanced protection, equivalent to 80% long-term TSS removal.
- Erosion (flow-duration) – maintain existing erosion regime in the west and north tributaries.
- Peak Flow Rates and Flood Mitigation – match proposed development peak flow rates to existing conditions peak flow rates in total discharge to ESPA/PSW.

Per provincial guidance and typical approach, the SWM strategy should meet the above objectives through the implementation of a multi-component, “treatment train” approach that includes SWM measures distributed across the landscape including at-source and at end-of-pipe. At-source controls have become more-or-less synonymous with Low Impact Development (LID), and are designed and operated with the aim of reducing surface runoff volumes and rates, and encouraging infiltration of clean water across the developing landscape, more closely mimicking existing conditions and aiding in water quality control. More traditional end-of-pipe controls such as SWM ponds provide quality control through sediment settling within a permanent pool and extended detention of "first flush" storm events, and post-to-pre- quantity control through the use of active storage and peak flow restricting outlet structures. Both at-source and end-of-pipe components help to reduce erosion threshold exceedance risk in downstream receiving water systems.

Key control components of the resultant SWM strategy recommended for the HVSP area include:

- At-source controls including infiltration of the first 25 mm of runoff for all clean impervious and landscaped surfaces within the developing lands.
- Four new end-of-pipe SWM facilities providing quality and quantity control.
- Two at-source storage facilities and one underground storage facility providing peak flow reduction (quantity control) only.
- An expansion / retrofit to the existing North Wabanaki SWMF.

At-source controls are recommended to retain and infiltrate 25 mm from storm events.
While the at-source controls provide some quantity control for their respective subcatchments, their primary goal is to replicate existing conditions water balance. Continuous model simulations using a representative 30-year meteorological dataset were completed for existing and future conditions considering at-source controls to assess the long-term impacts on water balance from the proposed developments. The proposed at-source infiltration strategy results in a match of post-to-pre groundwater recharge upstream of the ESPA/PSW, while runoff volumes to the feature increase. Runoff volumes to the ESPA/PSW increase due to the road and parking lot area within the proposed development, which is not infiltrated at-source.
Any reduction in road, parking, or other at-surface impervious surfaces within the upstream development would reduce total runoff to the feature. The existence of a known "hydraulic window" (i.e., a lack of underlying aquitard) underlying the ESPA/PSW means that the increased runoff volume being directed to the feature will no doubt result in increased recharge within the feature, thereby leading to a net increase in recharge at a "system" level.

End-of-pipe SWM controls, in the form of stormwater ponds and underground storages, are proposed to match future peak flow rates to existing conditions peak flow rates within the west and north tributaries, as well as directly to the ESPA/PSW. The four new stormwater ponds, underground business park storage, and the enhanced North Wabanaki SWMF provide quantity control for their respective subcatchments. The storages have been sized to replicate 5-year and 100-year peak outflow rates to the channels from existing to future conditions.

An Enhanced level of water quality protection, equivalent to long-term reduction of 80% of TSS, can be achieved through wet, end-of-pipe facilities or a multi-component “treatment train” approach.

Two at-source storages are proposed to match future conditions peak flow rates (up to the 1:100-year storm) to future conditions minor storm peak flow rates (1:5 year storm). Both local storages, as well as the business park underground storage, drain to the North Wabanaki SWMF. All storages will provide quantity control.

The sizing, location, and potentially even the type of proposed storage are subject to change, with the understanding that they attenuate future outflow rates to the existing 5-year and 100-year magnitudes. In other words, though proposed herein as end-of-pipe wet SWM facilities, it is only the function of the control measure, and not necessarily the form, that requires preservation to adhere to the SWM strategy outlined herein. Should preliminary and final design indicate that an alternate approach can achieve the required control targets, such can/should be entertained.

A site-specific, feature based water balance assessment and scoped Environmental impact Study (EIS) will need to be completed and submitted to the GRCA at the draft plan of subdivision or site plan stage.

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