Leamington Stormwater Master Drainage Study for Reid Drain, Silver Creek and Big Creek Watersheds

Prepared by:
Stantec Consulting Ltd.

Prepared for:
Municipality of Leamington

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Sign-off Sheet

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Prepared by ____________________
(signature)

Nick Emery, P.Eng.

Reviewed by ____________________
(signature)

Steve Brown, P.Eng.

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Abbreviations

AES	Atmospheric Environment Services
AMC	Antecedent Moisture Conditions
BMP	Best Management Practice
CA	Conservation Authority
ECA	Environmental Compliance Approval
ERCA	Essex Region Conservation Authority
GI	Green Infrastructure
ha	hectares
HGL	Hydraulic Grade Line
HWL	High Water Level
IDF	Intensity-Duration-Frequency
L/s	Litres per second
LID	Low Impact Development
LTVCA	Lower Thames Valley Conservation Authority
m	metres
m^3	cubic metres
m^3/s	cubic metres per second
mm	millimetres
MNRF	Ministry of Natural Resources and Forestry
MECP	Ministry of Environment, Conservation and Parks
MTO	Ministry of Transportation Ontario
NRCS	National Resources Conservation Service
NWL	Normal Water Level
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
RVC_T	Runoff Volume Control Target
SCS	Soil Conservation Service (now NRCS)
SWM	Stormwater Management
SWMM	Stormwater Management Model
SWMF	Stormwater Management Facility
SWMP	Stormwater Management Practice
TSS	Total suspended solids
WQS	Water Quality Storm
WSEL	Water Surface Elevation

Glossary

1:5 year storm event (also referred to as 5-year storm	A storm event with a 1:5 year return period or 20% probability of occurrence in any given year.
Allowable release rate	A maximum specified flow rate at which development is allowed to discharge.
Antecedent moisture condition	The pre-storm soil moisture condition.
Backwater condition	A backflow condition or rise in water level which impacts conveyance capacity
Freeboard	The depth measured from the water surface elevation to a specified reference point (e.g. manhole cover, building opening, pond bank)
Holistic approach	An approach that considers in the context of the overall watershed.
Hyetograph	A graphical representation of the distribution of rainfall over time.
Interflow	In hydrology, interflow is the lateral movement of water in the unsaturated zone, or vadose zone, that first returns to the surface or enters a stream prior to becoming groundwater. Interflow occurs when water infiltrates into the subsurface, hydraulic conductivity decreases with depth, and lateral flow proceeds downslope.
Level of service	Level of service refers to the efficiency of the drainage system to capture and convey runoff away from the surface and buildings. In the context of drainage, level of service is described in terms of a return period.
Major	In the context of stormwater, major relates to a major storm event. For purposes of design, the major storm event is typically quantified as a 1:100 year storm event.
Minor	In the context of stormwater, minor relates to a minor storm event. For purposes of design, the minor storm event is typically specified as a 1:5 year storm event.
Permanent pool	The body of water which remains in the stormwater management pond.
Receiver	The receiving drain, watercourse or sewer.
Return period	A return period, also known as a recurrence interval, is an estimate of the likelihood of an event, such as an earthquake, flood or a river discharge flow to occur
Runoff	Surface water, from precipitation, that flow over the land surface.
Stormwater	Stormwater is the water from rain or melting snow that is not absorbed into the ground. It flows over land or impervious surfaces such as streets, parking lots and roofs.
Subcatchment	An area of land where all surface runoff converges or is assigned to a single point along a drainage feature. E.g. a storm sewer manhole.
Watercourse	An open channel that conveys water to a larger watercourse or waterbody.
Watershed	An area of land that drains into a watercourse or waterbody

1.0 INTRODUCTION

1.1 BACKGROUND

Significant greenhouse development is proposed within the Municipality of Leamington. To accommodate the proposed large-scale development and mitigate any adverse impacts to the receiving watercourses/municipal drains, a holistic stormwater management approach is required – one that evaluates the impacts of **increased stormwater runoff volume** at the watershed scale. This stormwater master drainage study serves to provide a stormwater management plan (SWMP) for the Silver Creek Drain, Reid Drain and Big Creek Drain watersheds. The study area is located within two separate Conservation Authority (CA) jurisdictions. The Essex Region authority (ERCA) governs the Reid and Silver Creek watersheds, which are tributaries of the Ruscom River, and the Lower Thames Valley authority (LTVCA) governs the Big Creek watershed. See **Figure 1** of **Appendix B** for a map outlining the study area.

While individual greenhouse development properties are currently required to provide stormwater management (SWM) controls to mitigate adverse impacts, three main concerns arise from the current lot level SWM approach:

1. Individual property SWM assessments can lead to inconsistent SWM measures being undertaken;
2. Surrounding roadways are typically elevated above existing topography – roadways acting as dykes and eliminating opportunities for floodproofing via overland flow routing; and
3. Erosion potential from large-scale development are not assessed or understood.

1.2 OBJECTIVE

The main objectives of the study are to evaluate the overall watershed drainage systems and derive specific stormwater design criteria such as the allowable release rate(s) and flood control measures for development to proceed without adversely impacting the overall drainage systems from an erosion and flood control perspective.

The study recommends a two-tiered allowable release rate approach. A lower tier release rate is to mitigate long-term erosion potential from increased runoff volume resulting from development. An upper tier release rate is to provide secondary outflow during infrequent storm events, thus reducing storage volume requirements and drawdown times during these infrequent storm events.

Flood control measures are recommended to a **minimum standard** equal to a 1:100 year return period. The following section further explains return periods in relation to level of service and risk.

1.3 UNDERSTANDING LEVEL OF SERVICE AND RISK

Level of service refers to the efficiency of the drainage system to capture and convey runoff away from the surface and buildings. In the context of drainage, level of service is described in terms of a return period – the likelihood that a storm event of specified magnitude will occur in any given year. For example, a 1:100 year storm event has a 1/100 or 1% chance of occurring in any given year. The return period can give a false sense of safety as a 1% chance is interpreted as an absolute rather than a statistical average.

To illustrate this point, the following table correlates return periods and probability of exceedance (or risk) over the design life.

Table 1.3 – Probability of Exceedance (Risk)

Return Period	Design Life					
	2	**5**	**10**	**25**	**50**	**100**
2	75%	97%	100%	100%	100%	100%
5	36%	67%	89%	100%	100%	100%
10	19%	41%	65%	93%	99%	100%
25	8%	18%	34%	64%	87%	98%
50	4%	10%	18%	40%	64%	87%
100	2%	5%	10%	22%	39%	63%

Risk (r) = $1 - (1\text{-}1/T)^{L}$, where T = return period and L = Design Life (MNRF, 2002)

For example, there is a 63% chance of exceeding a 1:100 year storm in the next 100 years. It should be acknowledged historical records used to derive return periods are often based on less than 100 years of data (61 years at Windsor Airport).

In summary, the minimum standard of 1:100 year design **does not guarantee** that a given site will never flood but rather, it provides mitigating measures to achieve a low risk of flooding. Where an individual site's potential damages due to flooding are high, it is the practitioner's responsibility to design to a more conservative standard or to provide a sufficient emergency flow route in accordance with the proponent's site-specific needs.

Assessing risk and level of service for a project must ultimately consider the consequence of failure (damages) resulting from exceedance of the design level of service.

1.4 HOW TO READ THIS REPORT

The following sections will provide a general discussion of the model analysis (section 2) and summarize the specific stormwater management plan to mitigate impacts of development as outlined in the study objectives (sections 3 and 4). Section 5 will provide a summary of the study and recommendations for implementation of the stormwater management plan. **Appendix A – Supplemental Information** provides more in-depth technical discussions and details under the same section number.

2.0 MODEL ANALYSIS

This section provides a general summary of the hydrologic and hydraulic model analysis method and parameters used to evaluate the existing drainage system and impacts of future development.

2.1 HYDROLOGY

2.1.1 Software

The analysis was performed using the PCSWMM 2017 Professional 2D software version 7.1.4280. PCSWMM utilizes the U.S. EPA SWMM5 engine (currently version 5.1.012). PCSWMM provides a modern, easy-to-use graphical user interface for the U.S. EPA SWMM5 program. The EPA Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality for rural and urban areas.

2.1.2 Rainfall

A wide range of rainfall events were considered to achieve various objectives, ranging from Regulatory Storms for flood control and more frequent design storms for erosion threshold analysis to actual measured storm events for model calibration.

Flood Control – Regulatory Storm

The LTVCA Regulatory Storm used for floodline mapping is based on the historical 1937 flood event, which is estimated to be equivalent to the 1:250 year flood. The corresponding design storm is a 12-hour event with rainfall amount of 113 millimeters.

The ERCA Regulatory Storm used for floodline mapping is defined as a 1:100 year 6-hour event with a rainfall of 3.9 inches (99 millimetres) and Probable Maximum Storm (also referred to as the Probable Maximum Precipitation) distribution. See **Appendix A** for a more detailed discussion.

The Probable Maximum Storm distribution is the largest precipitation event that can be reasonably expected to occur over a selected basin. The storm is typically used to calculate flow rates for the design of spillway structures and other hydraulic structures, where failure could result in the loss of life. Albeit the risk of loss of life is relatively low for the drainage systems in the region, the consequence of flooding is likely to result in significant damages to greenhouse crops. Combined with a general lack of overland flow routing, the foregoing distribution is appropriate.

With regards to potential impacts of climate change, the Windsor/Essex Region Stormwater Management Standards Manual identifies a “stress test” rainfall event to evaluate the resiliency of stormwater designs. The “stress test” is a 150 mm 24-hour storm which should be used to verify that freeboard is provided to account for potential increase in rainfall due to the climate change.

Erosion Control

The 1:5 year 4-hour Chicago storm and 32mm AES 12-hour storm were used for erosion threshold analysis purposes. The 32mm rainfall amount is based upon the 90th percentile storm for our region, as defined by the MECP (previously MOECC and MOE). This regional rainfall amount replaces the provincial standard 25mm that has commonly been used for erosion control. Refer to the Windsor/Essex Region Stormwater Management Standards Manual for a more detailed discussion. The Chicago and AES distributions allow evaluation of the drainage system under two various types of storm distributions – the Chicago storm evaluates the system under a high intensity thunderstorm whereas the AES storm is a regional low intensity storm.

Model Calibration

The following storm events were analyzed for model calibration:

1. March 30, 2017
2. November 18, 2017
3. September 29-30, 2017
4. May 11-15, 2018
5. August 11-12, 2014

Spatial variation of the storms was determined using radar rainfall obtained from NEXRAD Level III Digital Precipitation Rate (DPR) product for Detroit, Michigan station (Station ID: KDTX). The radar generally correlates well to rainfall measured by available rain gauges. See **Appendix C** for model calibration and rainfall details. While there are inherent limitations with the accuracy of the radar rainfall, and sometimes with rain gauges, the uncalibrated radar rainfall with limitations in accuracy is believed to provide a better rainfall representation than the alternative of applying the limited rain gauge rainfall over the entire 10,366 hectare Ruscom Station catchment area used for calibration.

2.1.3 Impervious Levels & Buildout Conditions

The model assumes 50% impervious for road right-of-way and 90% impervious for current and future buildout areas. **Important note: The municipality has projected the following proposed ultimate buildout limits for the purposes of completing this study:**

- **Big Creek watershed: 25% buildout, equivalent to 1,100 of 4,394 hectares**
- **Reid Drain watershed: 75% buildout, equivalent to 735 of 980 hectares**
- **Silver Creek watershed: 50% buildout, equivalent to 1,102 of 2204 hectares**

Current buildout conditions have been accounted for in the model as per the details summarized in **Figure 2** of **Appendix B,** including sites constructed this year under interim design criteria. The buildout percentages are exclusive of existing right-of-way and suburban residential lands.

2.1.4 Flow Generation

Model flows were generated using PCSWMM's RUNOFF and GROUNDWATER routines. The RUNOFF routine has commonly been used as part of the SWMM engine to produce runoff hydrographs based on kinematic wave theory of surface flow over a subcatchment. The latter GROUNDWATER routine is much less common, however it was found to be imperative to create a model that reasonably mimics actual runoff response of the study area.

The GROUNDWATER routine was incorporated not for the purposes of evaluating groundwater levels but rather to account for interflow. Interflow is the lateral movement of water in the unsaturated zone (the upper layer of soil) that transmits subsurface water to a watercourse prior to becoming groundwater. In simpler terms, this routine was used to mimic tile drainage of the agricultural fields. Through model calibration, it became evident that a large portion of flow generation is attributed to interflow or tile drainage rather than surface runoff. This model approach resonates with real-world conditions as the study area generally consists of very flat agricultural lands with highly impervious clay soils.

Many input parameters are required for the model to estimate the runoff response of a particular subcatchment. Refer to **Appendix A** for a detailed summary of parameters used.

2.1.5 Hydrologic Soil Group

The study area primarily consists of clay type soils that are classified as Hydrologic Soil Group D with the balance being sandy clay loams classified as Hydrologic Soil Group C. The Ruscom Station catchment consists of 77% group D soils, 17% group C and 6% group A. The Big Creek watershed consists of 100% group D soils. See **Appendix A** for additional information regarding Hydrologic Soil Groups and **Figure 3** of **Appendix B** for Essex Soils Map.

2.2 HYDRAULICS

2.2.1 Open Channel Sections

Open channel cross-sections were derived electronically using OMAFRA Lidar Digital Terrain Model (DTM) – Lake Erie Basin 2017. Cross-sections were taken at 100 metre intervals to capture variations in drain size and inverts throughout the study area. The Lidar derived sections were compared to a number of surveyed drain sections for ground-truthing and found to correlate very well with a typical variance of about 0.1 metres along the drain banks. A limitation of the Lidar product for this particular use is that it does not measure ground surface elevations below water. Therefore, the Lidar sections have drain bottom elevations that are, in some cases, shallower than actual drain bottom elevation. Drains within the study area are generally dry or have relatively small water depths as a result of lack of gradient and localized ponding. Ultimately, the shallower Lidar drains provide some level of conservatism with respect to hydraulic capacity assessments. Refer to **Appendix D** for details regarding the Lidar DTM.

2.2.2 Open Channel Roughness

Field observations confirmed that the open drains within the study area can generally be classified as having some weeds light to moderate brush on banks. A roughness coefficient of 0.035 to 0.050 was applied.

2.2.3 Culverts

Culvert types and diameters or box dimensions were determined in the field, as well as the distance from the top of headwall (if present) to culvert obvert. The OMAFRA Lidar Point Cloud was used to visually locate and measure the elevation of the headwall top, or the actual culvert obvert in the case of protruding culverts. From these values, inverts were calculated. Refer to **Appendix D** for details of the Lidar Point Cloud.

For 31 culverts, field verification was required at one or both ends. This could occur where a culvert did not have a headwall and either did not protrude or the protrusion coincided with a gap in the point cloud. This could also occur where the headwall or protrusion was obscured by overhanging vegetation. Entrance and exit loss coefficients of 1 were applied to all culverts.

2.3 CALIBRATION/VALIDATION

The model calibration effort expanded well beyond the study area, which is contained within Leamington's municipal boundary. The expanded limits model included drains and subcatchments within the Town of Kingsville and Lakeshore, reaching downstream (northerly) beyond the study limits up to the Ruscom station at the crossing of Ruscom River and County Road 46. See Appendix C for an outline of the Ruscom station catchment area.

The model calibration to observed data at the Ruscom gauge was instrumental in adjusting the hydrologic response of the model to mimic actual conditions. Ultimately, the model calibration provided an excellent fit to observed flow rate, volume, shape and timing. The key to the successful calibration was most assuredly incorporating the GROUNDWATER routine in the hydrologic analysis. This routine captured the unique drainage response of the study area in a way that surface runoff hydrology simply could not achieve on its own.

The calibration results clearly illustrate that drainage is predominantly driven by interflow or tile drainage with relatively minor contributions from surface runoff under most storm events. The results also demonstrate that flow rates and volumes are significantly impacted by the antecedent moisture conditions (i.e. moisture conditions preceding the storm event). Flow rates and volumes tend to be higher in the early spring and late fall when the moisture conditions in the upper layer of the soil are generally wet to saturated. Meanwhile, flow rates and volumes tend to be lower in the summer months when soils are dry. This is due to greater subsurface storage to attenuate flows and shrinking clay soils that yield higher infiltration of water, which seeps below the drainage tiles as groundwater. Detailed information regarding the calibration results is included in **Appendix C**.

The calibration was validated by comparing model flow at the Ruscom gauge to the flow derived from ERCA's floodline studies and mapping. **Table 2.3a** and **2.3b** below illustrate an excellent correlation, with the exception of flows at County Road 8 (CR8) where the simulated flows from the calibrated model suggest a notable reduction from the flows of the 1981 ERCA study. The comparison was based upon standard hydrologic parameters listed in section 2.1.4 of **Appendix A**. The comparison also assumed no hydraulic routing constraints (i.e. hydraulic modeling without culverts and with simulated surcharge conditions applied to the drain nodes which allows simulated HGL to exceed drain banks and force flows through the drain cross-section). This allowed for comparison to ERCA's 1981 floodline study, which was undertaken using a hydrologic routing approach is believed to not have accounted for hydraulic routing constraints.

Table 2.3a – Expanded Limits Model Flow & Elevation @ Ruscom Station

LOCATION	ERCA	SIMULATED
Flow (m3/s)		
Ruscom Station	**107.8**	113.1
Elevation (m)		
Ruscom Station	**182.82**	182.80

ERCA Column: Values derived from ERCA Regulatory Floodline Information

Simulated Column: Hydraulic modeling without culverts, roughness = 0.037 and simulated surcharge conditions applied to the drain cross-sections to allow HGL to exceed drain bank and force flows through the open drainage system.

Simulated Elevation: Based on normal depth outfall with slope adjusted to match ERCA elevation.

Table 2.3b – Expanded Limits Model Flow & Elevation @ Study Area Boundary

LOCATION	ERCA	SIMULATED
Flow (cms)		
Silver @ CR8 (D/S)	**45.3**	27.9
Reid @ CR8 (D/S)	**19.8**	12.4
Elevation (m)		
Silver @ CR8 (D/S)	**186.24**	186.24
Reid @ CR8 (D/S)	**186.51**	186.37

ERCA Column: Values derived from ERCA Regulatory Floodline Information

Simulated Column: Hydraulic modeling without culverts, roughness = 0.037 and simulated surcharge conditions

Simulated Elevation: Based on normal depth outfall with slope adjusted to match ERCA elevation.

3.0 ALLOWABLE RELEASE RATES

With a calibrated hydrologic/hydraulic model, a two-tiered allowable release rate approach considered the lower tier allowable release rate for frequent storms based on an erosion threshold analysis as well as an upper tier allowable release rate for larger, infrequent storm based on conveyance capacity analysis of the drainage system.

3.1 EROSION THRESHOLD ANALYSIS

3.1.1 Erosion Potential

Increased flows and alterations to sediment supply associated with land use change can exacerbate erosion within receiving watercourses. In turn, this can lead to channel instability, degradation of aquatic habitat, and can create downstream hazards by increasing rates of bank erosion and channel migration (CVC, 2010).

While development with proper SWM controls will effectively reduce peak flows, the runoff volume will be significantly increased by development with a corresponding increase in outflow duration from the storage facility (i.e. SWM pond). Thus, while peak flows are being reduced, the prolonged flow duration from many stormwater ponds to the receiving drain can increase erosion potential. Given the scale and magnitude of impervious level proposed by greenhouse development, an erosion threshold assessment was undertaken to identify site specific erosion threshold discharge targets. **Appendix E** includes a technical memo outlining the erosion threshold field assessment and development of erosion threshold discharge rates.

3.1.2 Erosion Analysis

For erosion control, the lower tier release rate is to be applied for all storms up to 1:5 year 4-hour with Chicago distribution. Based upon the results of the analysis, the following lower tier allowable release rates are recommended to maintain post-development effective discharge (work) at or below pre-development rates:

Recommended Lower Tier Allowable Release Rate:

- ***The lower tier allowable release rate for all storms up a 1:5 Year 4-Hour Chicago Storm should be:***
  - ***Silver Creek Drain – 2.5 L/s/ha***
  - ***Reid Drain – 2.9 L/s/ha***
  - ***Big Creek Drain – 1.5 L/s/ha***

Refer to **Appendix A** for more in-depth discussion on how the lower tier allowable release rates were derived.

The foregoing rates represent a minor revision from those presented in the Draft report dated November 6, 2018. It should be acknowledged that the Draft report rates may still be used ONLY for properties identified as current buildout per **Figure 2** of **Appendix B**.

3.2 CONVEYANCE CAPACITY ANALYSIS

For infrequent storms that exceed the 1:5 year minor (lower tier) storm, an upper tier allowable release rate is provided. A hydraulic analysis was performed to evaluate the overall conveyance capacity of the drainage networks within the Silver Creek Drain, Reid Drain and Big Creek Drain watersheds. Based upon the results of the analysis, the following upper tier allowable release rate is recommended:

Recommended Upper Tier Allowable Release Rate:

- ***The upper tier allowable release rate applied to storms exceeding a 1:5 Year 4-Hour Chicago Storm should be 6.0 L/s/ha.***

Refer to **Appendix A** for more in-depth discussion on how the upper tier allowable release rate was derived.

3.2.1 Minor Storm Capacity Assessment

Under minor storm conditions, the existing lands drain at relatively low rates, which are driven by agricultural tile drainage with little to no surface runoff from the generally flat topography. The existing drainage system is able to fully convey flows under a 1:5 year minor storm event.

3.2.2 Major Storm Capacity Assessment

Under the major design storms, the existing drainage spills its banks in several locations, as depicted in the floodline mapping in **Appendix G**. When temporary surface ponding is widely spread across undeveloped agricultural lands, the risk of damage is usually minimal. However, as development will progress and its density becomes more concentrated, the previous surface area available for short-duration surface ponding will be gradually eliminated - resulting in more concentrated surface ponding with increasing depth and potential for damage. The root of this issue is that the study area does not benefit from an overland flow route whereby the increasing surface ponding can be safely routed away from buildings. Rather, the elevated roadways act as overland flow barriers which confine the surface ponding to its surrounding low-lying lands; thus progressively increasing the potential for flood damage. The following section discusses flood control measures.

4.0 FLOOD CONTROL

This section discusses floodline mapping, floodproofing elevations, storage requirements to control peak flows from development and flood risks during winter conditions.

4.1 FLOODLINE MAPPING

Floodline mapping for the study is provided in **Appendix G**. Past standard practice for floodline mapping prescribed 125 hectares as a minimum upstream drainage area for drains to be considered as part of flood hazard mapping. Recent guidance suggests that smaller drainage areas may be appropriate. As such, all drains with contributing areas that include more than rights-of-way and suburban residential property frontage have been assigned a floodline elevation. The floodline elevations are derived from the Regulatory Storms as defined in section 2.1.2, with hydrologic parameters as listed in section 2.1.4 of **Appendix A**.

A two-zone floodway concept has been adopted for this study area. For all drains included in the floodline mapping, a minimum setback from top of bank of 8 metres plus depth of drain shall remain unobstructed and without fill placed within this setback to ensure that a sufficient **floodway corridor** is maintained. In addition, where designated on the floodline maps, **temporary floodplain areas** shall remain unobstructed and without fill placed until such time that it is determined that these areas can be developed without raising floodline elevations. Beyond the designated limits of the floodway corridor and temporary floodplain areas, the remaining areas within the study limits are to be considered as flood fringe – which is conditional development subject to meeting specified design criteria to the satisfaction of the Municipality and respective Conservation Authority.

The floodline maps prepared as part of this study have been substantiated with ERCA's current floodline maps and HEC data. Excerpts of ERCA's floodline information are provided in **Appendix H** for reference.

4.2 FLOODPROOFING ELEVATIONS

The floodline elevations provided in **Appendix G** provide a minimum standard for floodproofing elevations. Building elevations must satisfy minimum Conservation Authority (ERCA, LTVCA) floodproofing requirements with regards to minimum freeboard – which requires that the minimum lowest opening into all buildings be at least 0.3 metres above the floodline elevation or the on-site calculated 1:100 year water storage elevation, whichever is greater. Refer to the storage requirements in the following section.

4.3 STORAGE REQUIREMENTS

Consistent with the Windsor/Essex Region Stormwater Management Standards Manual, the 1:100 Year 6-hour storm Probable Maximum Storm distribution is recommended for evaluating the stormwater storage requirements of the proposed sites.

With regards to climate change adaptation, impacts from development should also be evaluated based on a “stress test” event, herein defined as 150mm of rainfall – representing a 39% increase compared to Windsor Airport’s 100-year 24-hour rainfall of 108mm. Refer to Windsor/Essex Region Stormwater Management Standards Manual for details. The “stress test” event is to be contained within the development property and below the lowest building opening.

4.4 WINTER CONDITIONS

With proposed large-scale greenhouse development changing the landscape of the pre-existing agricultural lands, the potential for ice buildup in the open channel drainage systems creates a significant flood risk that would otherwise result in relatively little to no damage from surface ponding across agricultural lands. There are several open drains alongside roadways which are subject to road salting and snowplow operations. These operations significantly increase the potential for ice buildup in the drains, which could result in a partial to full blockage of the conveyance channel and consequently, flooding of greenhouse development.

The prescribed floodline elevations of this study do not account for the potential risk associated with ice blockage, nor can it reasonably quantify the level of risk associated with such an event. However, the following is a list of potential risk mitigation measures:

1. Deepening of floodplain areas within floodway corridor for added conveyance/storage.
2. Drawdown of ponds during winter season to provide buffer storage and corresponding reduction in flows from snowmelt and/or winter rainfall events.

5.0 CONCLUSION

5.1 SUMMARY

1. Significant greenhouse development is proposed within the Municipality of Leamington. To accommodate the proposed large-scale development and mitigate any adverse impacts to the receiving watercourses/municipal drains, a holistic stormwater management approach is required – one that evaluates the impacts of **increased stormwater runoff volume** at the watershed scale.

2. The study recommends a two-tiered allowable release rate approach. A lower tier release rate is to mitigate long-term erosion potential from increased runoff volume resulting from development. An upper tier release rate is to provide secondary outflow during infrequent storm events, thus reducing storage volume requirements and drawdown times during these infrequent storm events.

3. On-site stormwater management controls should be designed to a **minimum standard** equal to a 1:100 year return period. Section 1.3 explains return periods in relation to level of service and risk.

4. <u>The municipality has projected the following proposed ultimate buildout limits for the purposes of completing this study:</u>

   - **Big Creek watershed: 25% buildout, equivalent to 1,100 of 4,394 hectares**
   - **Reid Drain watershed: 75% buildout, equivalent to 735 of 980 hectares**
   - **Silver Creek watershed: 50% buildout, equivalent to 1,102 of 2204 hectares**

5. <u>Current</u> buildout conditions have been accounted for in the floodline mapping as per the details summarized in Figure 2 of Appendix B, including sites constructed in 2018 under interim design criteria.

6. The model calibration to observed data at the Ruscom gauge was instrumental in adjusting the hydrologic response of the model to mimic actual conditions. Ultimately, the model calibration provided an excellent fit to observed flow rate, volume, shape and timing. The calibration results clearly illustrate that drainage is predominantly driven by interflow or tile drainage with relatively minor contributions from surface runoff under most storm events. The results also demonstrate that flow rates and volumes are significantly impacted by the antecedent moisture conditions (i.e. moisture conditions preceding the storm event).

5.2 RECOMMENDATIONS

1. For erosion control, the following lower tier release rate is to be applied for all storms up to 1:5 year 4-hour with Chicago distribution;
   - *Silver Creek Drain – 2.5 L/s/ha*
   - *Reid Drain – 2.9 L/s/ha*
   - *Big Creek Drain – 1.5 L/s/ha*

2. For infrequent storms that exceed the 1:5 year minor (lower tier) storm, an upper tier allowable release rate of 6.0 L/s/ha is recommended.

3. The floodline elevations provided in Appendix G provide a minimum standard for floodproofing elevations. Building elevations must satisfy minimum Conservation Authority (ERCA, LTVCA) floodproofing requirements with regards to minimum freeboard – which requires that the minimum lowest opening into all buildings be at least 0.3 metres above the floodline elevation or the on-site calculated 1:100 year water storage elevation, whichever is greater.

4. Storage requirements shall be based on the 1:100 year 6-hour storm with Probable Maximum Storm distribution as follows;

1st hour – 8%	*3rd hour – 11%*	*5th hour – 15%*
2nd hour – 9%	*4th hour – 49%*	*6th hour – 8%*

   The site shall also be designed to contain the "stress test" event volume within the property and below the lowest building opening. The "stress test" event is herein proposed to be 150mm as defined in the Windsor/Essex Region Stormwater Management Standards Manual.

5. **Important Note to Proponents and Practitioners**: Minimum freeboard depth is a floodproofing measure based on a minimum standard level of service, which has been defined herein as the floodline elevation or the on-site calculated 1:100 year water storage elevation, whichever is greater. (Refer to section 1.3 for further discussion on level of service and risk). The design criteria herein do not guarantee that a given site will never flood but rather, they provide mitigating measures to achieve a low risk of flooding. Where an individual site's potential damages due to flooding are high, it is the practitioner's responsibility to design to a more conservative standard or to provide a sufficient emergency flow route in accordance with the proponent's site-specific needs. Consideration should also be given to Winter Conditions as discussed in section 4.4.

6. The findings and recommendations of this study have accounted for pond facilities and controlled flow rates based upon the current buildout condition depicted in Figure 2 of Appendix B. These flow restrictions, even those on private property, are accounted for with the understanding that the Municipality acknowledges the responsibility to ensure that these existing ponds as well as future ponds are properly designed and function as designed. As such, the Municipality must secure their

legal right to inspect the pond construction, enforce maintenance or remedial works if required, and/or mobilize on private property to perform any necessary remedial works at the cost of the owner.

7. Stormwater ponds are to be built as landforms (i.e. ponds shall not be raised above ground via dykes which could potentially fail).

8. A two-zone floodway concept has been adopted for this study area. For all drains included in the floodline mapping, a minimum setback from top of bank of 8 metres plus depth of drain shall remain unobstructed and without fill placed within this setback to ensure that a sufficient floodway corridor is maintained. In addition, where designated on the floodline maps, temporary floodplain areas shall remain unobstructed and without fill placed until such time that it is determined that these areas can be developed without raising floodline elevations. Beyond the designated limits of the floodway corridor and temporary floodplain areas, the remaining areas within the study limits area to be considered as flood fringe – which is conditional development subject to meeting specified design criteria to the satisfaction of the Municipality and Conservation Authority.

9. The floodline model should be kept up-to-date as a living model that incorporates new development as it occurs. This would allow for evaluation of impacts from potential drainage channel/floodplain improvements on a site-by-site basis.

APPENDIX A

Supplemental Information

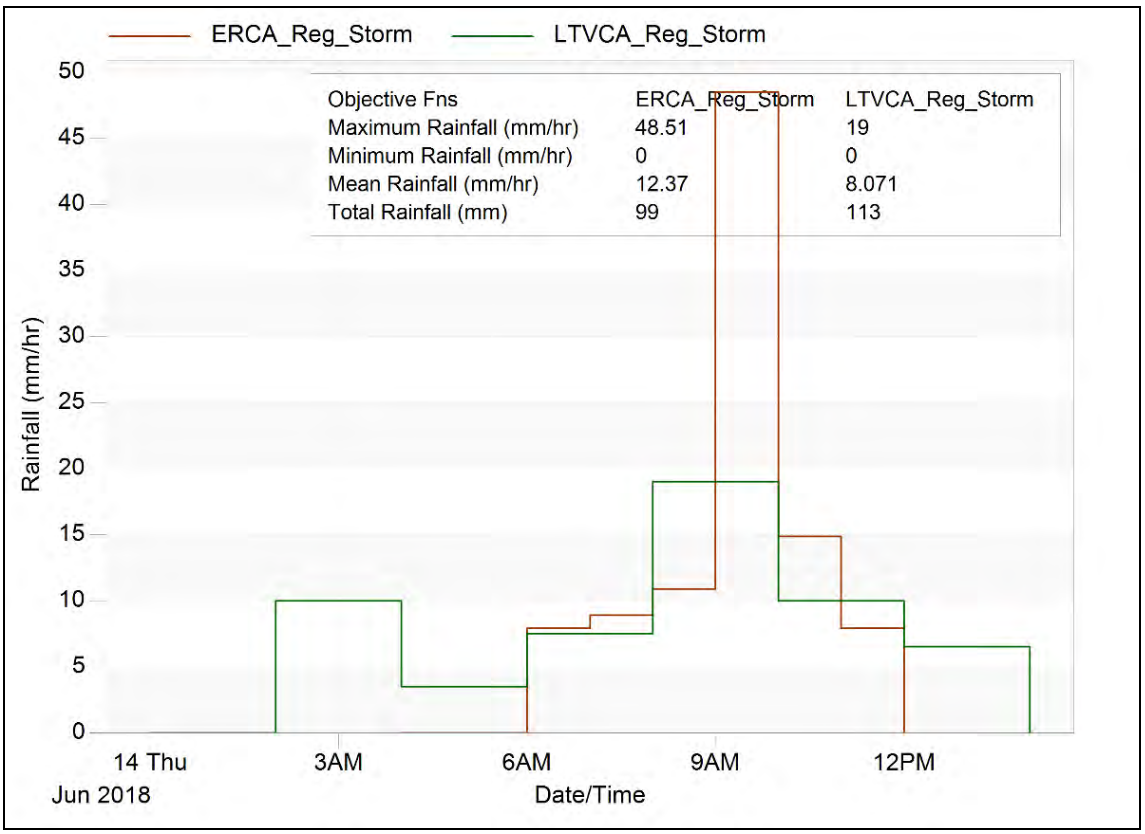
1.0 MODEL ANALYSIS

1.1 HYDROLOGY

1.1.1 Rainfall

The Regulatory Storm differs for ERCA and LTVCA. ERCA defines the Regulatory Storm as a 1:100 Year Design Storm. Insofar as ERCA's July 1981 Floodline Studies report pertaining to Ruscom River is concerned, said storm is defined as a 1:100 year 6-hour event with a rainfall of 3.9 inches (99 millimetres) and Probable Maximum Storm distribution. LTVCA defines the Regulatory Storm based upon the 1937 historical flood event. While the ERCA storm is 14 mm less volume than the LTVCA storm, it is a more concentrated and intense rainfall over 6 hours rather than 12 hour and was thus expected to be a more conservative storm for establishing floodline elevations. However, a comparison of hydrologic calculation results for the Big Creek watershed suggests that the LTVCA Regulatory Storm results in greater peak discharges than the ERCA Regulatory Storm. Consequently, the ERCA storm was used to calculate the floodlines for the Reid Drain and Silver Creek watersheds and the LTVCA storm was used to calculate the floodlines for Big Creek.

Graph A1 – Regulatory Storms



1.1.2 Flow Generation

Many input parameters are required for the model to estimate the runoff response of a particular subcatchment. The following are standard parameters used for all modeling scenarios, unless otherwise noted. The highlighted parameters were adjusted for model calibration purposes to account for varying antecedent moisture conditions.

RUNOFF routine parameters:

- **Flow Length**

  Subcatchment flow lengths were assumed to be twice the subcatchment width, where flow length x width = subcatchment area. This shape approximately represents average width to length ratio of the modelled subcatchments.

- **Subcatchment Slope**

  A version of the 85/10 method was used to determine overall slope within each subcatchment. This method focuses on the central 75% of the data to reduce the impact of outlying high and low points. The SWOOP 2015 DEM was used for this exercise, and the 10th and 85th percentile elevation within each subcatchment was calculated using Python scripting. Dividing this range by 75% of the calculated length produced a slope for each non-right-of-way subcatchment. The slope of right-of-way subcatchments was held at 0.5%.

- **Roughness**

  Overland flow roughness was set as 0.011 for impervious and 0.17 for pervious.

- **Depression Storage**

  Depression storage was set as 2.5mm for impervious and 20mm for pervious (Dp). The pervious value is higher than typical value of 10mm for open field, however this value is supported by calibration results and seems appropriate given the very flat topography of the study area.

- **Surface Infiltration – Green-Ampt**

  The Green-Ampt method was used to simulate infiltration at the surface. Parameters used are as follows:

  - Suction Head = 180mm
  - Saturated Conductivity = 2 mm/hr
  - Initial Moisture Deficit (IMD) = 0.10 (Porosity – Initial Moisture)

GROUNDWATER routine parameters:

- **Lateral Flow**

  For the purposes of this study modeling, lateral flow represents the interflow or tile drainage from the agricultural lands. The lateral flow equation includes coefficients and exponents which were calibrated to match observed flows, thus mimicking the runoff response of the tile drainage systems. The following parameters were derived from model calibration:

- A1, A2 = 0.022
- B1, B2 = 1
- A3 = 0

- **Initial/Threshold Water Table Elevation**

  Initial water table elevation corresponds to the water table elevation whereas the threshold water table elevation represents the minimum elevation for tile drainage (interflow) to occur. As the study is predominantly Brookston clay soils, a 0.3m thick upper layer of soil was assumed to mimic subsurface water that is temporarily stored and slowly drained by tile drainage (interflow) prior to becoming groundwater. The assumed 0.3m is consistent with the Essex Soils Report which classifies a 0.3m thick A horizon – the surface soil layer consisting of organic materials and finer structure (i.e. good vertical movement of water). Thus, surface elevation of each subcatchment groundwater layer was set at the drain bank elevation and the initial/threshold water table elevation was set at 0.3m below surface elevation. There is only one exception for the calibration of the September 29, 2016 storm event, where the initial water table elevation set below the threshold elevation. For this event, a depth of 0.33m or additional 30mm of aquifer storage (AQ) was added to simulate the initial groundwater flow that did not produce runoff.

- **Soil Parameters**

  The following soil parameters were used:

- Porosity = 0.48 (Saturated conditions)
- Wilting Point = 0.27 (Dry conditions)
- Field Capacity = 0.38 (Wet conditions - the amount of soil moisture or water content held in the soil after excess water has drained away)
- Initial Moisture (IM) = 0.38
- Saturated Conductivity = 2 mm/hr
- Conductivity Slope = 30
- Tension Slope = 10
- Deep Groundwater Flow or Seepage (GWF):
  - 10 mm/hr for A soils
  - 2.5mm/hr for C soils
  - 0.5mm/hr for D soils

1.1.3 Hydrologic Soil Group

Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. Where A's generally have the smallest runoff potential and Ds the greatest.

Details of this classification can be found in 'Urban Hydrology for Small Watersheds' published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55.

Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure

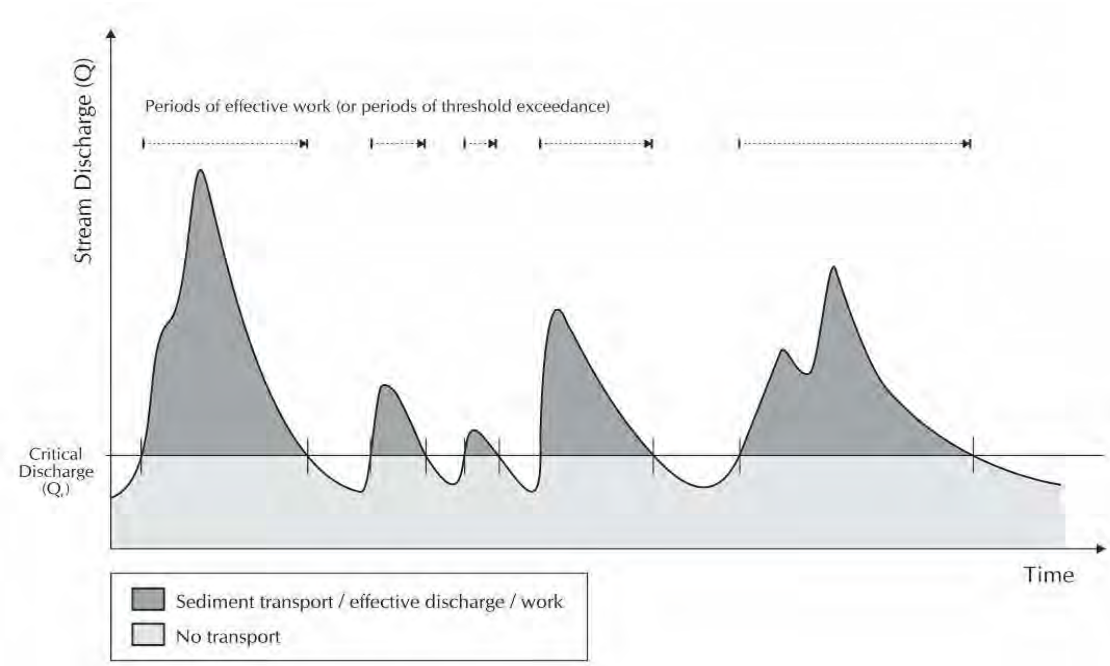
Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

2.0 ALLOWABLE RELEASE RATES

2.1 EROSION THRESHOLD ANALYSIS

The prescribed lower tier release rates serve to mitigate erosion from development by limiting effective work periods to pre-development conditions. As depicted in **Graph A2** below, effective work occurs when flows exceed the critical discharge rate.

Graph A2 – Effective Work



Appendix F depicts discharge graphs at the study watershed boundary limits (County Road 8) for Reid Drain, Silver Creek and Big Creek under both the 5 year and 32 mm storms discussed in section 2.1 of the report. The critical discharge for each watershed is depicted by the "exceedance line" and volume of exceedance values represent the effective work – same principle as depicted in **Graph A2** above. The lower tier allowable release rate has been adjusted to satisfy the design criteria that effective work under "Ultimate" conditions (per buildout limits of section 2.1.3) does not exceed the effective work of the "Undeveloped" condition. The "Unrestricted" condition is presented for illustrative purposes to show the impact of the ultimate buildout conditions without stormwater management measures in place.

2.2 CONVEYANCE CAPACITY

From a conveyance capacity perspective, the overall drainage system could accommodate full buildout of the study area at a controlled flow rate 6 L/s/ha without spilling low banks (i.e. bank on land side which is sometimes much lower than road side).

From a tile drainage perspective, OMAFRA's Drainage Guide for Ontario (Publication 29) recommends larger Drainage Coefficients in soils of coarse texture and little to no surface drainage, such as those in the study area. A Drainage Coefficient of 50 mm/day, which equates to a discharge rate of 5.8 L/s/ha (rounded to 6) is believed to be a reasonable approximation of the level of agricultural drainage that exists. As compared to the model results, the calibration of the March 30, 2017 storm produced an overall peak flow of 4.6 L/s/ha as purely tile drainage (interflow) measured at the Ruscom gauge. During the same storm, an average of the individual peak tile drainage discharge rate was estimated to be 5.3 L/s/ha.

From a soil profile perspective, Brookston clay typical soil profile has a 300mm thick A horizon top layer. With a dry initial moisture deficit of 0.21 (fraction), the corresponding water depth to fully saturate this layer is 63mm.

Based on the foregoing perspectives, the recommended allowable release rate of 6 L/s/ha (52 mm/day) is deemed appropriate and furthermore, will mimic undeveloped conditions during periods of low groundwater seepage.

3.0 FLOOD CONTROL

3.1 FLOODLINE MAPPING

The Ministry of Natural Resources and Forestry (MNRF, previously MNR) 2002 Technical Guide for River and Stream Systems: Flooding Hazard Limit provides guidance on floodline mapping. Most notably, it recommends that stormwater ponds should not be considered in floodline mapping (i.e. floodline mapping should assume uncontrolled flow from development). The intent of this guidance is to ensure that potential pond failures as well as flows over and above the pond design capacity are accounted for in downstream flow and corresponding floodline mapping. Given the unique characteristics of the region, we believe that this guidance is not be applicable to the study area.

The study area conditions such as relatively flat topography, pond excavations below grade or with minor berming and ponds designed to accommodate either all or most of the runoff from the Regulatory Storms would result in pond facilities that can be relied upon to attenuate runoff. The foregoing is prefaced on the condition that pond facilities are appropriately designed to store the runoff from the 1:100 year storm and that the facilities are constructed and maintained to function as designed. This is consistent with recent approaches used by other Stantec offices for studies in other Ontario jurisdictions.

The findings and recommendations of this study have accounted for pond facilities in our floodline mapping study, even those on private property, with the understanding that the Municipality acknowledges the responsibility to ensure that the ponds are properly designed and function as designed. As such, the Municipality must secure their legal right to inspect the pond construction, enforce maintenance or remedial works if required, and/or mobilize on private property to perform any necessary remedial works at the cost of the owner.

For purposes of determining floodline elevations, a sensitivity analysis was performed to assess the hydraulics within a range of hydraulic capacities as described below:

- Hydraulic Condition A: As the upper range of hydraulic capacity, the culverts were ignored (removed from the model) and the open channels were assigned a roughness of 0.030.
- Hydraulic Condition B: As the lower range of hydraulic capacity, the culverts were included in the model and the open channels were assigned a roughness of 0.050. The floodline elevation at each point of interest was taken as the critical (higher) elevation of the two conditions. **Tables 4.1a to 4.1c** compare flows and elevations for varying hydraulic and buildout conditions.

Table 4.1a – Floodline Model Flow & Elevation –
Undeveloped Condition Simulated Without Hydraulic Capacity Constraints

LOCATION	ERCA	SIMULATED
Flow (cms)		
Silver @ CR8 (D/S)	**45.3**	28.1
Reid @ CR8 (D/S)	**19.8**	12.3
Elevation (m)		
Silver @ CR8 (D/S)	**186.24**	186.24
Reid @ CR8 (D/S)	**186.51**	186.51

ERCA Column: Values derived from ERCA Regulatory Floodline Information
Simulated Column: Hydraulic modeling without culverts, roughness = 0.037 and simulated surcharge conditions
Simulated Elevation: Based on normal depth outfall with slope adjusted to match ERCA elevation.

Table 4.1b – Floodline Model Flow & Elevation –
Current Buildout Simulated with Two Hydraulic Capacity Conditions

LOCATION	ERCA	Model - Hyd. Cond. A	Model - Hyd. Cond. B
	Flow (cms)		
Silver @ CR8 (D/S)	**45.3**	25.4	20.3
Reid @ CR8 (D/S)	**19.8**	11.5	10.1
	Elevation (m)		
Silver @ CR8 (D/S)	**186.24**	186.10	185.82
Reid @ CR8 (D/S)	**186.51**	186.42	186.27

ERCA Column: Values derived from ERCA Regulatory Floodline Information

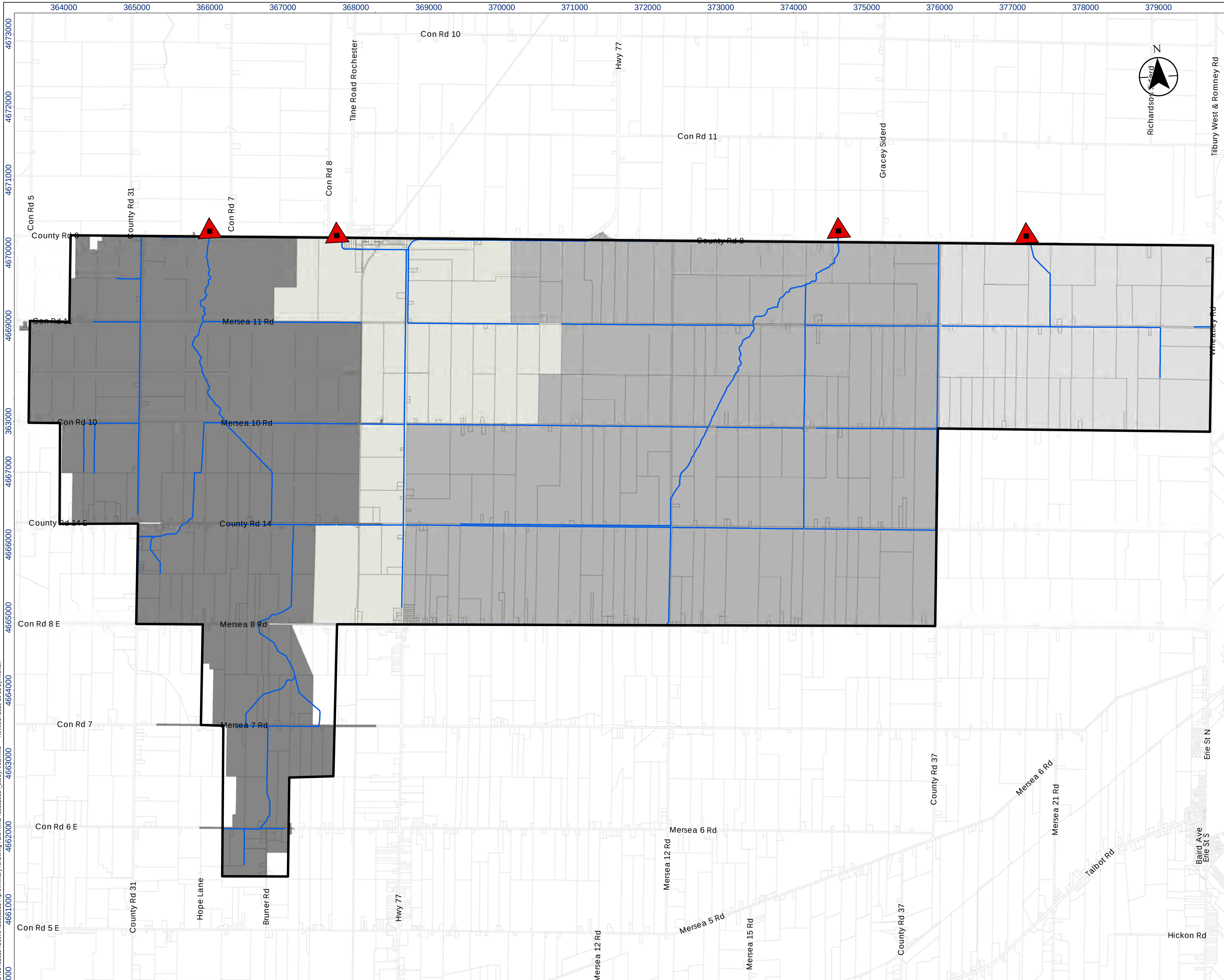
Table 4.1c – Floodline Model Flow & Elevation –
Current versus Ultimate Buildout Simulated with Hydraulic Condition B

LOCATION	ERCA	Model - Hyd. Cond. B	
		Current	Ultimate
	Flow (cms)		
Silver @ CR8 (D/S)	**45.3**	20.3	19.3
Reid @ CR8 (D/S)	**19.8**	10.1	8.4
	Elevation (m)		
Silver @ CR8 (D/S)	**186.24**	185.82	185.76
Reid @ CR8 (D/S)	**186.51**	186.27	186.07

ERCA Column: Values derived from ERCA Regulatory Floodline Information

APPENDIX B

Figures



Stantec

Legend

- Parcel Fabric
- Project Boundary

Catchments

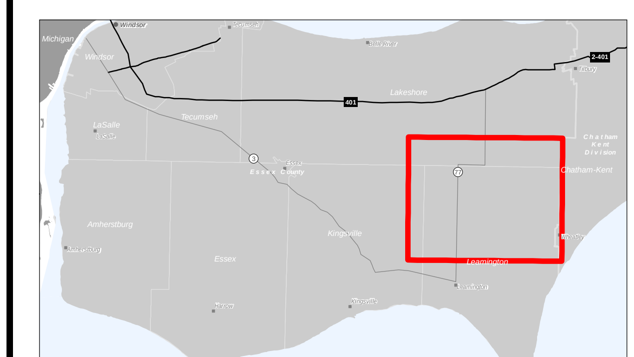
- Silver Creek
- Reid
- Big Creek
- Robb Dales
- Drains in Project Boundary
- Outfalls

0 1,200 2,400 metres

1:26,000 (At original document size of 22x34)

Notes

1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2018.
3. Orthoimagery © First Base Solutions, 2018. Imagery Date, 2018.



Project Location

Municipality of Leamington

165620134

Prepared by LMF on 2018-10-31

Client/Project

LEAMINGTON STORM WATER DRAIN STUDY

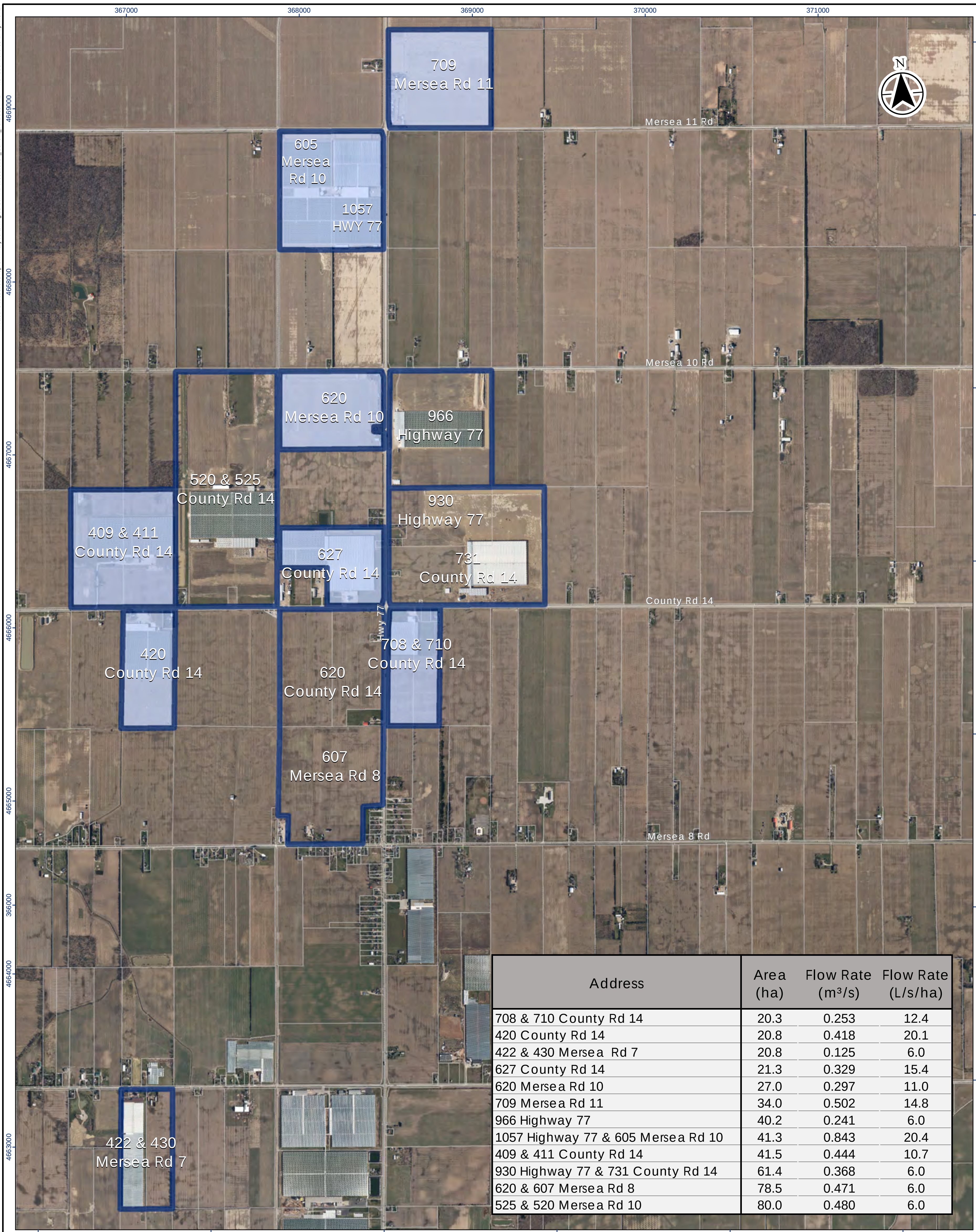
Figure No.

1

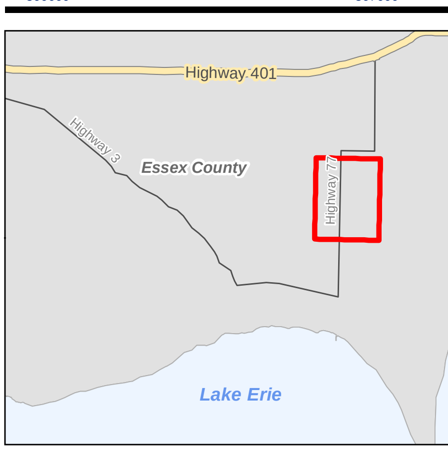
Title

Project Study Area

W:\active\165620134\preliminary\drawing\GIS\MXD\165620134_Current_Buildout.mxd Revised: 2019-05-17 By: lflorian



Address	Area (ha)	Flow Rate (m³/s)	Flow Rate (L/s/ha)
708 & 710 County Rd 14	20.3	0.253	12.4
420 County Rd 14	20.8	0.418	20.1
422 & 430 Mersea Rd 7	20.8	0.125	6.0
627 County Rd 14	21.3	0.329	15.4
620 Mersea Rd 10	27.0	0.297	11.0
709 Mersea Rd 11	34.0	0.502	14.8
966 Highway 77	40.2	0.241	6.0
1057 Highway 77 & 605 Mersea Rd 10	41.3	0.843	20.4
409 & 411 County Rd 14	41.5	0.444	10.7
930 Highway 77 & 731 County Rd 14	61.4	0.368	6.0
620 & 607 Mersea Rd 8	78.5	0.471	6.0
525 & 520 Mersea Rd 10	80.0	0.480	6.0



Legend

Parcel Fabric

Sites with Pre-Existing Rates as Provided by N.J. Peralta

0 250 500 1,000 Meters

1:23,000 (At Original document size of 11x17)

Stantec

Project Location
Municipality of Leamington

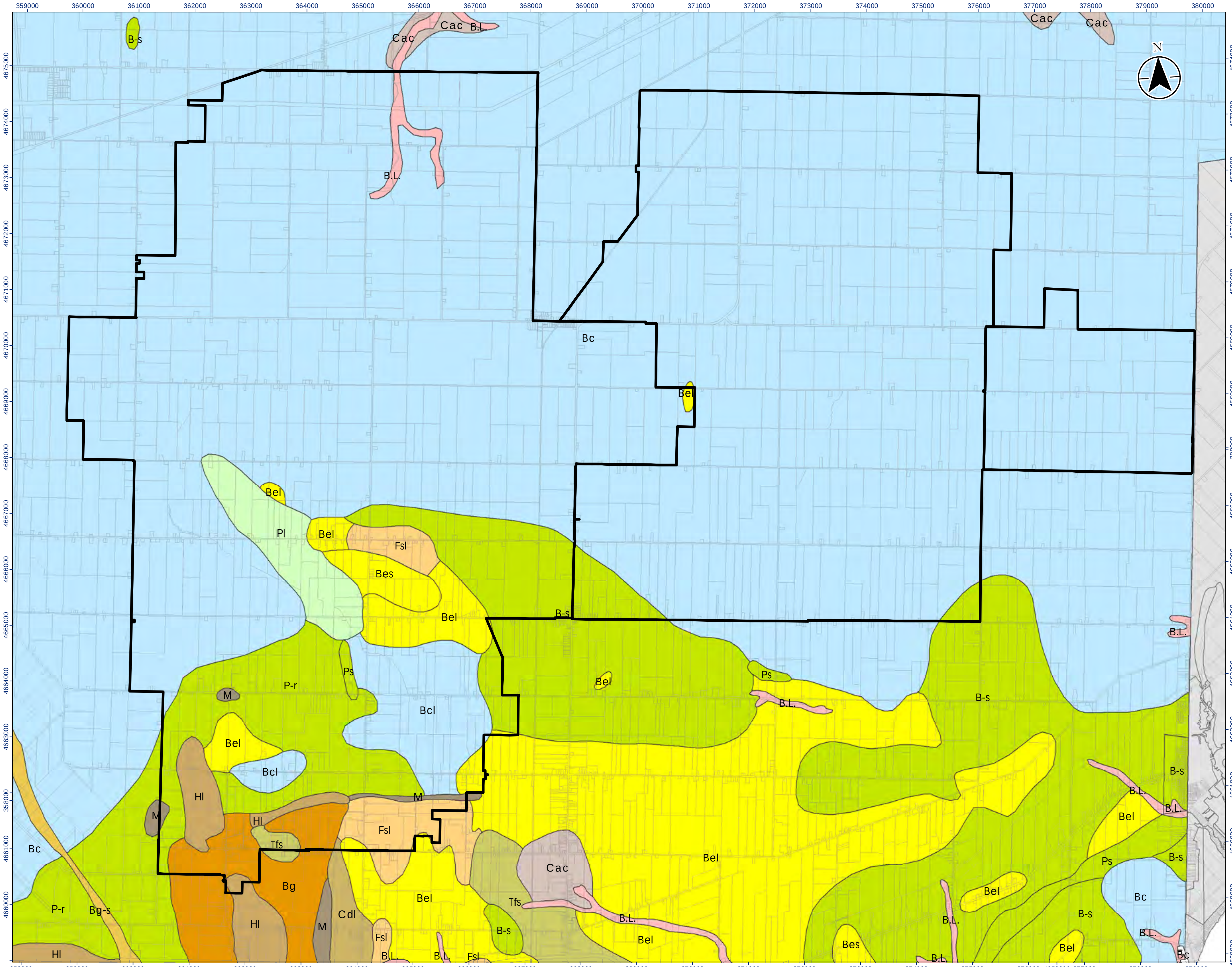
165620134 REVA
Prepared by LMF
on 2019-05-17

Client/Project
LEAMINGTON MASTER DRAINAGE STUDY

Figure No.
2

Title
Current Buildout

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N



Stantec

Legend

B-s	Gs
B.L.	Hl
Bc	Hs
Bcl	Jc
Bel	M
Bes	Ma
Bg	P-r
Bg-s	Pc
C-s	Pcl
Cac	Pl
Cacl	Ps
Cc	Tfs
Cdl	Toc
Es	Tos
Fl	Was
Fsl	

0 1 2 4 Kilometers

1:70,000 (At original document size of 11x17)

Notes
1. Coordinate System: NAD 1983 UTM Zone 17N
2. Base features produced under license with the Ontario Ministry of Natural Resources and Forestry © Queen's Printer for Ontario, 2017.
3. Orthoimagery © First Base Solutions, 2016. Imagery Date, 2018.

Project Location
Municipality of Leamington

165620134
Prepared by LMF on 2018-06-05

Client/Project
LEAMINGTON STORM WATER DRAIN STUDY

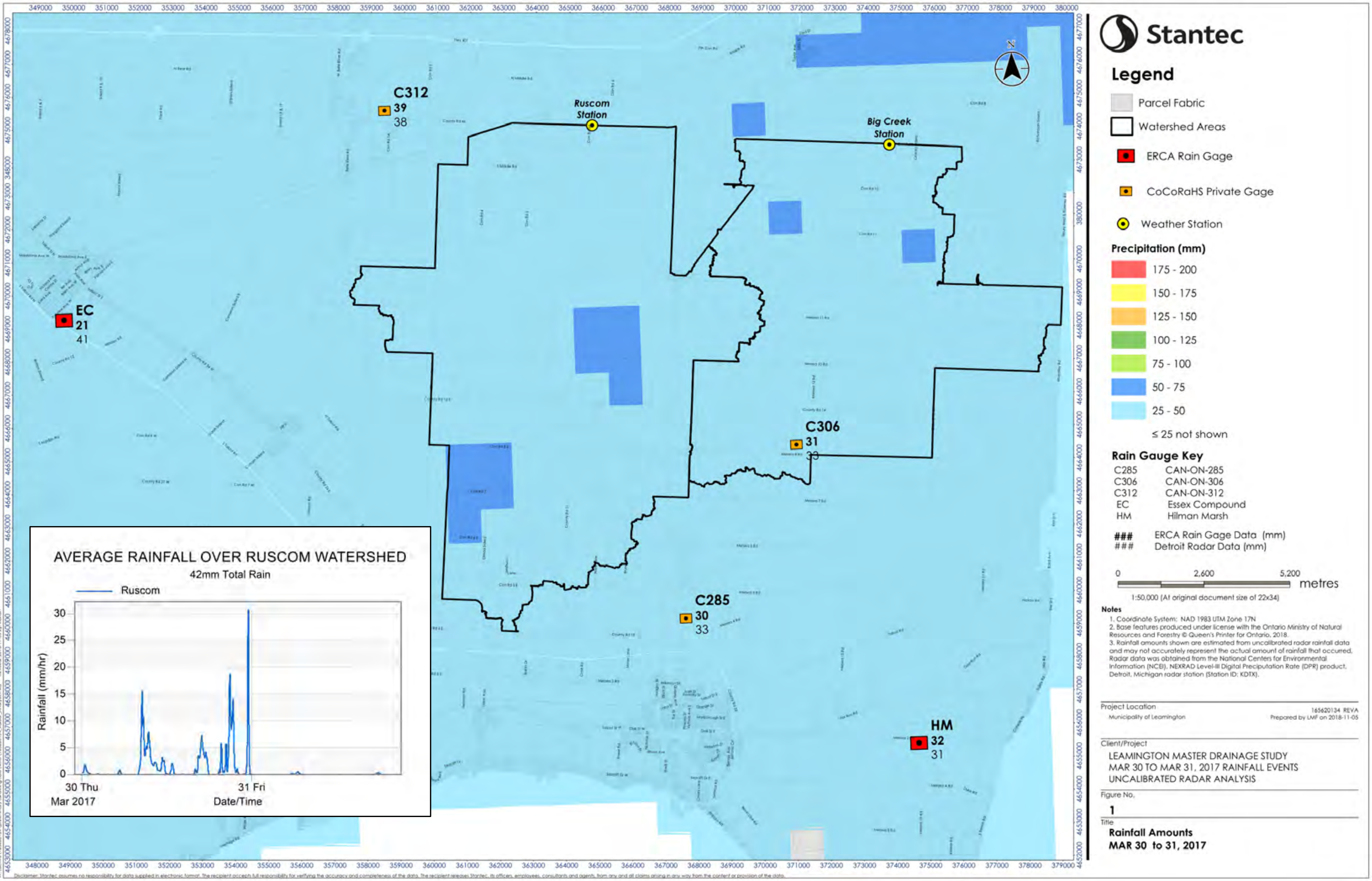
Figure No.
3

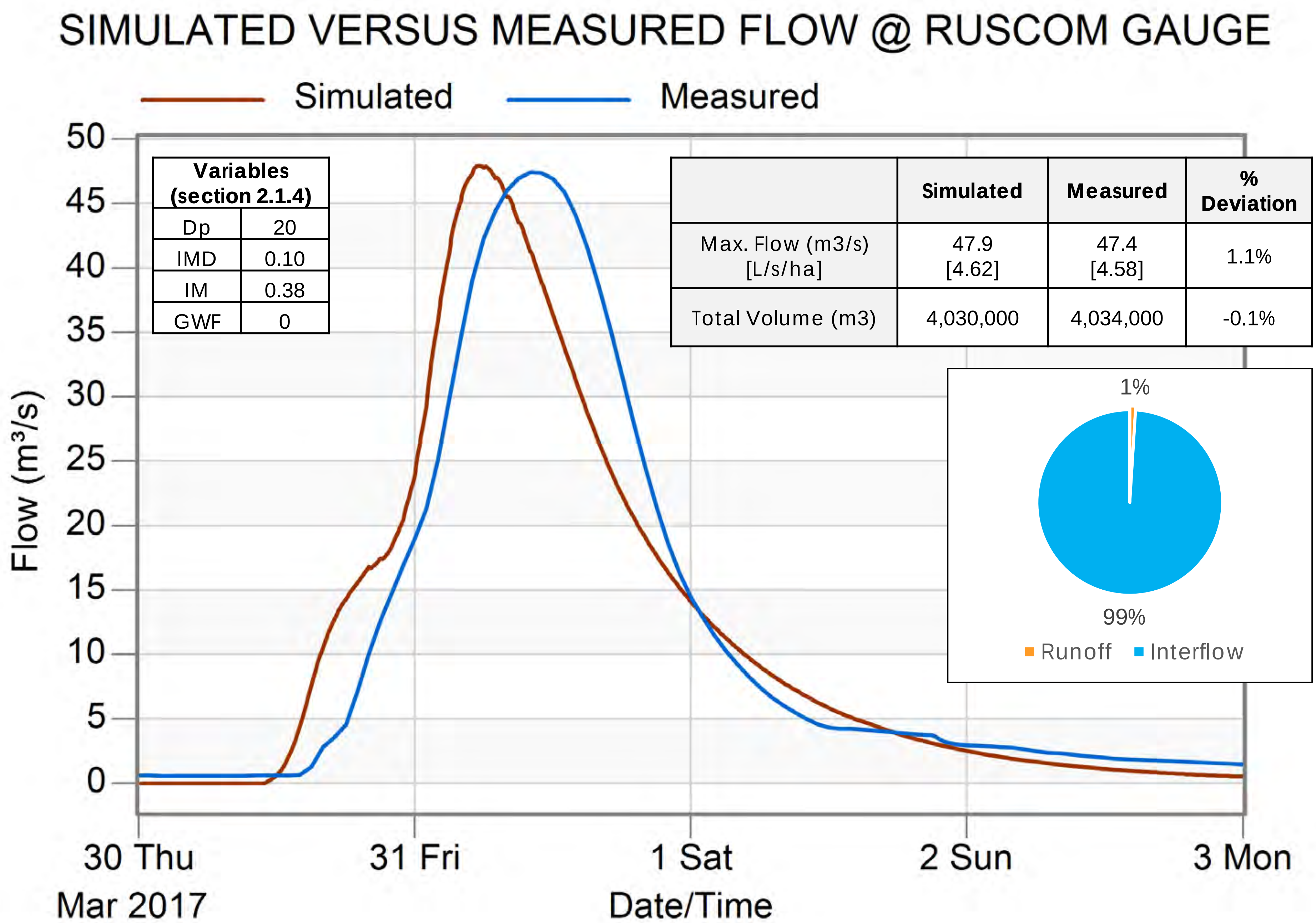
Title
Soil Classification - Essex County

APPENDIX C

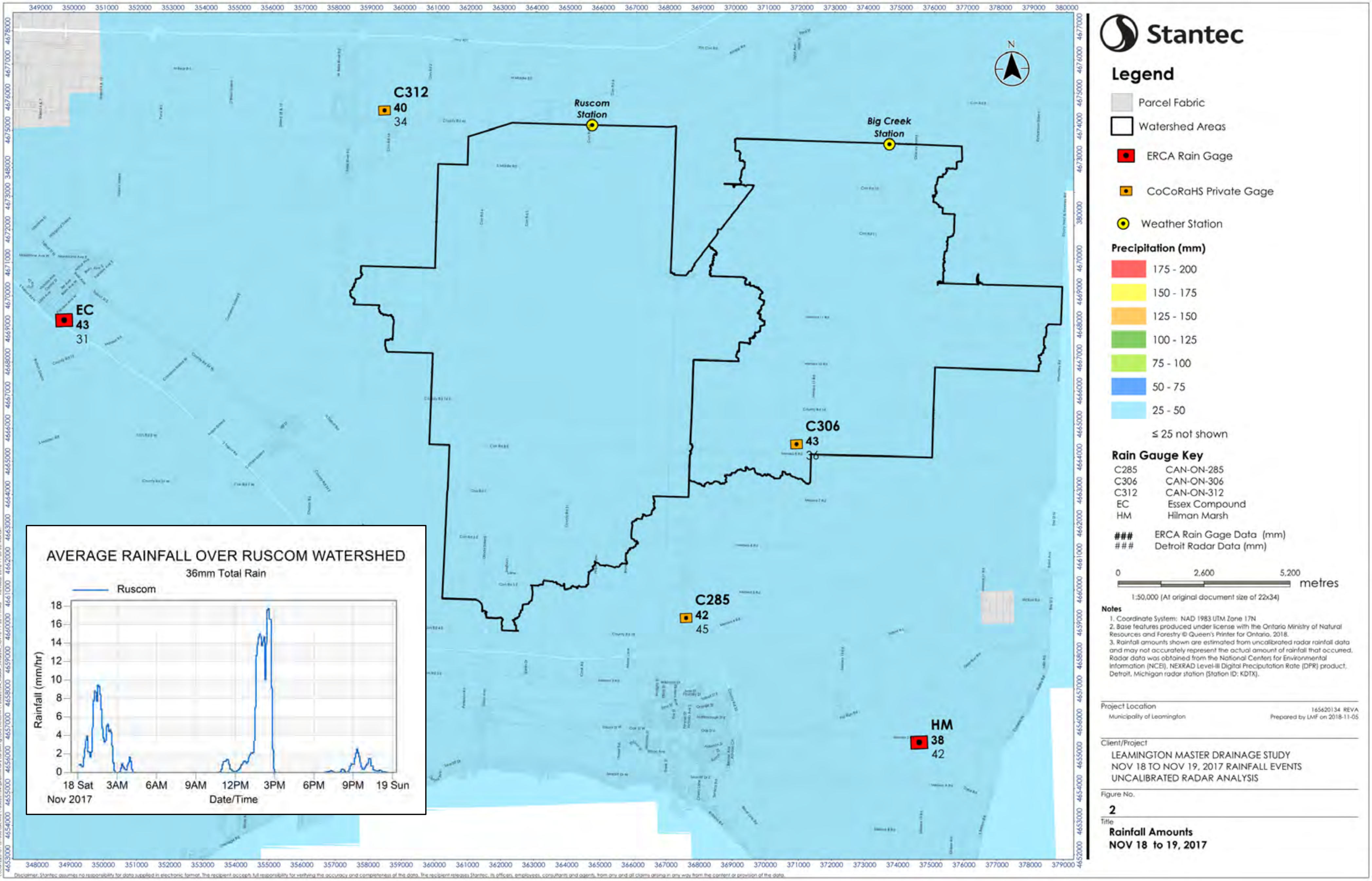
Model Calibration

Radar Rainfall – March 30 to 31, 2017

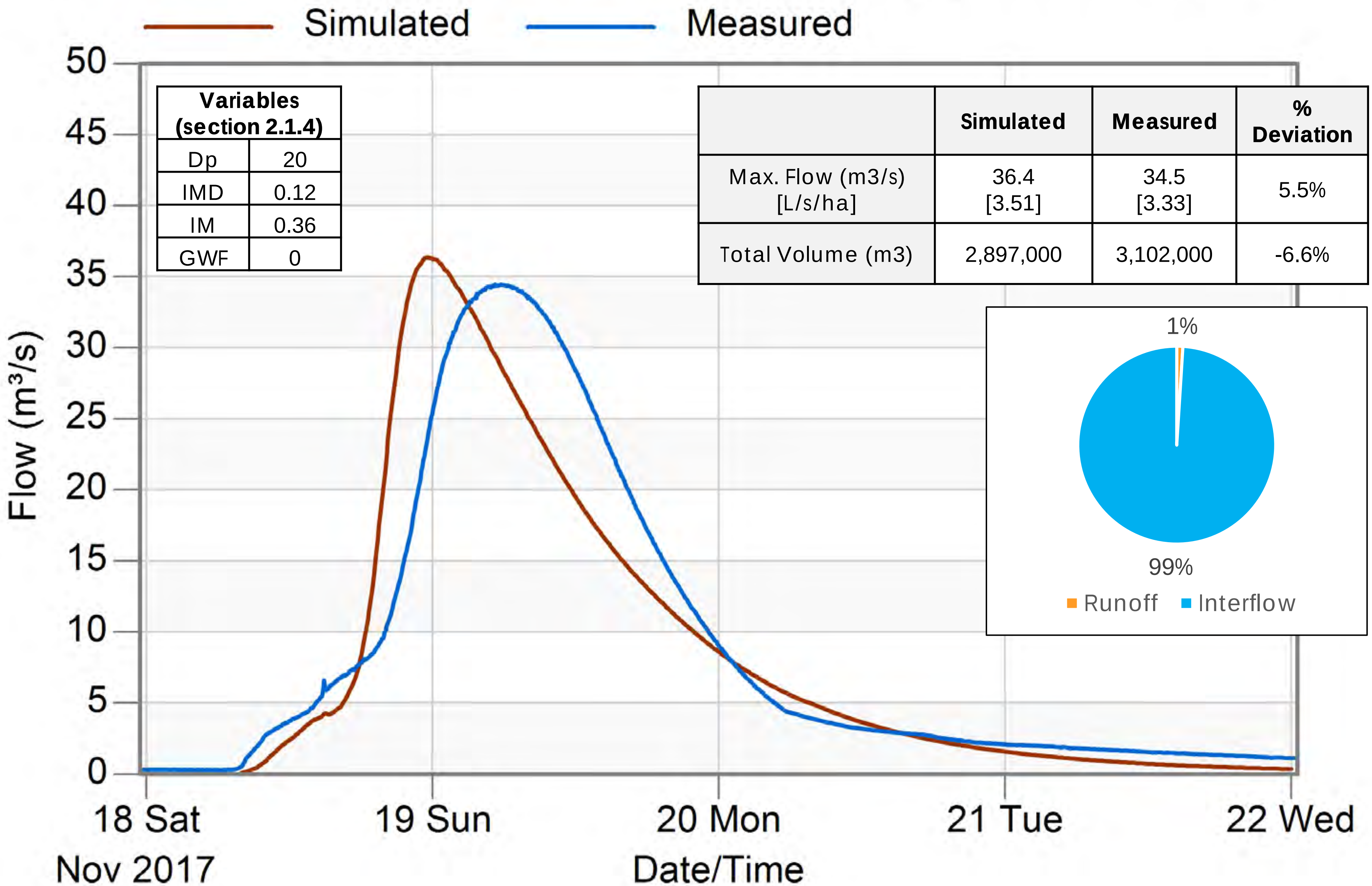



SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE
Simulated
Measured
Flow (m³/s)
50
45
40
35
30
25
20
15
10
5
0
Variables (section 2.1.4)
Dp 20
IMD 0.10
IM 0.38
GWF 0
Simulated
Measured
% Deviation
Max. Flow (m3/s) [L/s/ha] 47.9 [4.62] 47.4 [4.58] 1.1%
Total Volume (m3) 4,030,000 4,034,000 -0.1%
1%
99%
Runoff
Interflow
30 Thu
31 Fri
1 Sat
2 Sun
3 Mon
Mar 2017
Date/Time

Radar Rainfall – November 18 to 19, 2017



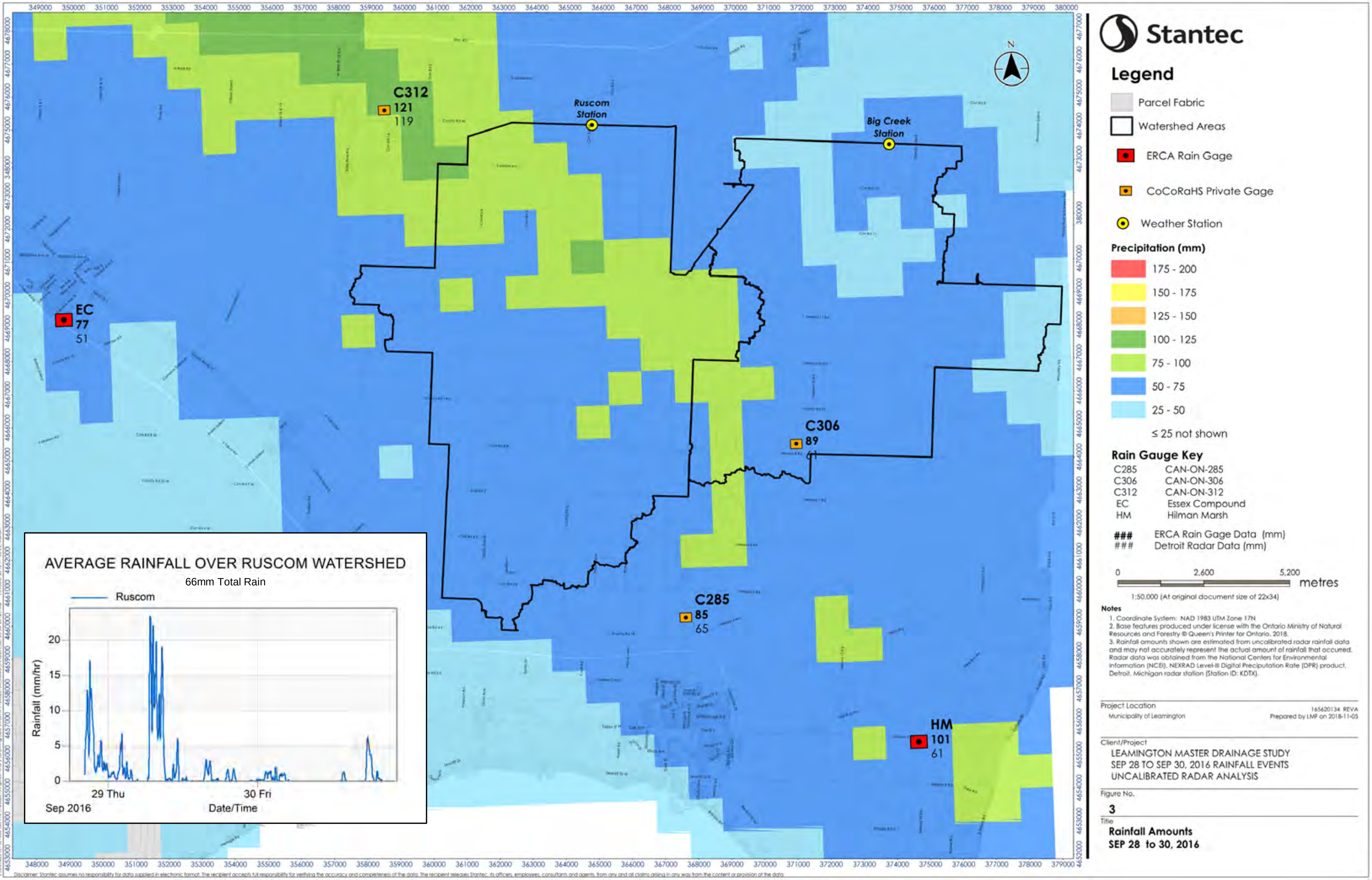
SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE



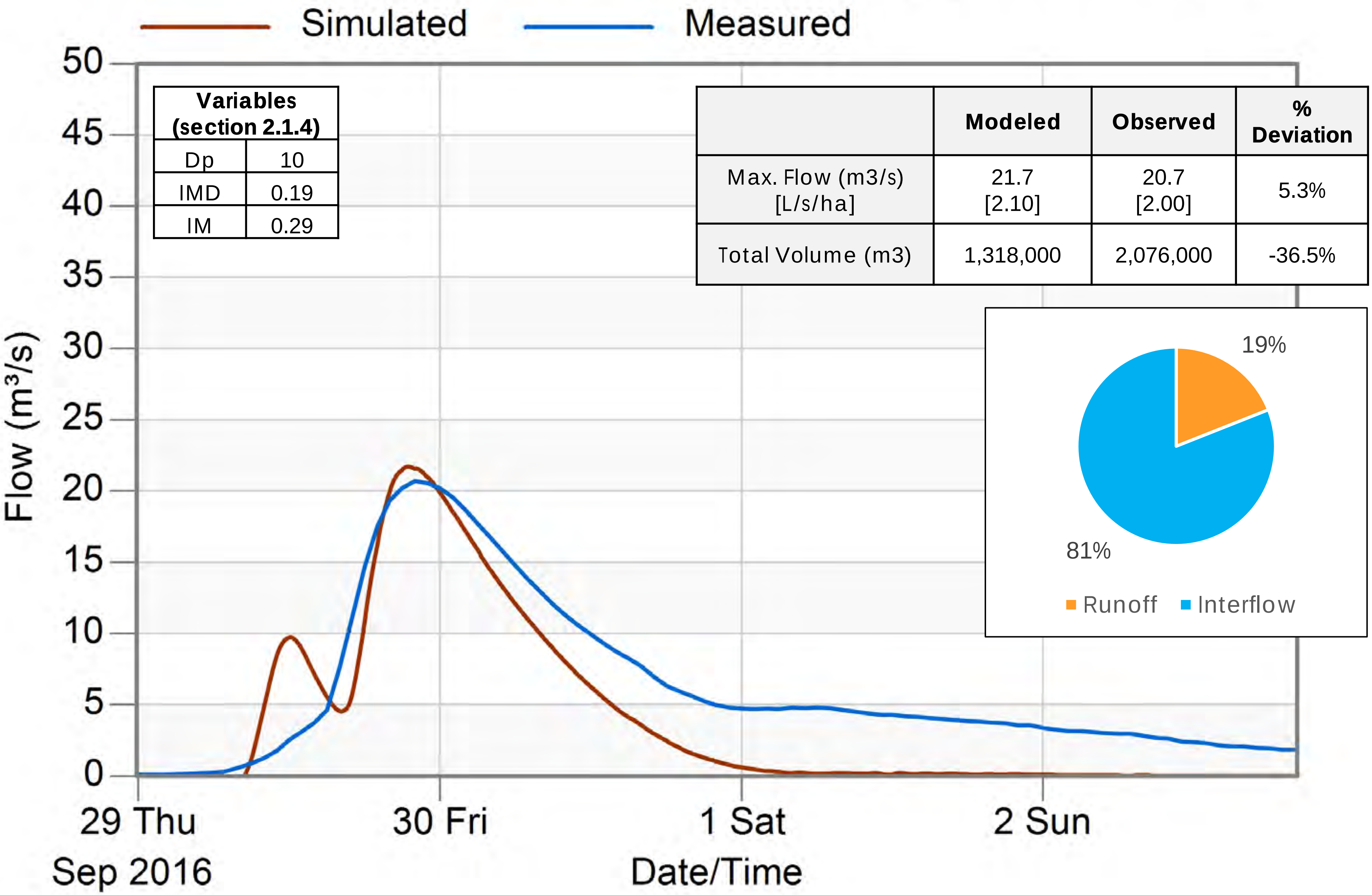
Variables (section 2.1.4)	
Dp	20
IMD	0.12
IM	0.36
GWF	0

	Simulated	Measured	% Deviation
Max. Flow (m3/s) [L/s/ha]	36.4 [3.51]	34.5 [3.33]	5.5%
Total Volume (m3)	2,897,000	3,102,000	-6.6%

Radar Rainfall – September 28 to 30, 2016

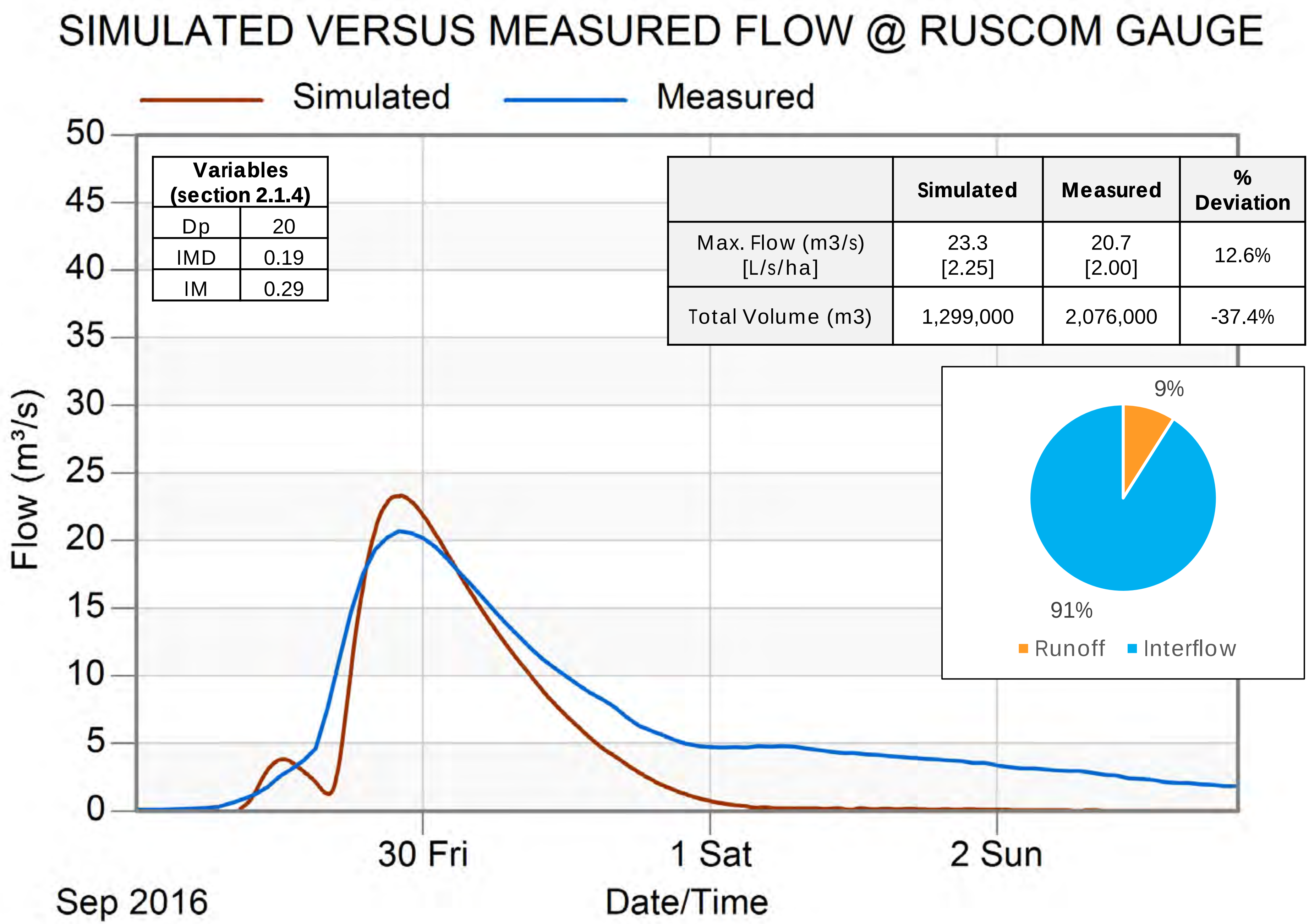


SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE



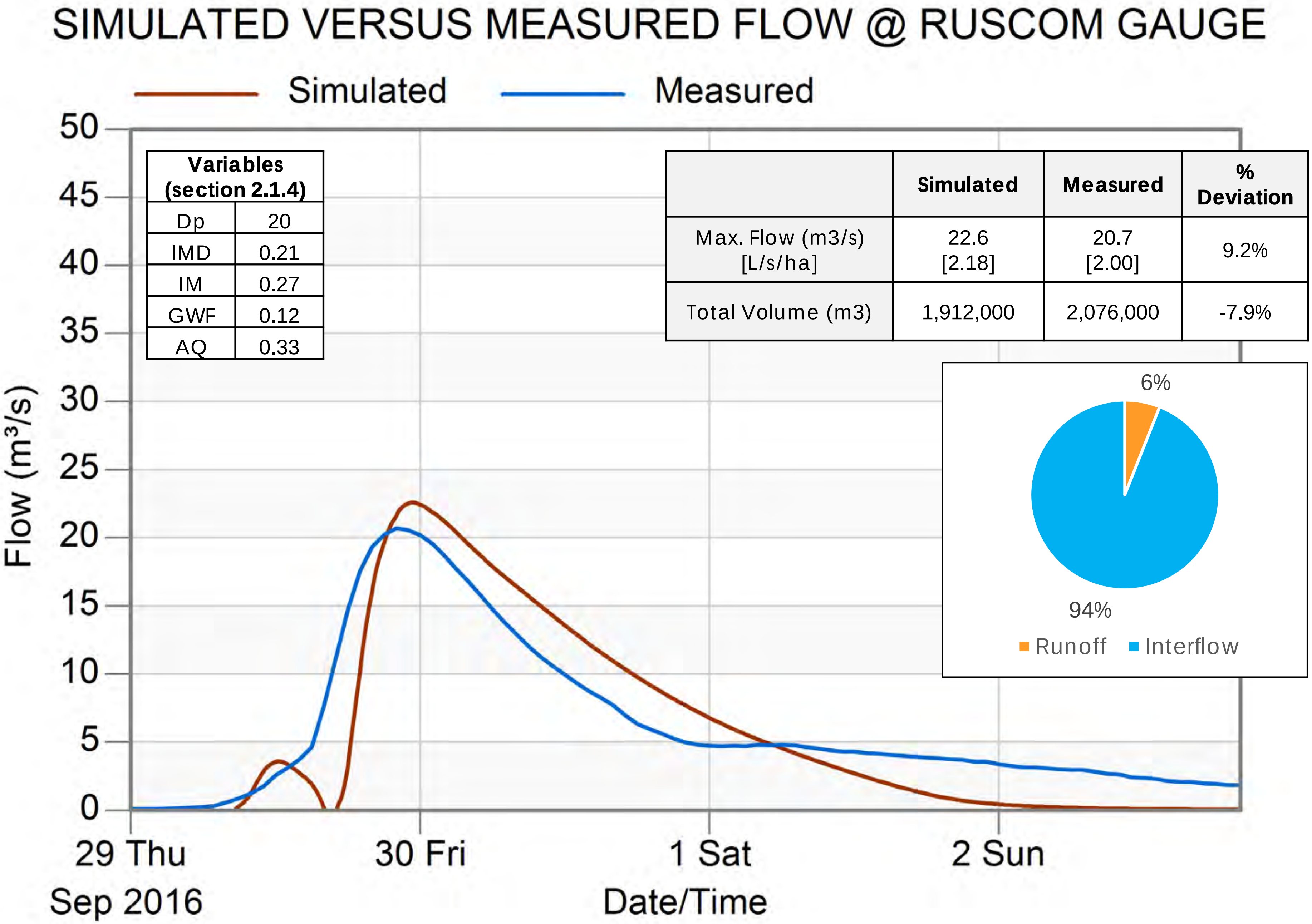
Variables (section 2.1.4)	
Dp	10
IMD	0.19
IM	0.29

	Modeled	Observed	% Deviation
Max. Flow (m3/s) [L/s/ha]	21.7 [2.10]	20.7 [2.00]	5.3%
Total Volume (m3)	1,318,000	2,076,000	-36.5%

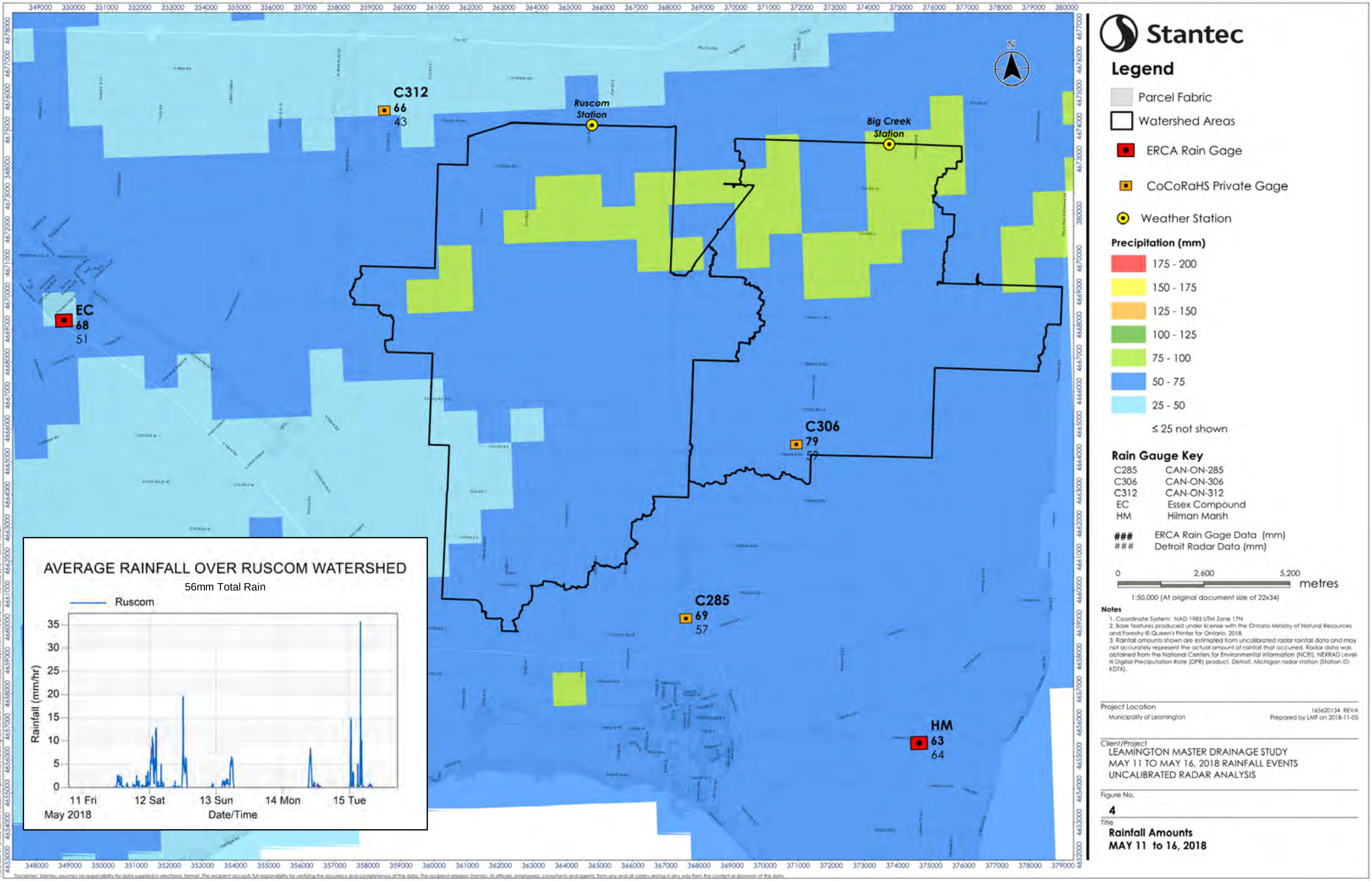


Variables (section 2.1.4)	
Dp	20
IMD	0.19
IM	0.29

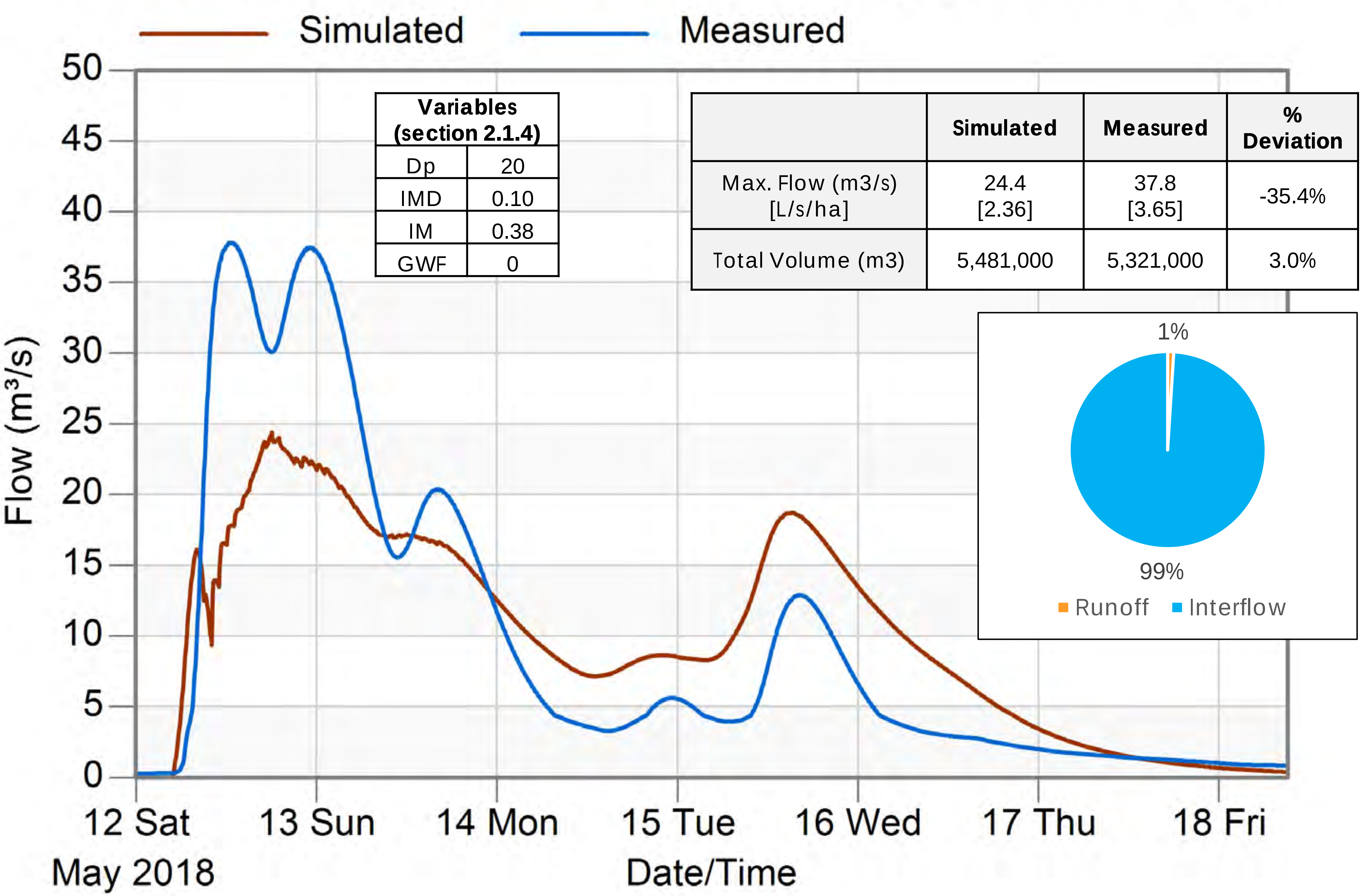
	Simulated	Measured	% Deviation
Max. Flow (m3/s) [L/s/ha]	23.3 [2.25]	20.7 [2.00]	12.6%
Total Volume (m3)	1,299,000	2,076,000	-37.4%


SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE
Simulated
Measured
Variables (section 2.1.4)
Dp 20
IMD 0.21
IM 0.27
GWF 0.12
AQ 0.33
Simulated
Measured
% Deviation
Max. Flow (m3/s) [L/s/ha]
22.6 [2.18]
20.7 [2.00]
9.2%
Total Volume (m3)
1,912,000
2,076,000
-7.9%
6%
94%
Runoff
Interflow
50
45
40
35
30
25
20
15
10
5
0
Flow (m³/s)
29 Thu
30 Fri
1 Sat
2 Sun
Sep 2016
Date/Time

Radar Rainfall – May 11 to 16, 2018



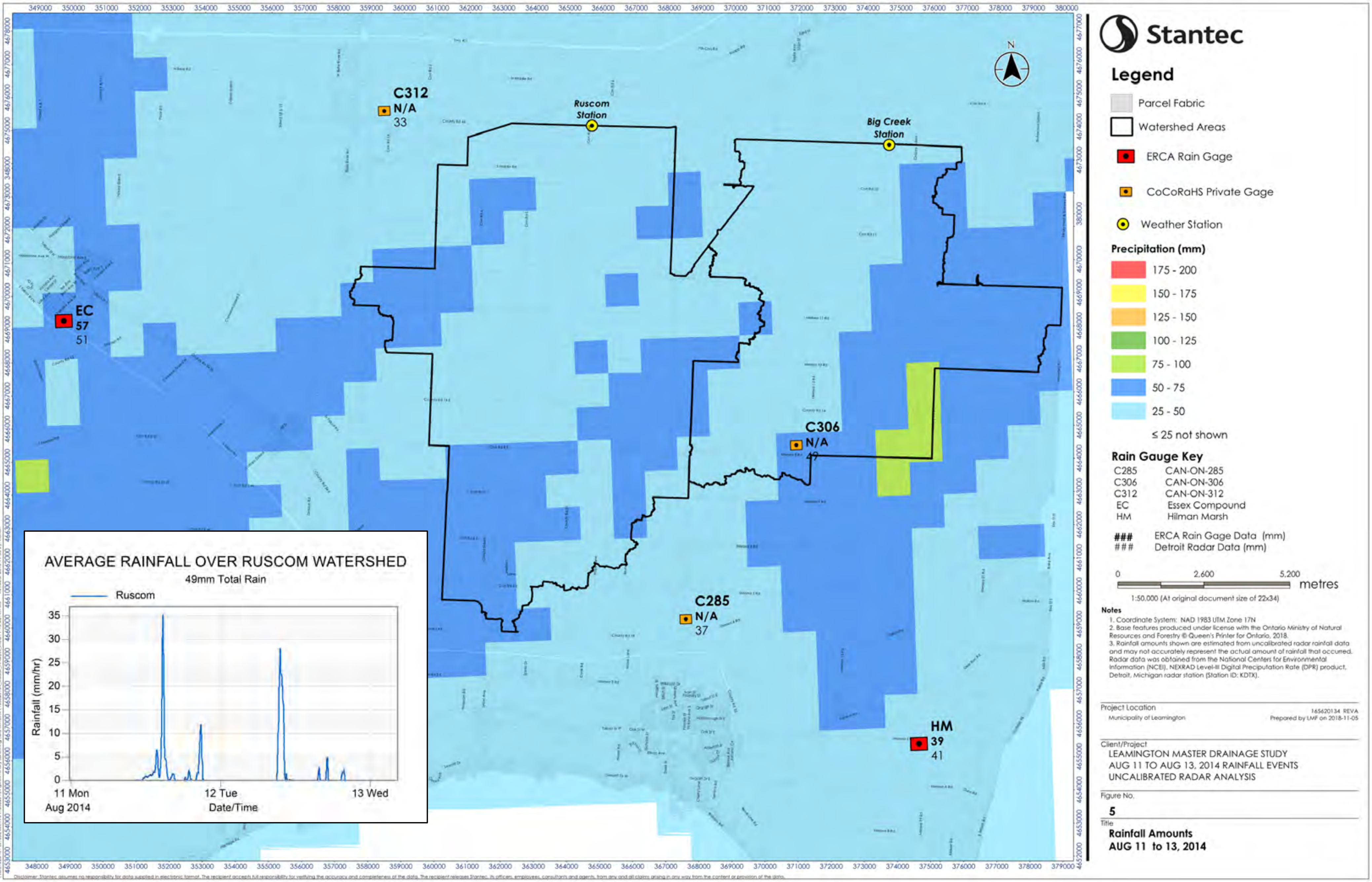
SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE



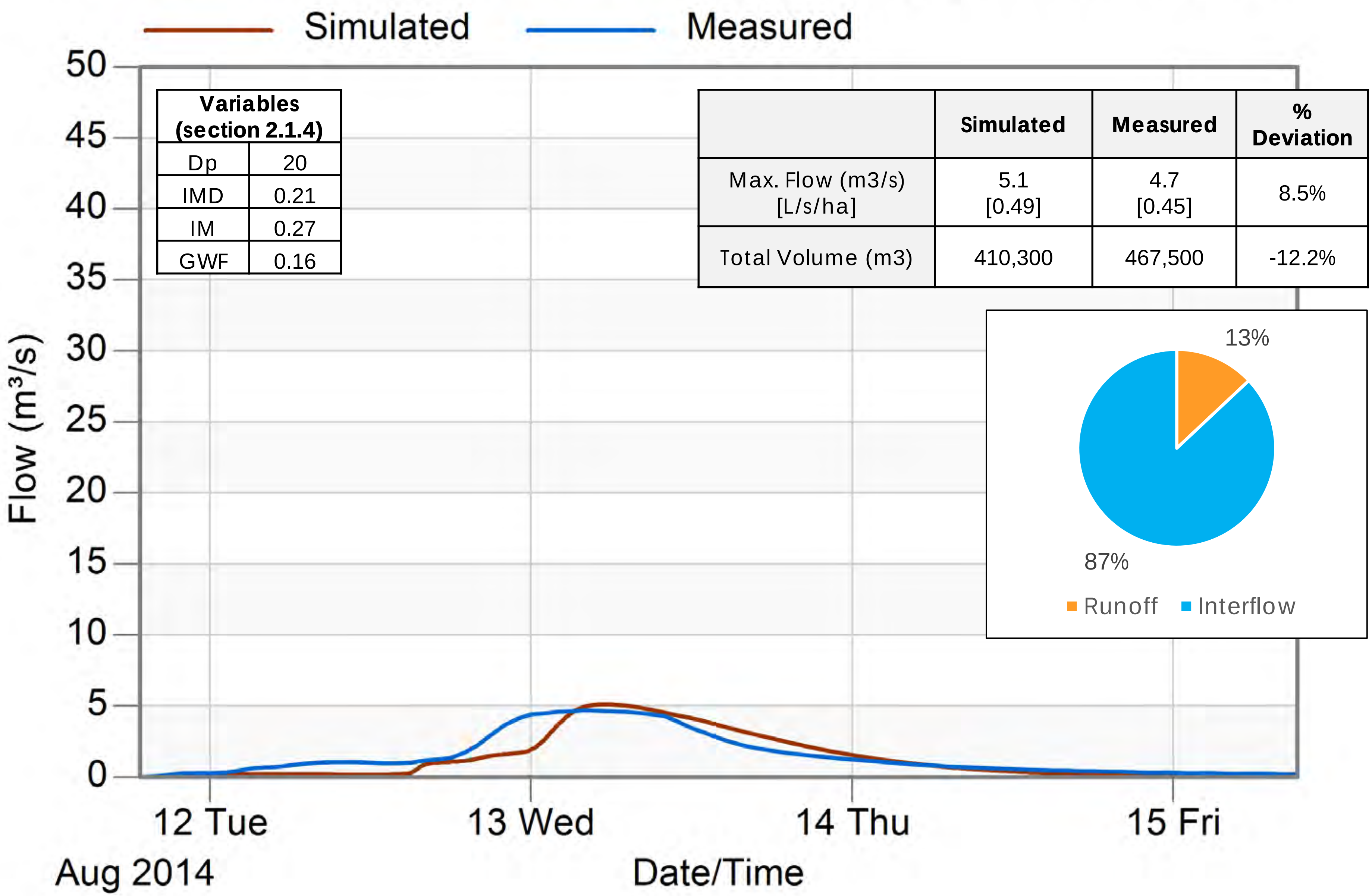
Variables (section 2.1.4)	
Dp	20
IMD	0.10
IM	0.38
GWF	0

	Simulated	Measured	% Deviation
Max. Flow (m3/s) [L/s/ha]	24.4 [2.36]	37.8 [3.65]	-35.4%
Total Volume (m3)	5,481,000	5,321,000	3.0%

Radar Rainfall – Aug 11 to 12, 2014

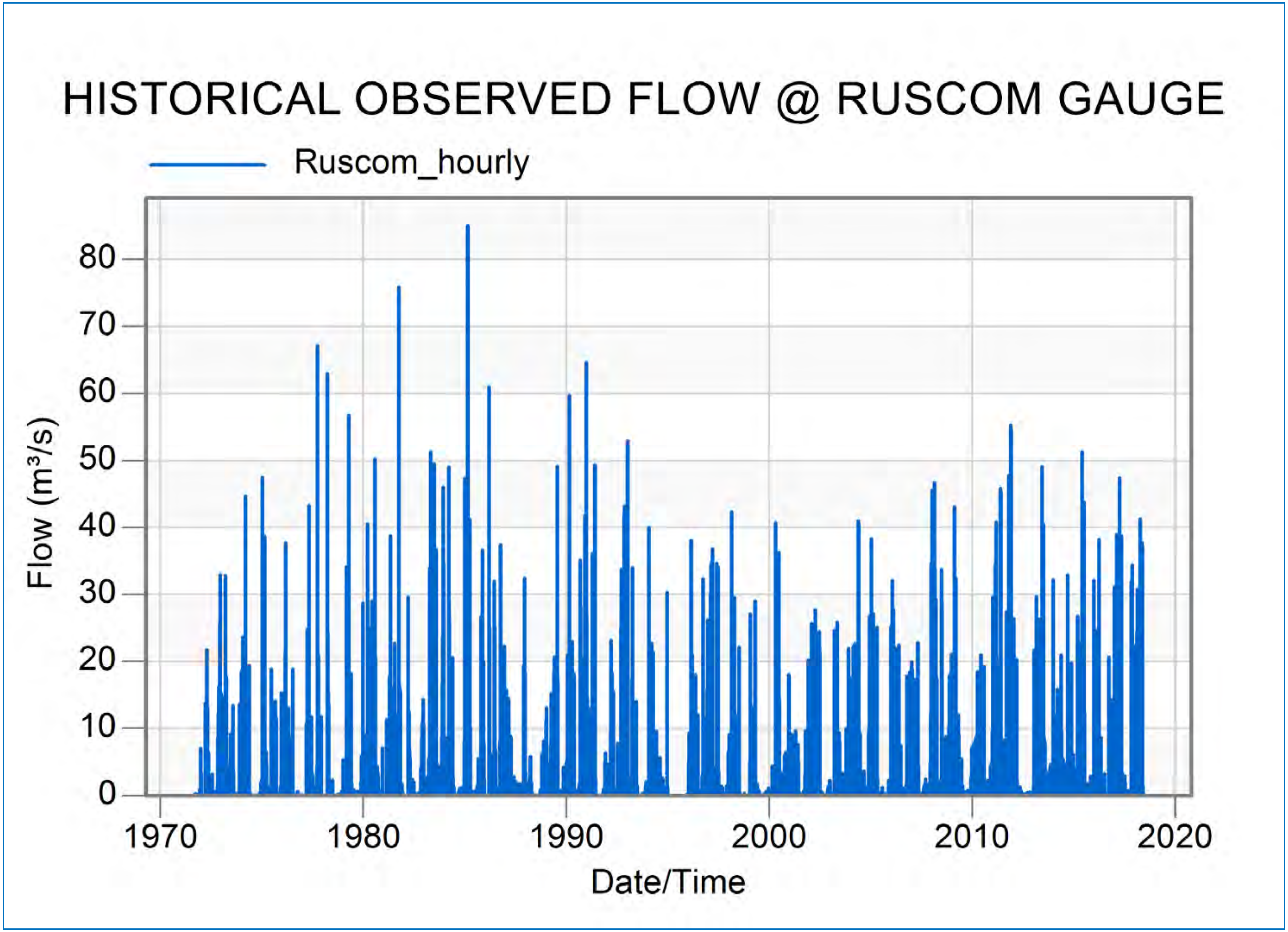


SIMULATED VERSUS MEASURED FLOW @ RUSCOM GAUGE



Variables (section 2.1.4)	
Dp	20
IMD	0.21
IM	0.27
GWF	0.16

	Simulated	Measured	% Deviation
Max. Flow (m3/s) [L/s/ha]	5.1 [0.49]	4.7 [0.45]	8.5%
Total Volume (m3)	410,300	467,500	-12.2%

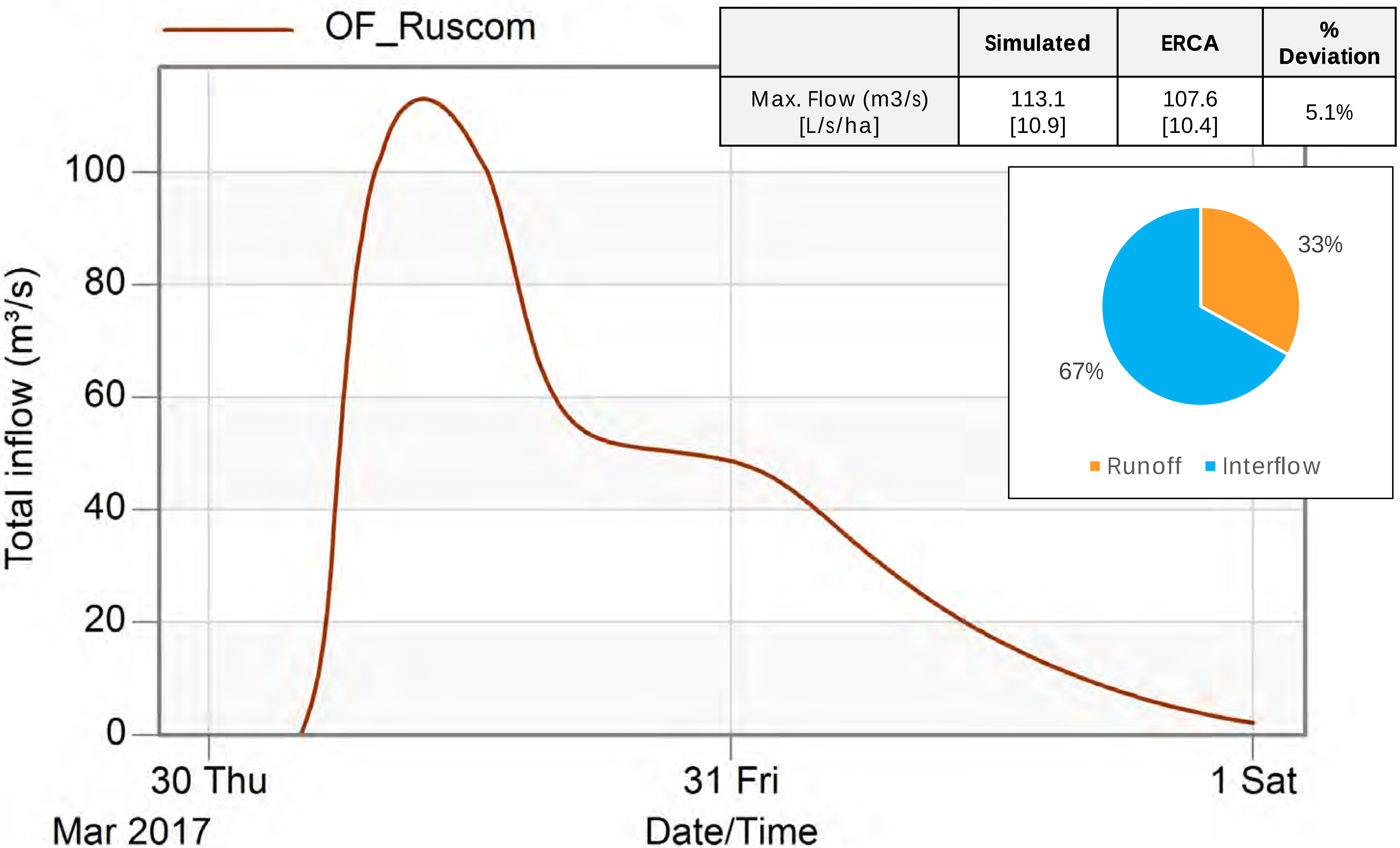


HISTORICAL OBSERVED FLOW @ RUSCOM GAUGE
Ruscom_hourly
Flow (m³/s)
0
10
20
30
40
50
60
70
80
1970
1980
1990
2000
2010
2020
Date/Time

RUSCOM GAUGE MAXIMUM HOURLY FLOW GREATER THAN 2-YEAR (July 1971 to June 2018)

Date	Max. Hourly Flow (m3/s)	Return Period (yrs)	Date	Max. Hourly Flow (m3/s)	Return Period (yrs)
1/10/1975	47.4	2.3	**7/21/1989**	49.1	2.8
9/26/1977	67.1	18.5	**2/23/1990**	59.7	7.2
3/21/1978	62.9	10.3	**12/30/1990**	64.6	13.2
4/14/1979	56.7	6.3	**6/1/1991**	49.3	3.0
7/28/1980	50.2	3.5	**1/5/1993**	52.9	4.9
10/1/1981	75.8	30.3	**10/20/2011**	47.8	2.4
5/2/1983	51.3	4.1	**11/23/2011**	51.7	4.5
6/28/1983	49.5	3.2	**11/30/2011**	55.3	5.5
3/21/1984	49.0	2.5	**6/13/2013**	49.1	2.7
1/1/1985	47.3	2.1	**6/1/2015**	51.3	4.1
2/24/1985	**84.9**	**83.3**	**3/31/2017**	47.4	2.2
3/11/1986	60.9	8.5			

SIMULATED 100 YEAR FLOW @ RUSCOM GAUGE



	Simulated	ERCA	% Deviation
Max. Flow (m3/s) [L/s/ha]	113.1 [10.9]	107.6 [10.4]	5.1%

APPENDIX D

Topographic Datasets

APPENDIX D – TOPOGRAPHIC DATASETS

Three datasets were used to capture various input parameters as described below:

Product	Horizontal Resolution	Vertical Accuracy	Use
OMAFRA Lidar Point Cloud – Lake Erie Basin 2017	8 points/m²	~10 cm (open areas); ~20 cm (vegetated areas)	Culvert and headwall elevations
OMAFRA Lidar Digital Terrain Model – Lake Erie Basin 2017	50 cm	~10 cm (open areas); ~20 cm (vegetated areas)	Drain cross sections; Node elevations
Southwestern Ontario Orthophotography Project 2015 Digital Elevation Model	2 m	~50 cm	Subcatchment slopes

OMAFRA Lidar Point Cloud – Lake Erie Basin 2017

This dataset was used to determine culvert and headwall elevations. This data was acquired by Airborne Imaging Inc. using a Leica ALS70-HP system flown at a height of 1,000 metres between April 7 and 14, 2017 at a density of approximately 8 points per square metre. The vertical accuracy in non-vegetated areas is within 9.0 cm at the 95 % confidence level. In vegetated areas, this rises to 19.8 cm at the 95th percentile. No statement of horizontal accuracy is made by the provider.

OMAFRA Lidar Digital Terrain Model – Lake Erie Basin 2017

This dataset was used to generate drain cross-sections and node elevations. The digital terrain model (DTM) was derived from the Lidar Point Cloud described above at 50 centimetre horizontal resolution, and is intended to represent the ground surface only, excluding structures and vegetation.

Southwestern Ontario Orthophotography Project 2015 Digital Elevation Model

This dataset was used to calculate subcatchment slopes. The digital elevation model (DEM) has a 2 metre horizontal resolution, and was acquired between April 12 and May 23, 2015. The product has a stated accuracy of 50 centimetres both vertically and horizontally, with reduced vertical accuracy where dense vegetation and large structures exist. All three elevation products are unable to penetrate the water surface.

Vertical Coordinate System

The elevation values included in this report are stated using the Canadian Geodetic Vertical Datum of 1928 - 1978 Adjustment (CGVD-1928:1978). The OMAFRA Lidar products described above were provided in a different coordinate system, the Canadian Geodetic Vertical Datum of 2013 (CGVD-2013). These products were converted to CGVD-1928:1978 before inclusion in the model by applying a constant adjustment factor of 0.465 metres, determined by comparing known benchmarks in and near the study area.

Figure D1 – Aerial and Lidar Point Cloud Plan View of Box Culvert

Figure D2 – Lidar Point Cloud Isometric View of Box Culvert

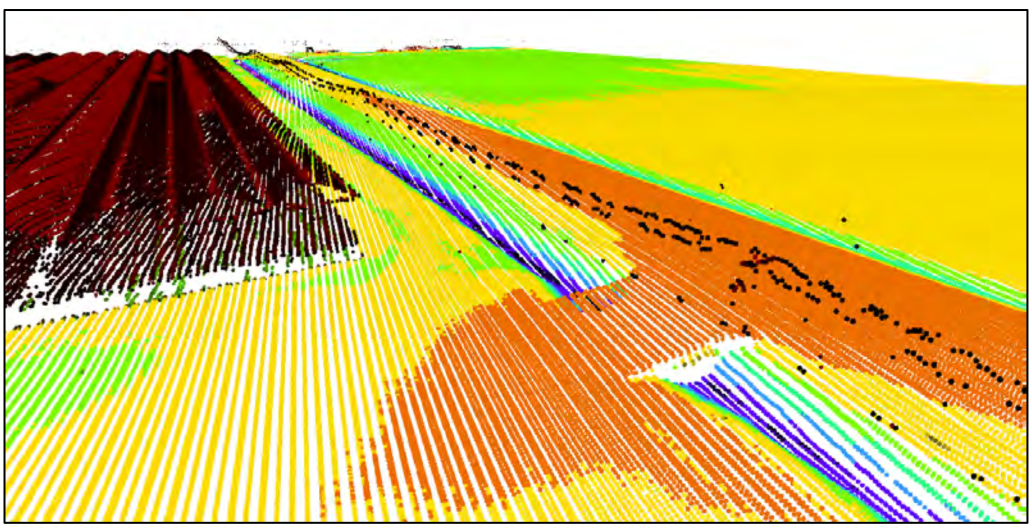
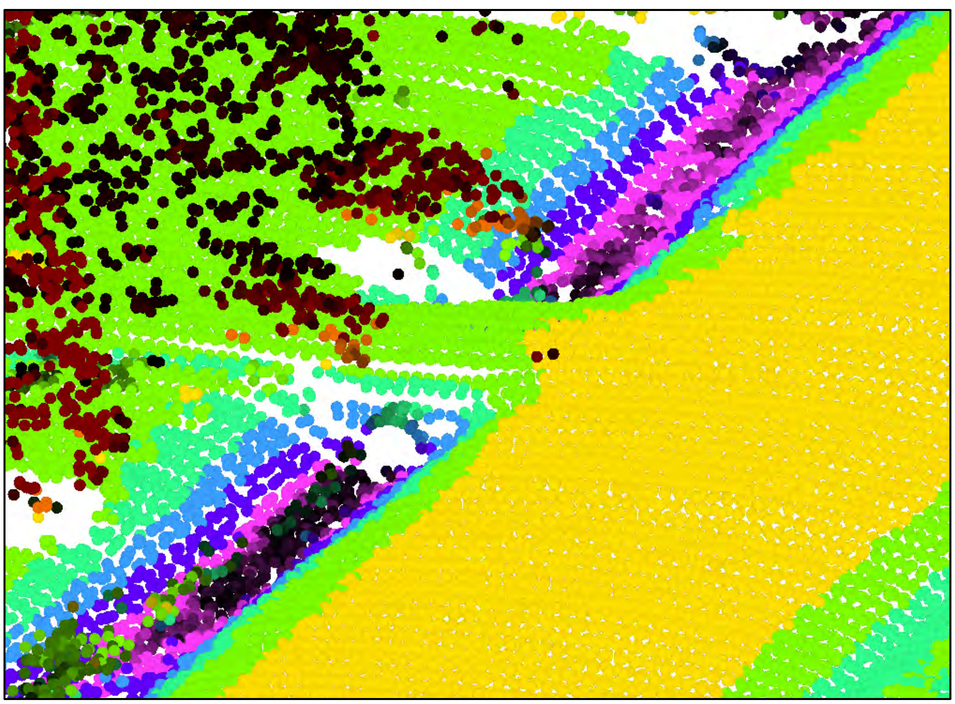


Figure D3 – Aerial and Lidar Point Cloud Plan View of Circular Culvert

Figure D4 – Lidar Point Cloud Isometric View of Circular Culvert



APPENDIX E

Erosion Threshold Assessment

Stantec

Memo

To:	Alain Michaud Windsor, ON Office	From:	Scott Cowan, Jeff Muirhead Waterloo, ON Office
File:	165620134	Date:	June 8, 2018

Reference: **Erosion threshold assessment, Leamington ON**

Increased flows and alterations to sediment supply associated with land use change can exacerbate erosion within receiving watercourses. In turn, this can lead to channel instability, degradation of aquatic habitat, and can create downstream hazards by increasing rates of bank erosion and channel migration (CVC, 2010).

Significant greenhouse development is proposed within the Municipality of Leamington, Ontario. Given the potential impact of this on existing land use and flows, it is recommended that an erosion threshold analysis be incorporated into the Municipality's stormwater master plan. The purpose of this investigation was to determine erosion threshold discharges for the Silver Creek Drain, Reid Drain, and Big Creek Drain located within the Municipality of Leamington. The scope of this erosion threshold analysis involved various desktop and field components, including:

- Review background information including topographic mapping, geologic mapping, and aerial photographs;
- Perform detailed geomorphic site investigations; and
- Perform an erosion threshold analysis.

BACKGROUND REVIEW

The study area is located within the St. Clair Clay Plains physiographic region. This region is characterized by little relief and till plains smoothed by shallow deposits of lacustrine clay (Chapman and Putman, 1984). Bedrock geology maps published by the Ontario Geological Service indicate that the till plains are underlain by light brown, medium grained limestone from the Dundee Formation (Hewitt, 1972). A review of aerial photographs indicated that the surrounding land use is predominately agricultural and most of the study watercourses have been altered or straightened.

DETAILED GEOMORPHIC SITE INVESTIGATION

Detailed geomorphic site assessments were completed at three representative reaches within Silver Creek Drain and Big Creek Drain watersheds, and two representative reaches within the Reid Drain watershed. The locations of the site assessments are illustrated in Figure 1. Site assessments were completed by Stantec on November 21st and November 22nd, 2017, and included the following:

- Qualitative evaluation of watercourse stability;
- Documentation of vegetation characteristics;
- Geomorphic survey using a Real-Time Kinematic (RTK) GPS;
- Geo-referenced site photographs detailing channel, banks, notable erosion, and scour; and
- Characterization of substrate gradation by collecting sediment samples for sieving analyses.

Reference: Erosion threshold assessment, Leamington ON

The locations and results of the detailed geomorphic site assessment are provided in Figure 1 and Table 1, respectively. Site photos are provided in Appendix A.

Figure 1 - Locations of detailed geomorphic site assessments

Reference: Erosion threshold assessment, Leamington ON

Table 1 - Results of geomorphic site assessments (sorted from the most downstream to the most upstream for each watershed)

Location	Bank Vegetation	Substrate	Stability
Silver Creek Drain Watershed			
SC-8	Heavily vegetated with shrubs, grasses, and sparse trees	Slightly loose silty clay loam	Bank slumping and erosion on both banks. Some aggradation on channel bottom. Low flow meandering planform with pools and riffles.
SC-14	Drain recently cleaned out. Grass present on banks. Vegetation on bottom 3rd of bank likely removed when drain cleaned out	Very firm silty clay	Drain recently cleaned out. Trapezoidal drainage feature with no ongoing geomorphic processes. Very stable.
SC-7	Drain recently cleaned out. Grasses and shrubs present on the banks. Vegetation on bottom 3rd of bank likely removed when drain cleaned out	Firm silty clay	Drain recently cleaned out. Trapezoidal drainage feature with no ongoing geomorphic processes. Very stable.
Reid Drain Watershed			
RD-8	Heavily vegetated with shrubs, grasses, and sparse trees	Moderately compact silty clay with a thin armour layer of coarse gravel. Emergent vegetation observed	Localized bank slumping and erosion on both banks.
RD-10	Shrubs, grass	Silty clay	Trapezoidal drainage feature with no ongoing geomorphic processes. Very stable. Some aggradation observed.
Big Creek Drain Watershed			
BC-8	Heavily vegetated with shrubs, grasses, and sparse trees	Fine gravel with sand, and some silt and clay	Basal scour identified on both banks. Fallen trees. vertical banks on outside bends.
BC-10	Grasses and shrubs	Fairly firm Silty clay with some trace coarse gravel	Stable with evidence of low flow sinuosity within the channel.
BC-14	Grasses with shrubs	Fairly firm silty clay with emergent vegetation	Trapezoidal drainage feature with no ongoing geomorphic processes. Very stable.

As seen in Table 1 above, the majority of sites were characterized by cohesive materials (i.e. clay). For these sites at least 85% of the soil samples at these sites were silt and clay. The only site where the channel boundary is not defined by cohesive sediments was BC-8, where the channel boundary is defined by non-cohesive (fine gravel and sand) bed material, specifically 40% gravel and 50% sand.

Based on the results of the site assessments it was determined that reach SC-8, RD-8, and BC-8 demonstrate the highest degree of instability (i.e. limited floodplain access with evidence of bank instability and basal scour) within their respective watersheds. As a result, these reaches are deemed the most geomorphically sensitive to changes in flow or sediment regime within their respective watersheds. Consequently, critical discharges derived for these representative reaches represent conservative estimates of erosion threshold at their respective locations illustrated on Figure 1.

Reference: **Erosion threshold assessment, Leamington ON**

EROSION THRESHOLD ANALYSIS

The purpose of the erosion threshold analysis is to determine the magnitude of discharges required to potentially entrain and transport sediment in the channel. Rather than indicating complete erosion of the channel boundary, the erosion threshold indicates a flow which may initiate motion of the channel materials. Erosion threshold analysis does not address any sediment supply characteristics which are important to consider in evaluating the potential long-term erosion, degradation, and/or aggradation of a watercourse. Erosion threshold targets were developed for the three watersheds and are provided in Table 2 below.

Table 2 - Erosion threshold analysis

	Silver Creek Drain	Reid Drain	Big Creek Drain
Reach	SC-8	RD-8	BC-8
Drainage Area (ha)	2360	937	3432
Water surface slope (%)	0.08	0.09	0.18
Manning's n	0.025	0.025	0.030
Method of Analysis	Chow, 1959	Chow, 1959	Chow, 1959
Critical Particle Size – D_{50} (mm)	Clay	Clay	2.7 mm
Critical Shear Stress (N/m²)	5.75	5.50	5.27
Critical Discharge (m³/s)	4.20	2.99	1.28
Target Critical Discharge (L/s/ha)	1.78	3.19	0.37

The critical discharge needed to entrain the median grain size in SC-8 and RD-8 was estimated at 4.20 and 2.99 m³/s, respectively, which was based on the critical shear stress of 5.75 and 5.50 N/m², respectively. These values were determined using the Chow (1959) method for determining allowable shear stress for cohesive sediments. The critical discharge needed to entrain the median grain size in BC-8 was estimated at 1.28 m³/s which was based on a critical bed shear stress of 5.27 N/m². This was developed using the Chow (1959) method for determining allowable shear stress for non-cohesive sediments.

LIMITATIONS

The estimates of erosion threshold are based on conditions observed at the time of the site investigation, and although they are intended to be conservative, are subject to change upon modification of controlling influences (i.e. sediment supply, hydrological regime, and channel morphology).

Based on site observations, it appears that many of the drains in the study area are maintained. Maintenance activities may include channel widening, bank grading, vegetation clearing, and further entrenchment. These works have the potential to alter channel morphology and conveyance which in turn can impact the presented erosion thresholds.

Additionally, it should be noted that impacts to the sediment supply characteristics in a watershed can impact the potential for aggradation, degradation, and/or erosion within the receiving watercourses. As such, maintaining the existing sediment supply is an important component to preserve the existing dynamic equilibrium.

CONCLUSION

This report presents the findings of the erosion threshold analysis completed for the Silver Creek Drain Watershed, Reid Drain Watershed, and the Big Creek watershed within the Municipality of Leamington. Critical discharges were determined to be 4.20, 2.99, and 1.28 m³/s for the Silver Creek Drain, Reid Drain, and Big Creek Drain watersheds,

Reference: Erosion threshold assessment, Leamington ON

respectively. These values correspond to target critical discharges of 1.78, 3.19, and 0.37 L/s/ha for the Silver Creek Drain, Reid Drain, and Big Creek Drain watersheds.

STANTEC CONSULTING LTD.,

Scott Cowan, P.Geo., CTech.
Fluvial Geomorphologist
Phone: (519) 585-7306
Scott.Cowan@stantec.com

Jeff Muirhead, M.ASc., P.Eng.
Water Resources Engineer
Phone: (519) 585-7309
Jeff.Muirhead@stantec.com

Attachment: Appendix A – Photographic Inventory

c. Lorenzo Brignoli

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Chapman. L.J., Putnam, D.F., (1984). “The Physiography of Southern Ontario”. Ontario Geological Survey, Special Volume 2. Ontario Ministry of Natural Resources, Toronto.

Chow, VT. (1959). “Open Channel Hydraulics”. McGraw Hill, Boston, MA. 680 pp.

Credit Valley Conservation Authority (CVC), (2010). “Fact Sheet II – Instream Erosion and Geomorphological Considerations in Stormwater Management”. Prepared by the Credit Valley Conservation Authority

Hewitt, D.F., (1972). “Paleozoic Geology of Southern Ontario”. Ontario Division of Mines. GR105. Accompanied by Map 2254

APPENDIX A:
PHOTOGRAPHIC INVENTORY

Photo 1: (SC – 8) Silver Creek Drain looking upstream, approximately 200 m North of Essex County Road 8. Some localized bank erosion is visible in the foreground.

Photo 2: (SC – 8) Silver Creek Drain looking downstream, approximately 200 m North of Essex County Road 8.

Photo 3: (SC – 14): Silver Creek Drain looking upstream towards Essex County Road 14 bridge (approximate distance 100 m).

Photo 4: (SC – 14): Silver Creek Drain looking downstream approximately 100 m North of Essex County Road 14.

Photo 1: (SC – 7) Silver Creek Drain looking upstream towards Mersea Road 7 culvert (approximate distance 140 m).

Photo 1: (SC – 7) Silver Creek Drain looking downstream from Mersea Road 7 culvert.

Photo 7: (BC – 8) Big Creek approximately 80 m downstream of Essex County Road crossing (visible in background), looking upstream.

Photo 8: (BC – 8) Big Creek approximately 80 m downstream of Essex County Road crossing, looking downstream.

Photo 9: (BC – 8) Big Creek approximately 80 m downstream of Essex County Road crossing, detail of bed material (for scale: shovel is approximately 250 mm long).

Photo 10: (BC – 10) Big Creek approximately 200 m downstream of Mersea Road 10 culvert crossing, looking upstream.

Photo 11: (BC – 10) Big Creek looking downstream from Mersea Road 10 culvert, notice the low flow sinuous channel that has developed.

Photo 12: (BC – 14) Big Creek (9th Concession road drain) parallel to Essex County Road 14 (on left side of photo), looking downstream. Approximately 1 km East of the intersection with Hwy 77.

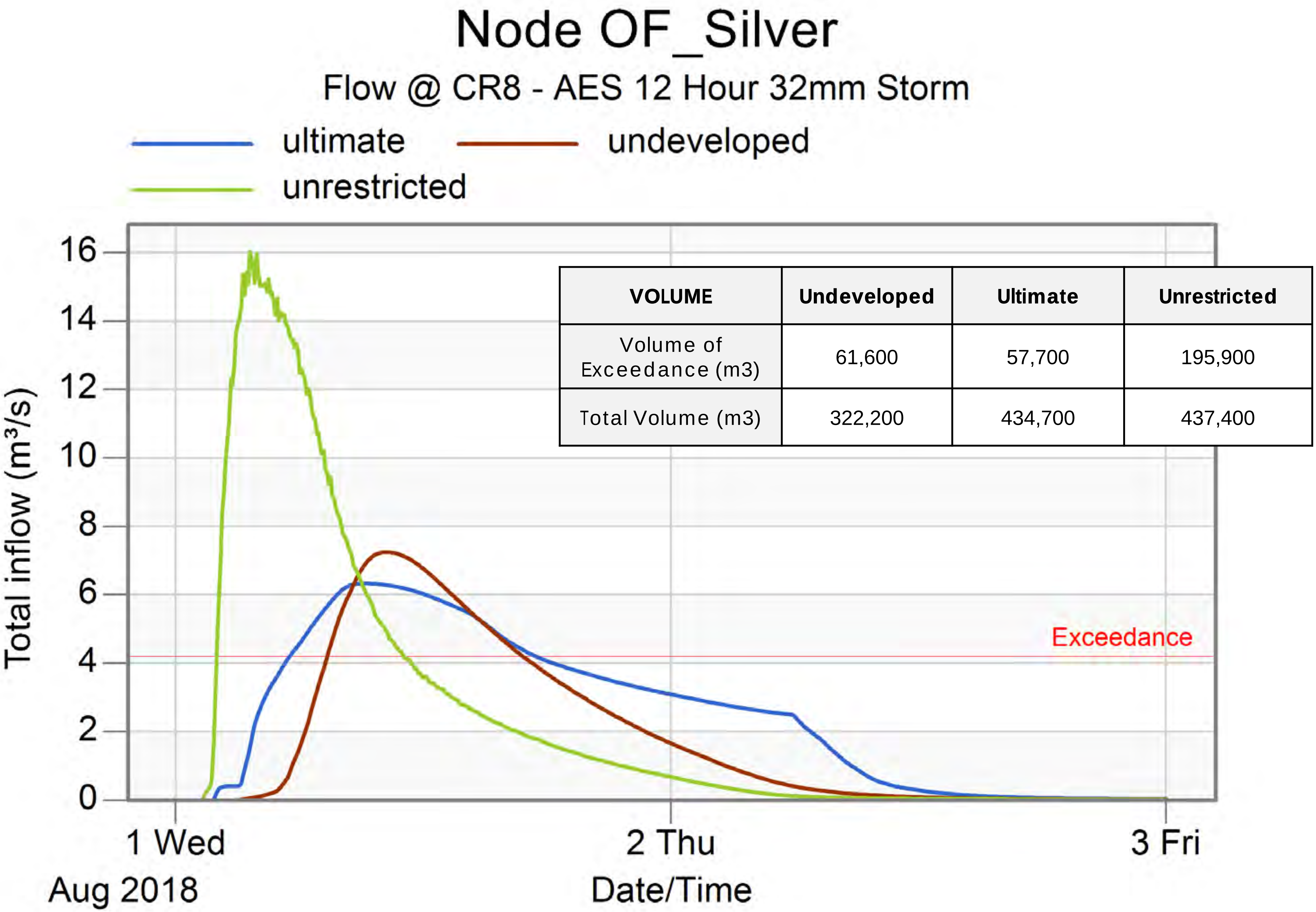
Photo 13: (RD – 8) West Branch of Reid Drain, approximately 100 m downstream of Essex County Road crossing, looking upstream.

Photo 14: (RD – 8) West Branch of Reid Drain, approximately 100 m downstream of Essex County Road crossing, looking downstream.

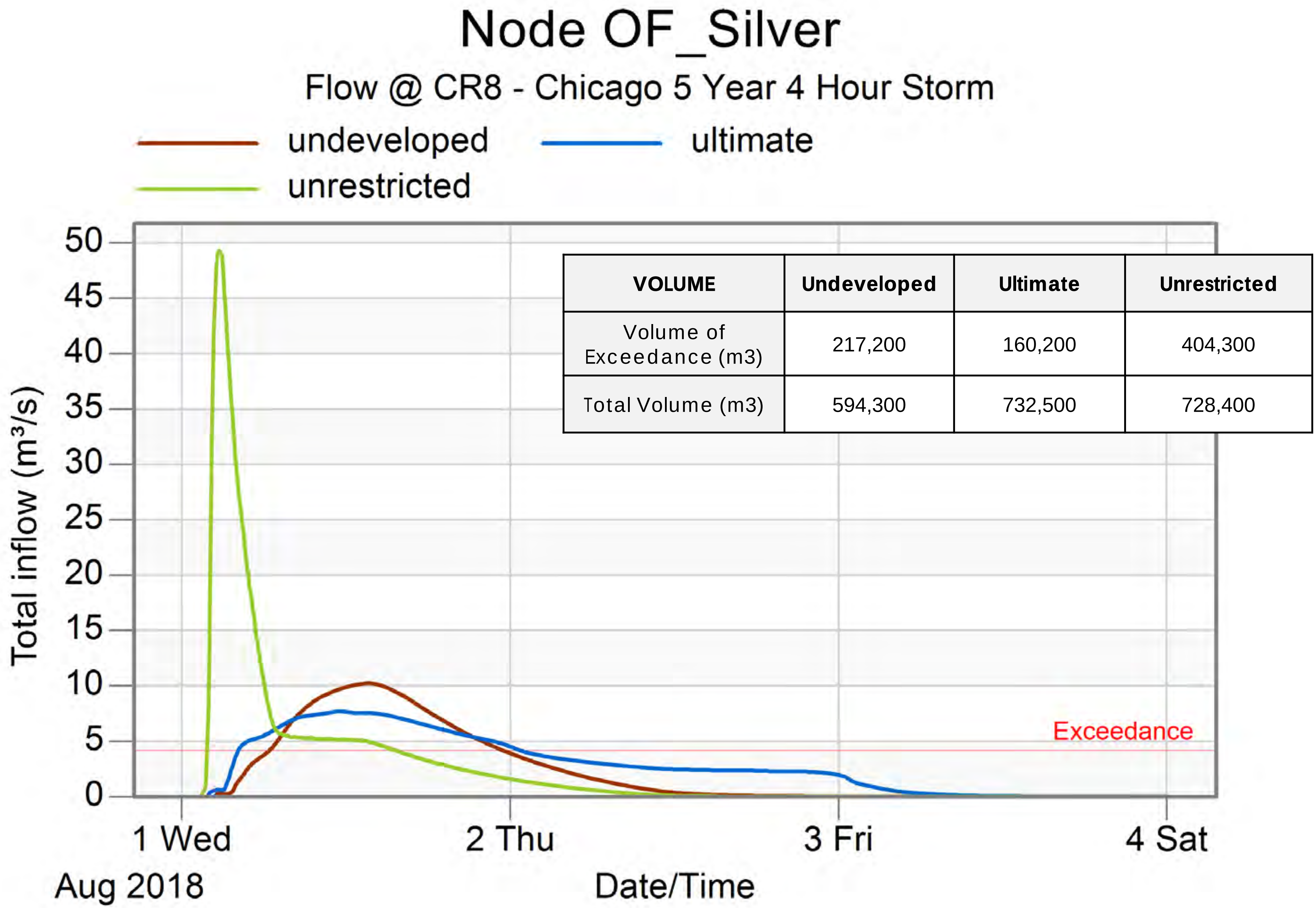
Photo 15: (RD – 10) West Branch of Reid Drain, at the intersection Mersea Road 10/Hwy 77, from left bank (flow is towards the left of the picture, Hwy 77 in background)

APPENDIX F

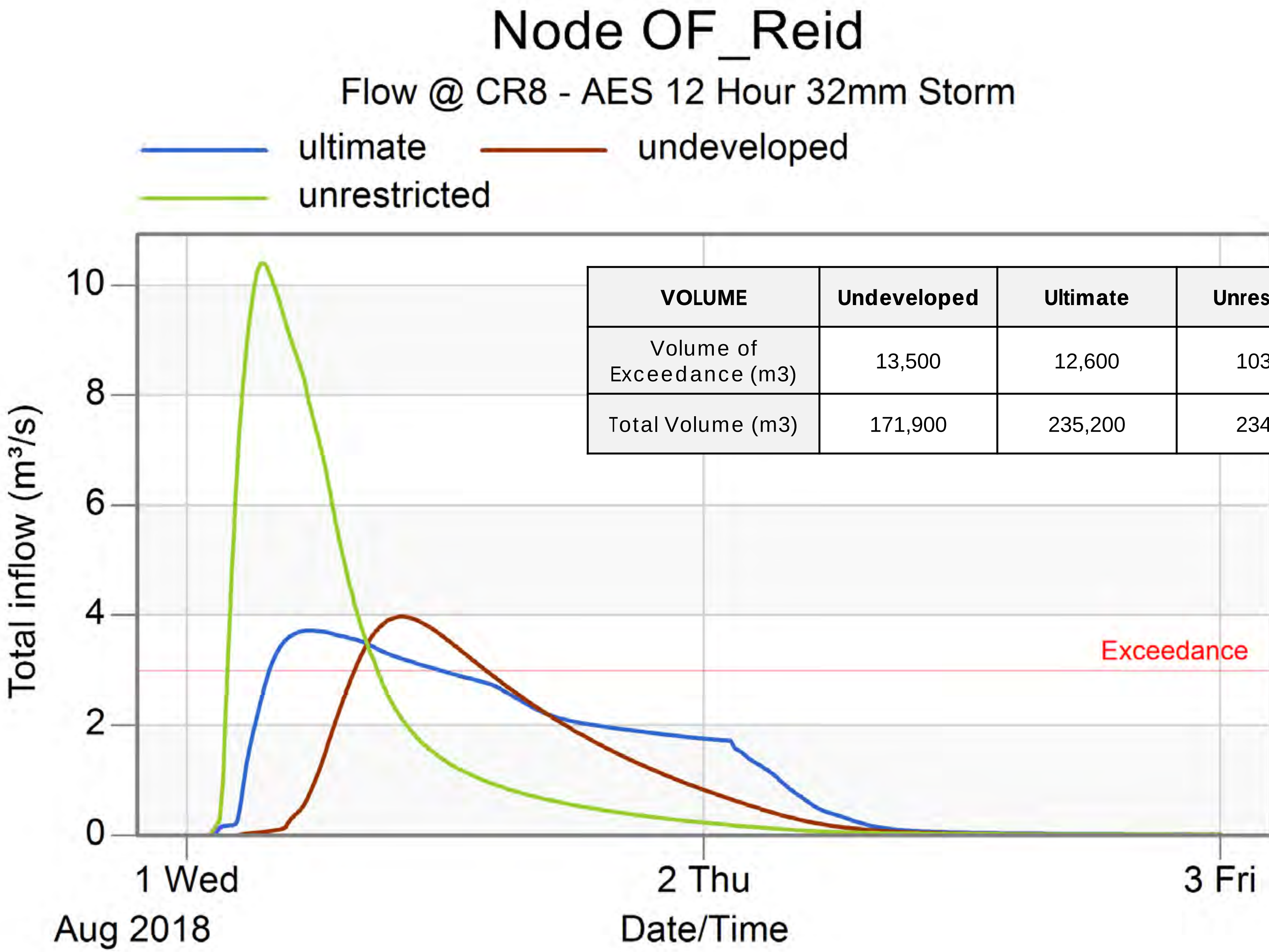
Erosion Threshold Analysis



VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	61,600	57,700	195,900
Total Volume (m3)	322,200	434,700	437,400



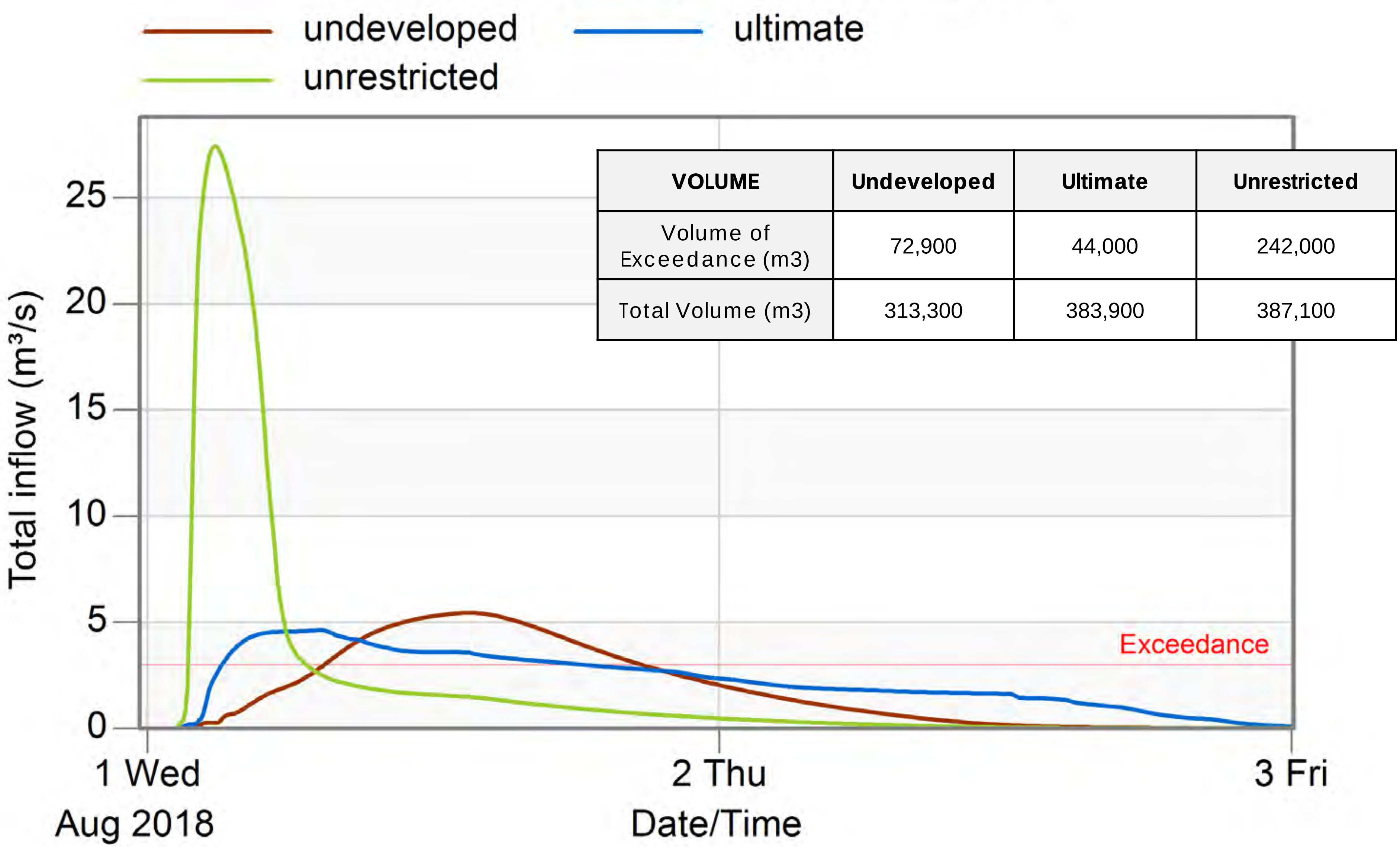
VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	217,200	160,200	404,300
Total Volume (m3)	594,300	732,500	728,400



VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	13,500	12,600	103,900
Total Volume (m3)	171,900	235,200	234,600

Node OF_Reid

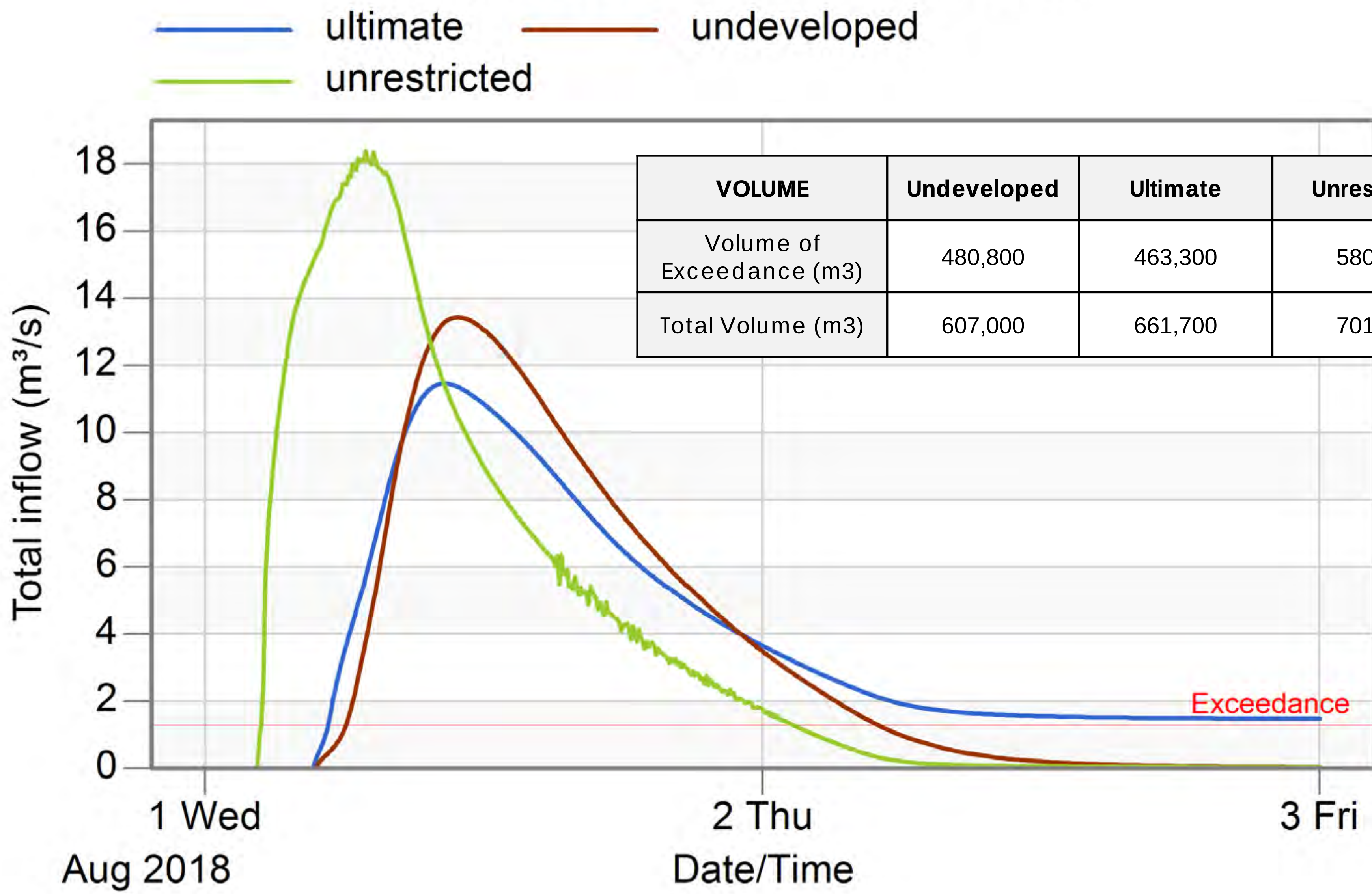
Flow @ CR8 - Chicago 5 Year 4 Hour Storm



VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	72,900	44,000	242,000
Total Volume (m3)	313,300	383,900	387,100

Node OF_Big

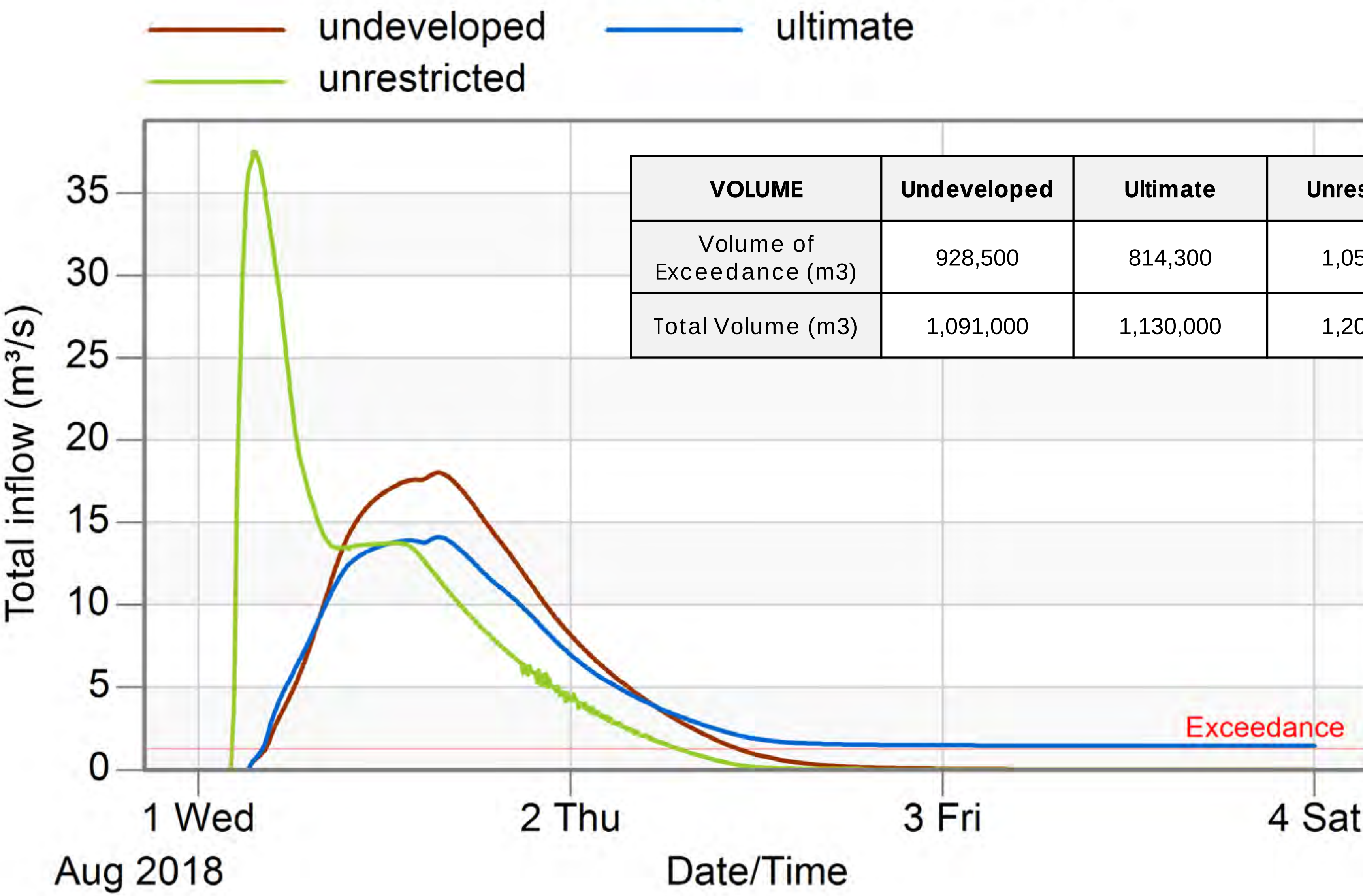
Flow @ CR8 - AES 12 Hour 32mm Storm



VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	480,800	463,300	580,300
Total Volume (m3)	607,000	661,700	701,000

Node OF_Big

Flow @ CR8 - Chicago 5 Year 4 Hour Storm



VOLUME	Undeveloped	Ultimate	Unrestricted
Volume of Exceedance (m3)	928,500	814,300	1,059,000
Total Volume (m3)	1,091,000	1,130,000	1,206,000

Fluvial Geomorphic Guidelines

FACT SHEET II:

INSTREAM EROSION AND GEOMORPHOLOGICAL CONSIDERATIONS IN STORMWATER MANAGEMENT

Increased flows associated with land use change can exacerbate erosion within receiving watercourses. This can lead to channel instability, degraded aquatic habitat, and can create downstream hazards by increasing rates of bank erosion and channel migration. This occurs because the natural rates of erosion, which maintain channel form and function, are exceeded through increases in flows that can do work in the channel, or alternatively changes to the sediment supply. By applying site appropriate stormwater management measures, negative impacts to water quality and aquatic habitat associated with undesirable and potential costly geomorphological change in watercourses can be mitigated. It should be noted that impacts to sediment supply should also be considered in development of a comprehensive stormwater management plan through the protection of natural sediment supplies. Maintenance of potential sediment supplies is a fundamental component in maintaining dynamic equilibrium.

To facilitate these objectives, this fact sheet outlines geomorphological considerations and general methods for addressing instream erosion in the design and implementation of stormwater management plans.

An understanding the potential geomorphological response of a receiving watercourse to changes in flow regime allows the sensitivity of the channels to be assessed. It also allows quantification of their potential to assimilate flows without exacerbating or increasing instream erosion beyond natural rates.

In support of this approach a target flow is usually defined for comparison between pre- and post-development conditions. This target flow is usually defined as an erosion threshold, which is the flow that theoretically can entrain bed or bank sediments within the most sensitive reach (**Figure 5a**). In defined watercourses these flows are based on bed and bank materials and channel geometry. In natural systems creeks regularly see flows that entrain and transport sediment; this is part of the natural process that maintains creek form. Issues arise when changes in the watershed's hydrology results in an increase in the frequency or period of erosive events, or a cumulative increase in the quantity of flow that can entrain and transport sediment (**Figure 5b**)

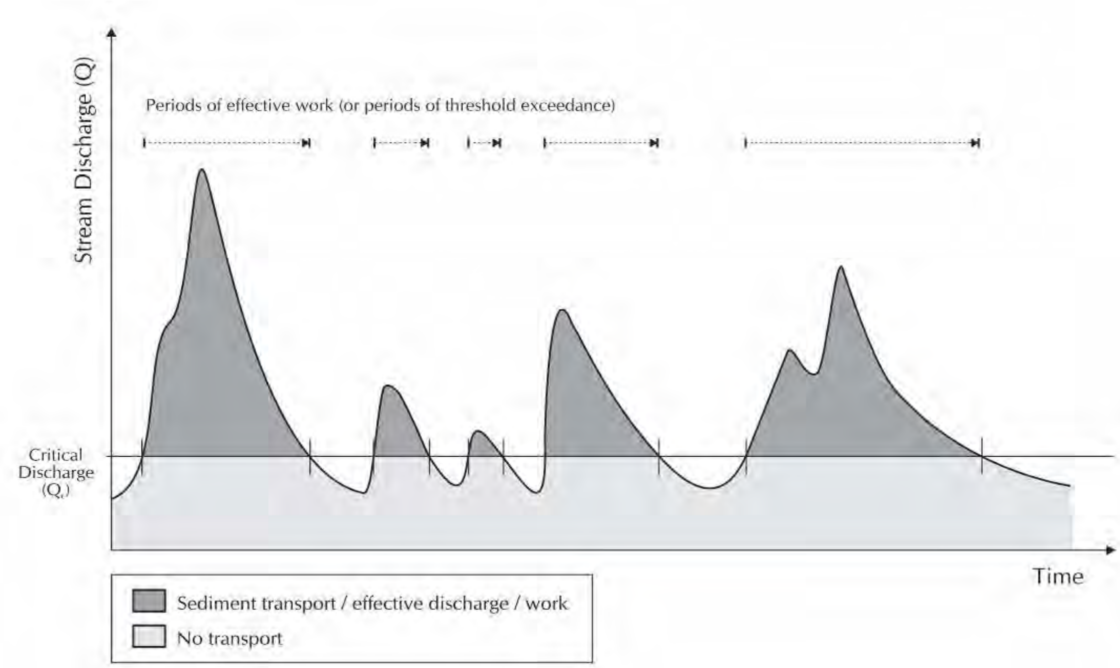


Figure 1 a) Example flood hydrograph showing theoretical potential for sediment transport.

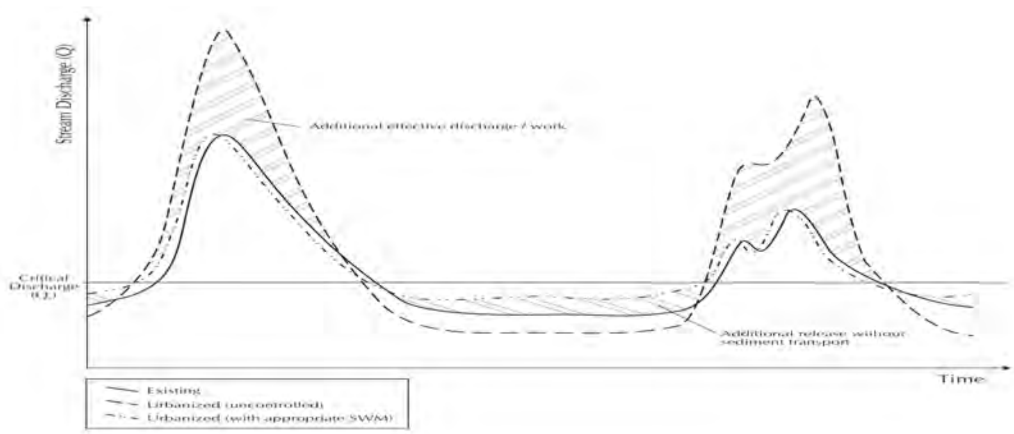


Figure 2 b) Example flood hydrographs showing the potential reduction of effective work with appropriate storm water management (SWM) before and after land use change.

Theoretically an erosion threshold is assessed by first defining reaches (homogenous sections of watercourse) along the network of channels that could potentially be impacted. The most sensitive reaches within the channel network are defined. From these reaches target critical velocities or critical shear stresses for the bed or bank materials can be defined. Based on detailed field work and analysis of these reaches conservative thresholds can be defined. Once the critical shear stress or velocity is known the equivalent discharge can be determined from detailed measurements of the watercourse geometry. These threshold flows can be used to compare exceedance of pre- to post-development flows.

Site appropriate erosion thresholds for sensitive reaches can be assessed through a geomorphological assessment. The geomorphological assessment must be completed by a qualified fluvial geomorphologist, with at minimum their masters degree in fluvial geomorphology and their P.Geo., or equivalent qualification at the discretion of the Conservation Authority. In general, the geomorphological assessment fulfils this requirement by:

- Evaluating channel sensitivity to flow regime change;
- Identifying specific reaches that would be sensitive to changes in hydrology; and
- Provides thresholds from these reaches based on an appropriate detailed assessment to guide stormwater management.

The assessment, at minimum, should consist of:

- Reach delineation based on scientifically defensible methodology (e.g. Montgomery and Buffington, 1997, Richards et al. 1997, Toronto and Region Conservation Authority, 2004);
- Rapid assessment to evaluate stability of reaches based on acceptable rapid assessment protocols (e.g., Index of Stability (Downs, 1995), Rapid Geomorphological Assessment (Ontario Ministry of the Environment, 2003), Rapid Stream Assessment Technique (Galli, 1996), reach-by-reach assessment of sensitivity based on erosion potential, or other suitable methods in discussion with CVC staff (including reach by reach assessment of erosion indices);
- Detailed examination of most sensitive reaches following standard geomorphological protocols for characterization of reaches; and
- Define erosion thresholds based on scientifically defensible models. Numerous models are available; a range of model should be applied to assess model sensitivity and gain a better understanding of the range of erosive conditions. Modeled results should also be compared to actual field observations. The simplest method being spot observations of active or inactivity of entrainment at different velocities, discharges, and/or flow depths. Erosion thresholds will not be accepted without at least a cursory level of field verification.

The geographical extent of the assessment should be decided by identifying a zone of potential impact. This is usually defined as the length of channel downstream of the development to the next major confluence for simple single pond systems. More complicated plans involving multiple ponds, or more than one watercourse may require larger coverage and the provision of a number of thresholds from multiple reaches to properly assess potential impact to the channel network.

The limit of significant downstream impacts is associated with the capacity of the downstream watercourses to assimilate changes in hydrology. The potential capacity can be assessed in several ways. The simplest is an assessment of the relative scales of modified drainage area to receiving water courses drainage area. Another method is assessment of the scale of the receiving watercourse to downstream watercourses based on Horton stream numbering or similar classification. These or other methods should be used to provide a rationale for the study area. Irrelevant of the method applied the potential zone of influence or study should be defined in consultation with CVC staff to assure appropriate coverage.

Reach scale is usually the most useful spatial scale for delineation and classification in erosion studies. Reaches are homogenous sections of channels that have similar physical characteristics or controlling factors. Each reach displays similarity with respect to its physical characteristics such as channel form, function, and valley setting and therefore is likely to have similar response to changes in flow and sediment regimes within these units. Delineation of a reach considers planform, gradient, hydrology, local surficial geology, physiography, and vegetative/land cover control (Montgomery et al., 1997; Richards et al., 1997). Reach delineation should at minimum be based on assessment of current aerial photographs, surficial geology and topographic mapping. Desktop reach delineation should be field verified, with adjustments to desktop assessment, where necessary.

Selection of sensitive reaches is based on identification of reaches with the least capacity to assimilate increases in flow. There are several factors that can affect assimilation including stability, past impacts on channel form, threshold of dominant bed and bank materials, physiography, and size/physical capacity of the reaches channel. Minor receiving tributaries even if stable should be considered for detailed assessment if physical capacity is limited. Where multiple reaches are similarly sensitive along a tributary, multiple detailed assessments and erosion thresholds quantification may be required. At least one reach per receiving tributary should be defined, unless the selected downstream reach is shown to be limiting reach.

Detailed examination of most sensitive reaches should following standard geomorphological protocols for characterization of reaches. Standard protocols and field methods are outlined in Harrelson et al., 1994; Annable, 1996; Vermont Agency of Natural Resources, 2006; United States Environmental Protection Agency, 2004. Detailed geomorphic measurements should include at minimum:

- Bankfull cross-sectional dimensions of each reach using standard protocols and field indicators;
- Sediment size distribution of bed substrate based on a modified Wolman (1959) pebble count; if materials are fine additional field or laboratory grain size analysis may be required;
- In situ shear stress of bank material and bank characteristics (e.g. vegetation cover, bank height and sediment composition). Either or both torvane and penetrometer measurements should be collected to assess mechanical shear strength (note these are not entrainment shear stresses and should never be used as a surrogate);
- Five to ten cross-sections based on the size and complexity of the watercourse should be measured within the study area representing at minimum two complete meanders (these cross-sections should cover the range of typical geomorphic units within the reach);
- Each cross-section should extend beyond bankfull indicators and distance between measurements should be less than 5 percent of the bankfull width;

- Local energy gradients (i.e. current water, bankfull, riffle, and inter-pool) should be collected through a total station survey, the length should be 20-40 times the bankfull width;
- Bankfull gradient is to be measured from surveyed points of the bankfull position at each cross-section based on standard field indicators;
- Field observation of water depths and velocity on the day and indication of entrainment or transport on the day of observations; and
- A photographic record that provides support for documented bed, bank and channel observations.

Traditionally, surficial sediments in non-cohesive beds have been assessed through application of a modified Wolman (1959) pebble count. Although it provides a reproducible and simple methodology to apply it does have limitations that should be recognized and addressed. Reviews of field and statistical methodologies are provided by Bunte and Abt (2001) and Church et al. (1987). Characterization of bulk properties should include assessment of both riffle and pool materials, where substantial fines or cohesive sediments are present, they should be characterized. Given the difficulty of characterizing fine sediments across highly variable channel beds simple approaches to sampling and characterizing fine sediments can be applied, as long as the fine components of the surface and subsurface are recognized and accounted for in defining erosion thresholds.

Erosion thresholds determine the magnitude of flows required to potentially entrain and transport sediment in the channel. An erosion threshold provides a depth, velocity or discharge at which sediment of a particular size class, usually the median or averaged material, may potentially be entrained. This does not necessarily mean systemic erosion (i.e. widening or degradation of the channel); it simply indicates a flow, which may potentially entrain sediment (i.e. initiation of motion of materials). The thresholds should be based on the bulk properties of the substrate and bank materials. Usually it is based on the median grain size for non-cohesive sediments or bulk properties in cohesive sediments. It is recognized that the median grain size may not be the dominant sediment, or provide a good descriptor of the substrate. Any deviation from the use of the median grain size must be agreed upon by the CVC. Critical threshold calculations can be based on critical velocity or critical shear stress.

There are several commonly applied critical shear stress methods (e.g., Miller et al., 1977; Andrews, 1983; Van Rijn, 1984). There are also numerous methods for defining critical velocity (e.g., Komar, 1987), or permissible velocity (e.g., Neill, 1967). Chow (1959), Chang (1988), Fischenich (2001), and Julian (2002) all provide a range of potential graphical, tabular and both empirical and theoretical model approaches. This list is no way definitive and a more appropriate approach from those listed here may be required for a given system. It should also be remembered that all methods have assumptions and ranges of conditions under which they are applicable. It is assumed that the practitioner has an understanding the limitations of the models they are applying. Reasoning for the model selection and analysis approach should be included with reporting.

The critical or apparent critical velocity (if shear stress approaches are applied) and critical depth should be incorporated into at minimum, a typical measured cross-sections to translate these results into a more meaningful representative critical discharge. Typical cross-sections along with the slope and channel roughness for calculation of bankfull and threshold flows should be reported and justified. Comparisons between bankfull and threshold conditions should be provided to document reach sensitivity.

Modeling approaches are applied simply as a surrogate to field measurements of entrainment. Most studies involve several visits to sensitive reaches. Although assessment critical threshold through field observation is cost prohibitive by roughly quantifying the discharge on the days of observation and identifying the presence or absence of entrainment or transport upper and lower limits for modeled threshold results can be defined. It is assumed that the practitioner has the skills to identify entrainment and transport and assess discharge.

Once erosion thresholds are defined they can be used as targets to assess pre- to post-development conditions. In natural systems with defined watercourses erosion thresholds are exceeded regularly. As such, the key to maintaining natural channel function is not to increase the frequency of exceedance or cumulative effective work or force under the post-development condition. In some very sensitive systems, or where impacts have already occurred a level of over-control may be required. In most cases the goal is to match exceedance of the pre- to post-pre-development condition based on some measure of cumulative effective work or force. Pre- to post-exceedance analysis can be assessed from results from continuous modeling, characteristic first flush, synthetic discrete storm events, and/or the Distributive Runoff Control (DRC) approach.

The preferred method for assessing pre- to post-development erosion potential is some form of continuous modeling. Continuous modeling allows pond function with antecedent conditions to be assessed. It also allows the interaction of multiple ponds to be assessed for larger scale developments. With permission from the conservation authority, where potential impact or risk is limited or where stormwater management plans are temporary less stringent modeling may be accepted, such as from synthetic discrete storm events.

Pre- to post-development exceedance can be tested through several criteria. The simplest is cumulative time of exceedance. Although it provides a simple comparison, it does not provide information on the work or erosive force of flows once erosion thresholds are exceeded. As such, it is only a first cut and a more stringent assessment, which includes cumulative effective work, cumulative erosion index, or an appropriate surrogate should always be included in the assessment.

Cumulative Erosion Index (Ontario Ministry of the Environment, 2003):

$$E_i = \sum (V_t - V_c)\Delta t$$

Where	E_i	is the erosion index
	V_t	is velocity in the channel at time t
	V_c	is critical velocity above which entrainment will occur
	Δt	time step

Channel velocity and critical velocity can be replaced with channel shear stress and critical shear stress to provide a similar comparable index.

Cumulative Effective Work Index (Rowney and MacRae, 1992);

$$PWR = \sum (\tau_o - \tau_{thr}) V \Delta t$$

Where PWR is the cumulative stream energy expended above a threshold value

τ_o is the instantaneous shear stress at any boundary station

τ_{thr} is the threshold shear at this boundary station

Δt time step

The cumulative effective work index is similar in nature to a cumulative effective unit stream power. A combination of time of exceedance and more complicated effective work approaches must be applied and provided for review. It is anticipated that post-development exceedance would match pre-development exceedance; unless more stringent over control is required. In areas where erosion thresholds cannot be matched other mitigation measured, beyond simple end of pipe approaches may be required. Where they are deemed necessary these mitigation measures must be developed in consultation with the conservation authority.

It should be noted that the shape of the rising and falling limb of the storm hydrograph can impact entrainment and transport. As such, an example pre-to-post hydrograph should be provided for examination. The graphical representation should be from node within the sensitive reach, for a storm event that exceeds threshold. Where practical, it should be for a series of storm events.

Furthermore, addressing potential erosion issues is only one facet of developing an appropriate stormwater management plan. Addressing erosion does not preclude the need to address or meet other stormwater objectives such as, water quality, quantity control, base flow contribution, or onsite water balance. The first stage of developing a site appropriate stormwater management plan is discussing objectives, targets, and approaches through pre-project consultation with CVC staff.

Checklist

€ Geomorphological assessment that provides information on reach delineation and reach-by-reach sensitivity including:

- Identification of reach breaks;
- Reach-by-reach descriptions including physical conditions, sensitivity measured by an acceptable protocol, and evaluation of systematic adjustments/dominant processes;
- Mapping of zone of influence, reach breaks, pond locations, immediate receiving reaches, and sensitive reaches.

€ Detailed field assessment of the reaches most sensitive to changes in the hydraulic regime including summary of cross-section geometry, long profile (bankfull and bed gradient), bulk properties of substrate and bank materials, and photographic support. Quantification of erosion threshold(s) based on scientific models should include:

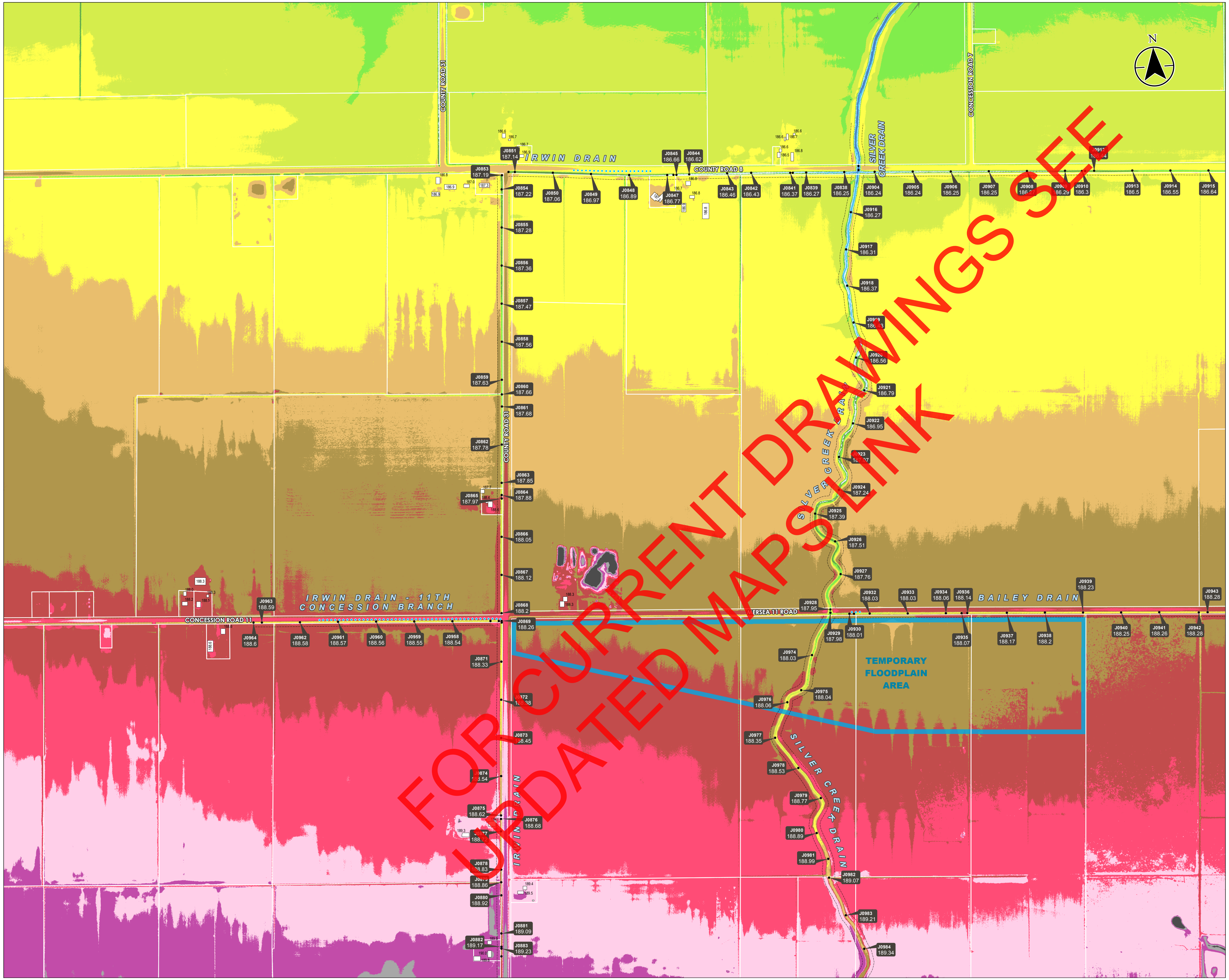
- Bed and bank threshold discharges, velocities, depths and shear stresses;
- Bankfull flow conditions, discharge, velocity, depth and shear stress;
- Ratios between threshold and bankfull, velocity, depth, discharge and shear stress;
- Example cross-sections for both bankfull and critical threshold conditions;

- Field observations including approximate measures of water depth, velocity, and transport conditions; and
- Utilized gradients and roughness estimates for bankfull and threshold condition should also be provided.

€ Assessment of pre- post-development exceedance analysis including:
- Time of exceedance for pre-and-post conditions;
- Cumulative effective shear stress and effective work; and
- An example, extracted, hydrograph for examination.

APPENDIX G

Floodline Mapping



Stantec

Legend

- Node ID / 1:100 Year Regulatory Flood Elevation (m)
- Modeled Node
- Proposed Floodway [4]
- Designated Temporary Floodplain Area

Ponding Above Road

- 0 - 30 cm at Pavement Edge
- > 30 cm at Pavement Edge
- Existing Building and Approximate Existing Grade Elevation (m)
- Buildout Area

Existing Ground Elevation (m)

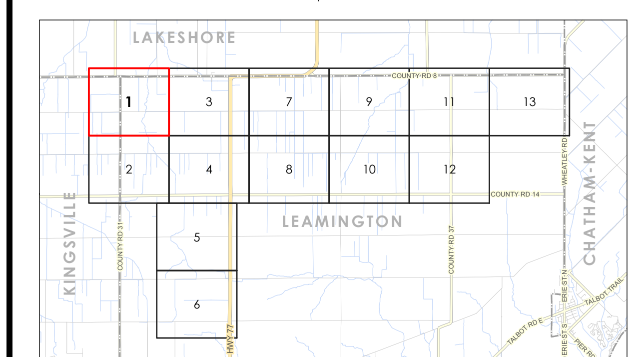
- ≥ 190.51
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- 185.01 - 185.50
- 184.51 - 185.00
- 184.01 - 184.50
- 183.51 - 184.00
- ≤ 183.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

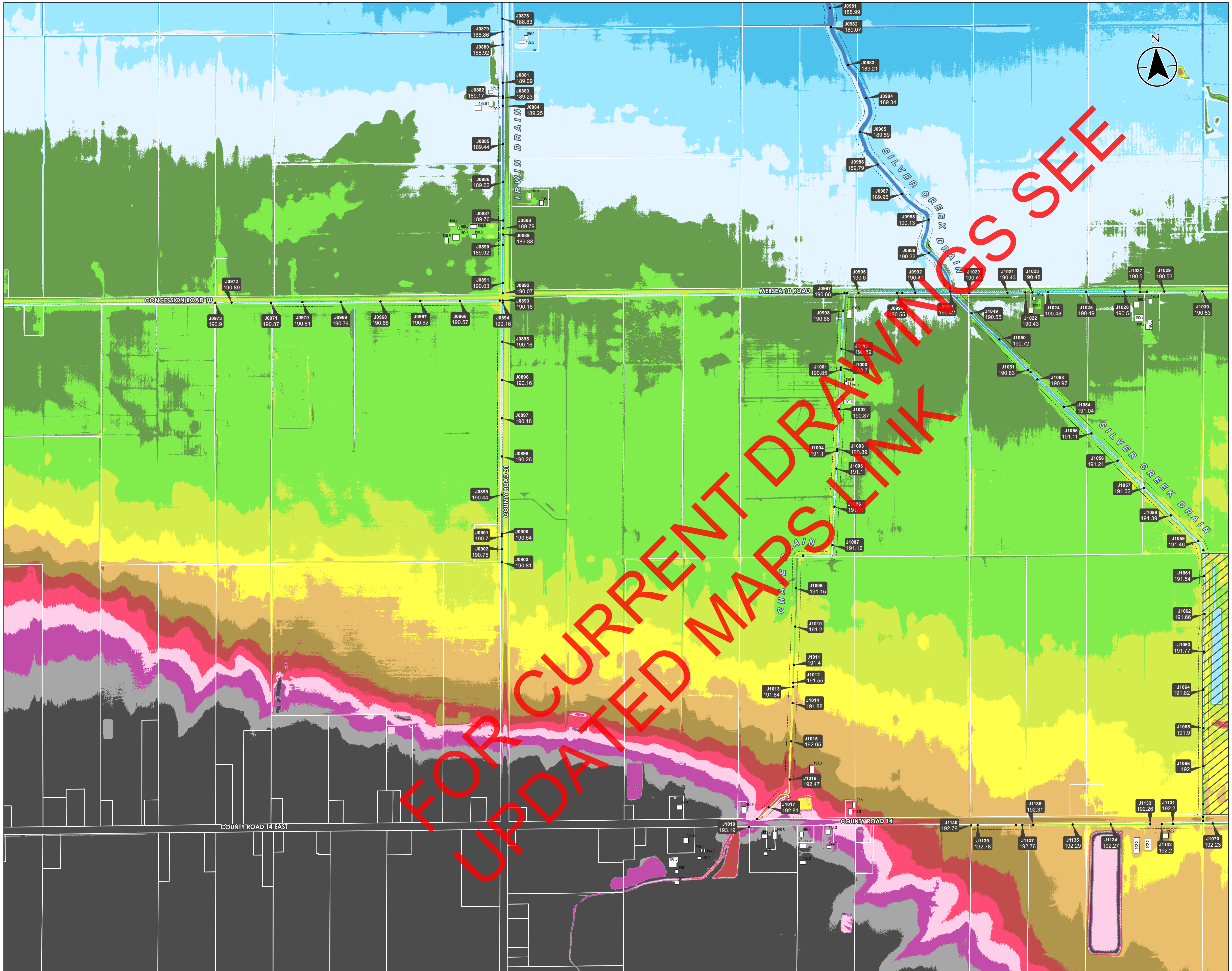
Figure No.

1

Title

Projected Flood Elevations 1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_1.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)
Modeled Node
Proposed Floodway [4]
Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge
> 30 cm at Pavement Edge
Existing Building and Approximate Existing Grade Elevation (m)
Buildout Area

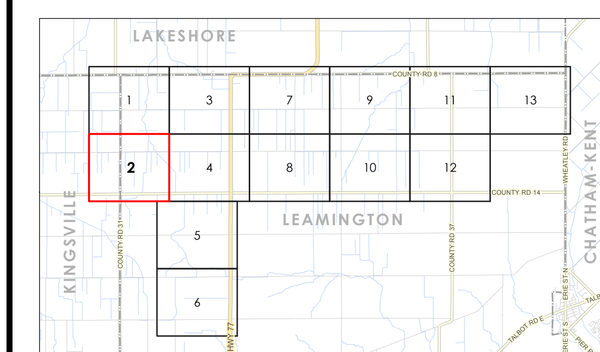
Existing Ground Elevation (m)

≥ 195.51
195.01 - 195.50
194.51 - 195.00
194.01 - 194.50
193.51 - 194.00
193.01 - 193.50
192.51 - 193.00
192.01 - 192.50
191.51 - 192.00
191.01 - 191.50
190.51 - 191.00
190.01 - 190.50
189.51 - 190.00
189.01 - 189.50
188.51 - 189.00
≤ 188.50

0 200 400 metres
1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 millimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location
Municipality of Leamington

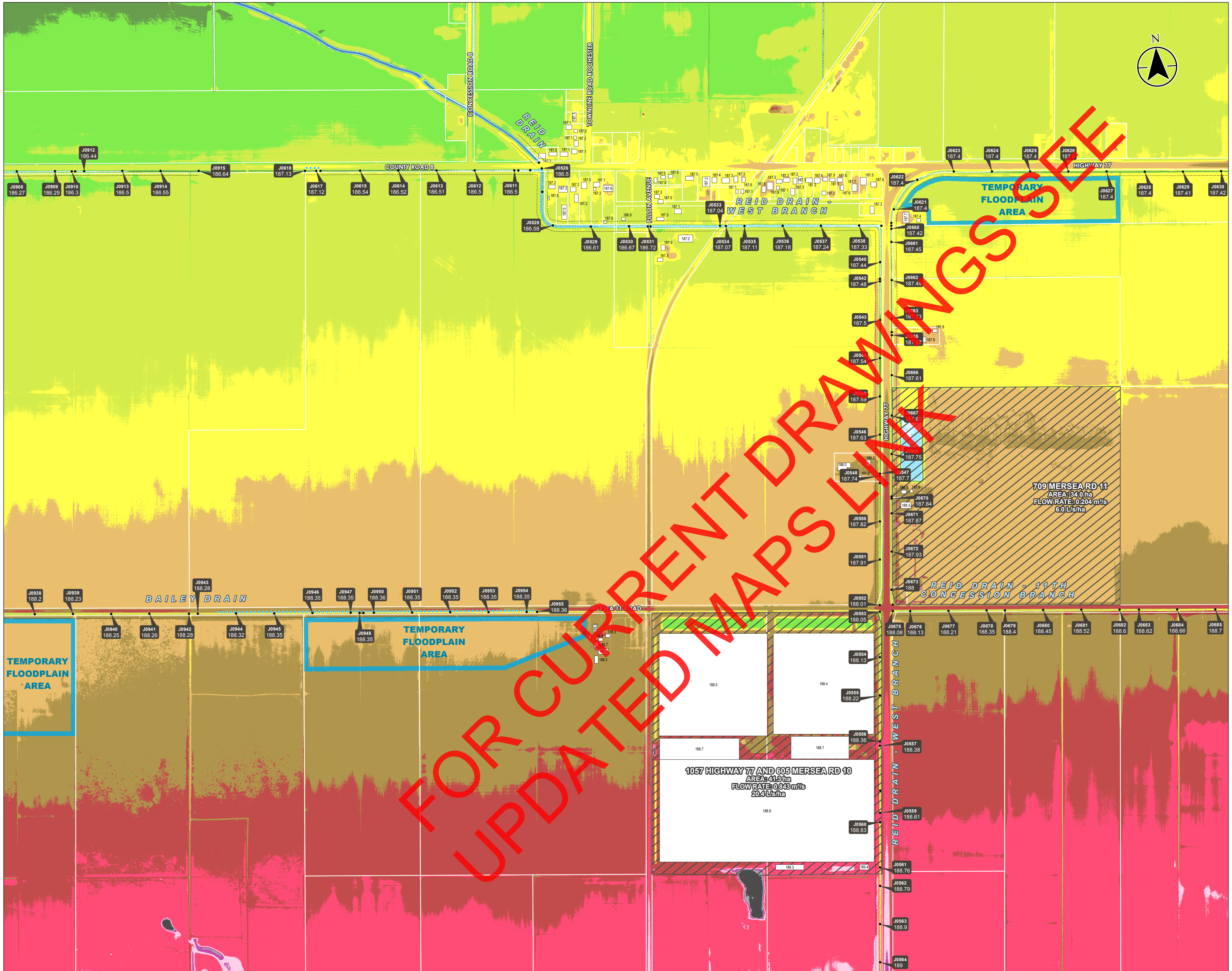
165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project
MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

Figure No.
2

Title
Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_2.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)
Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

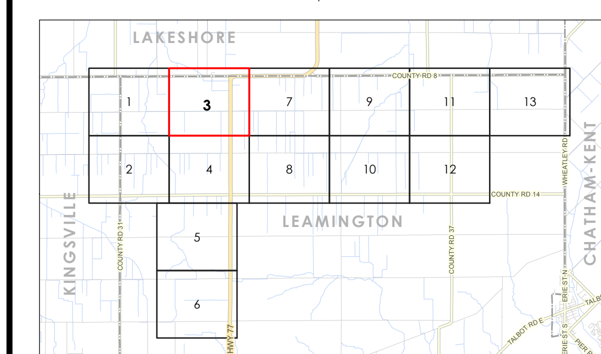
- ≥ 191.01
- 190.51 - 191.00
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- 185.01 - 185.50
- 184.51 - 185.00
- 184.01 - 184.50
- ≤ 184.00

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

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STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

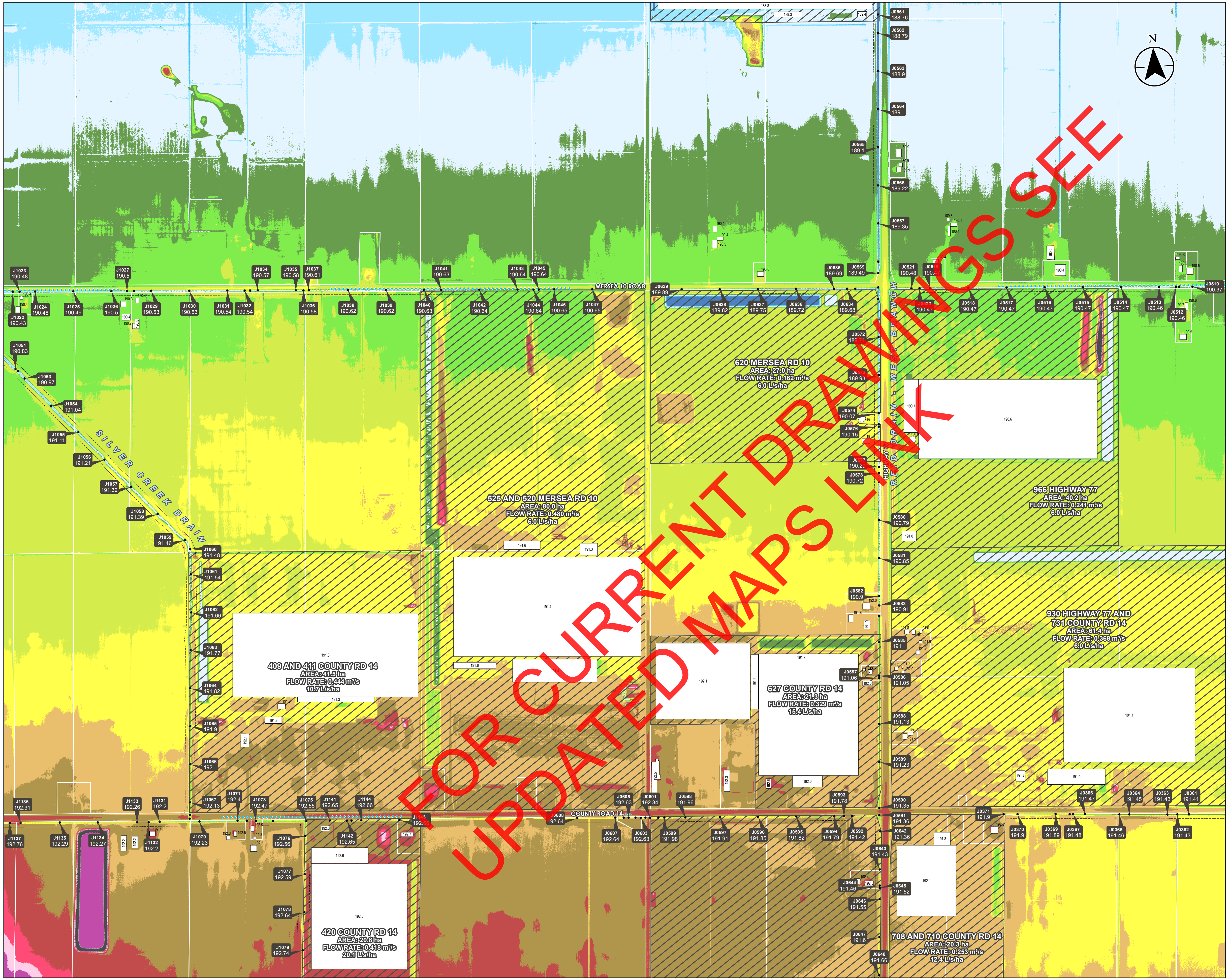
Figure No.

3

Title

Projected Flood Elevations
1:100 Year Event

V:\1656\active\165620134\floodline\MXD\165620134_BandedElevation_3.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m) [3]
Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

- ≥ 195.01
- 194.51 - 195.00
- 194.01 - 194.50
- 193.51 - 194.00
- 193.01 - 193.50
- 192.51 - 193.00
- 192.01 - 192.50
- 191.51 - 192.00
- 191.01 - 191.50
- 190.51 - 191.00
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- ≤ 188.00

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
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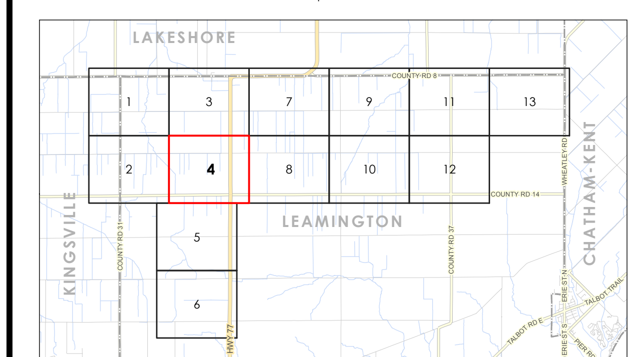


Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

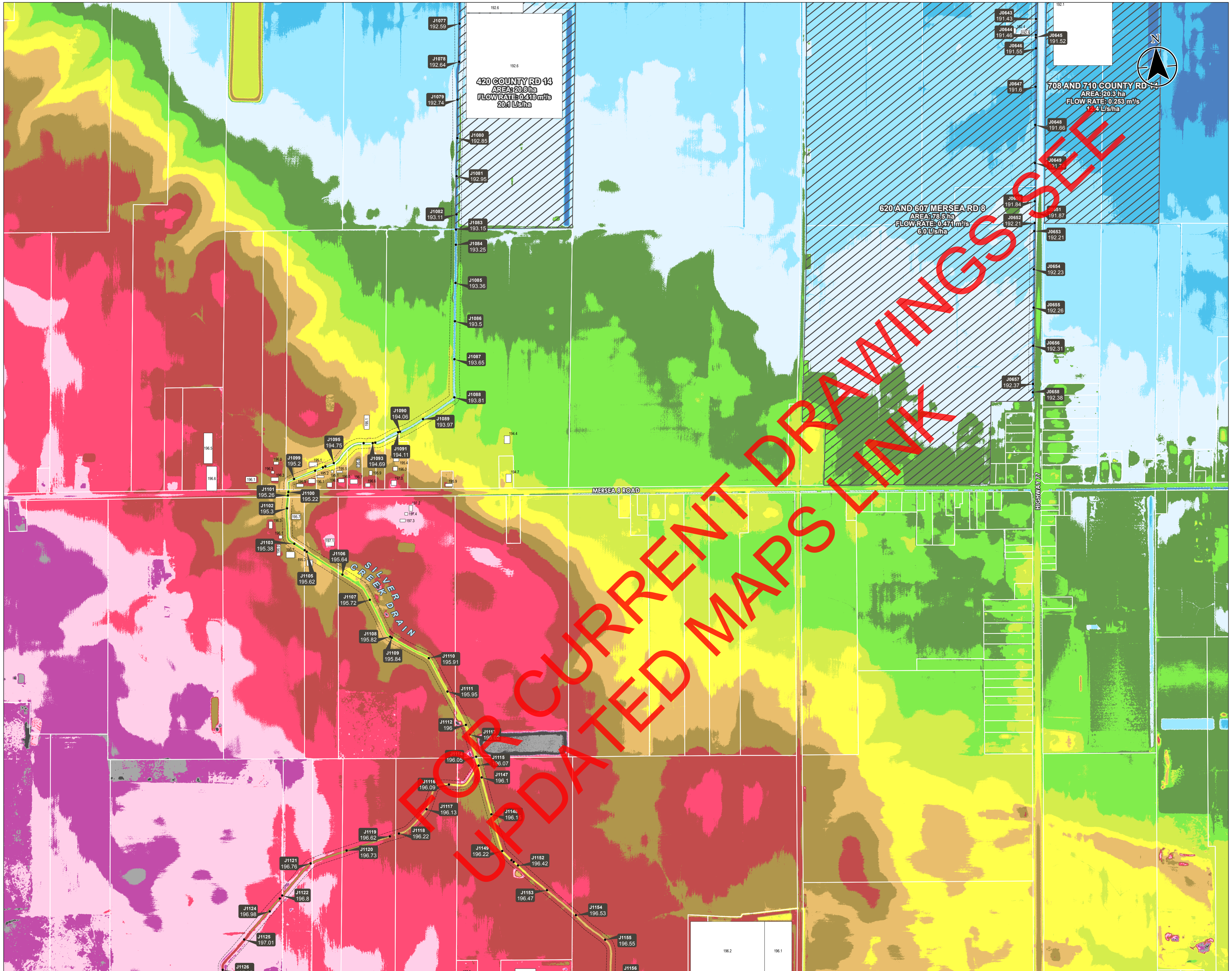
Figure No.

4

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_4.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

- Node ID / 1:100 Year Regulatory Flood Elevation (m)
- Modeled Node
- Proposed Floodway [4]
- Designated Temporary Floodplain Area

Ponding Above Road

- 0 - 30 cm at Pavement Edge
- > 30 cm at Pavement Edge
- Existing Building and Approximate Existing Grade Elevation (m)
- Buildout Area

Existing Ground Elevation (m)

- ≥ 198.51
- 198.01 - 198.50
- 197.51 - 198.00
- 197.01 - 197.50
- 196.51 - 197.00
- 196.01 - 196.50
- 195.51 - 196.00
- 195.01 - 195.50
- 194.51 - 195.00
- 194.01 - 194.50
- 193.51 - 194.00
- 193.01 - 193.50
- 192.51 - 193.00
- 192.01 - 192.50
- 191.51 - 192.00
- ≤ 191.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 millimetres, distributed using Probable Maximum Precipitation distribution.
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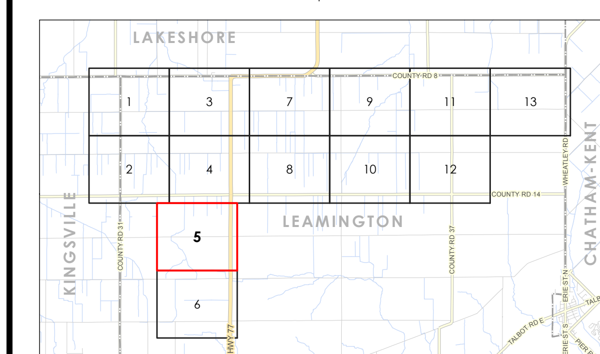

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Technical Review by AM on 2019-05-21

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STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

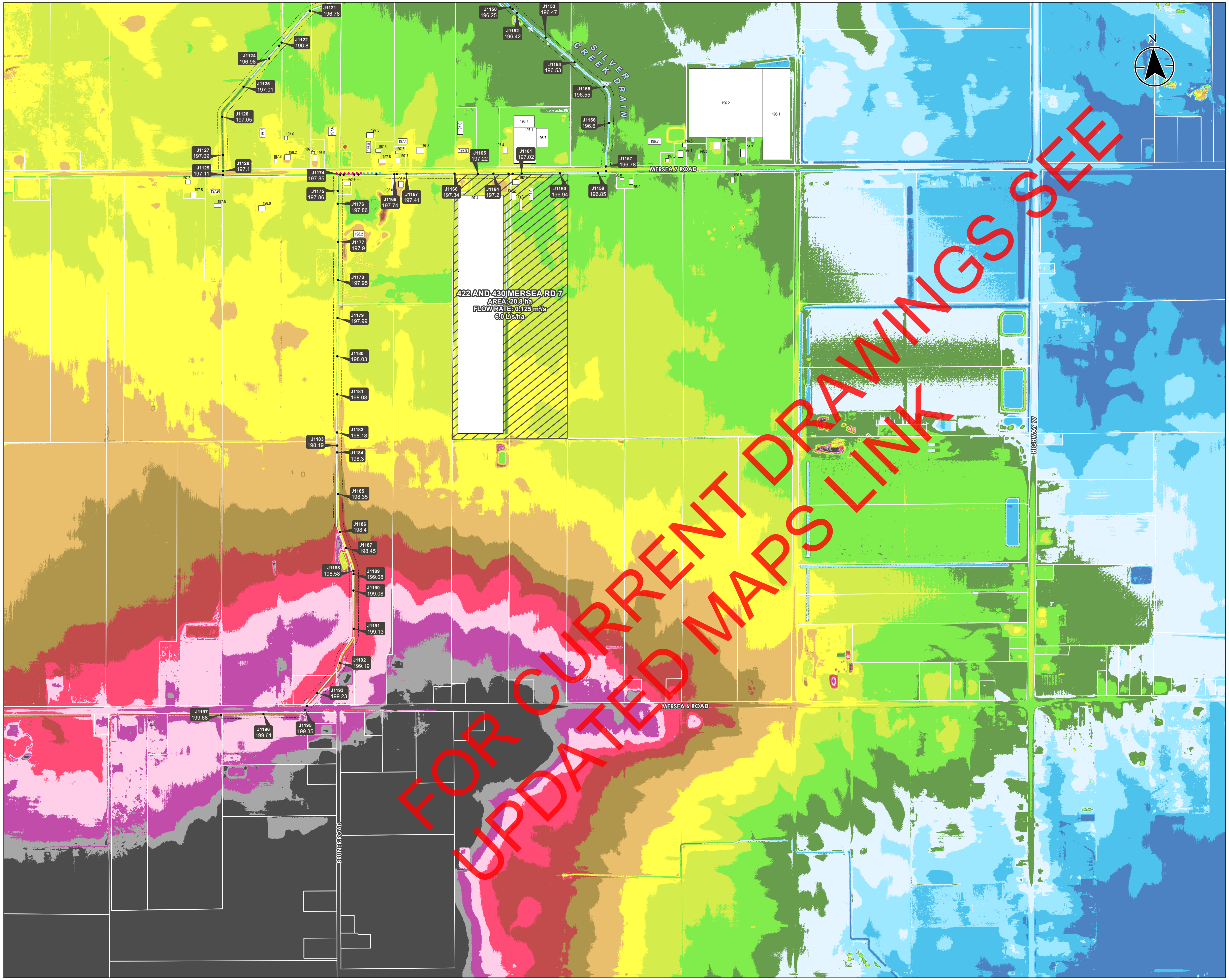
Figure No.

5

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_5.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m) [3]
Modeled Node
Proposed Floodway [4]
Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge
> 30 cm at Pavement Edge
Existing Building and Approximate Existing Grade Elevation (m)
Buildout Area

<VALUE>

- ≥ 201.51
- 201.01 - 201.50
- 200.51 - 201.00
- 200.01 - 200.50
- 199.51 - 200.00
- 199.01 - 199.50
- 198.51 - 199.00
- 198.01 - 198.50
- 197.51 - 198.00
- 197.01 - 197.50
- 196.51 - 197.00
- 196.01 - 196.50
- 195.51 - 196.00
- 195.01 - 195.50
- 194.51 - 195.00
- ≤ 194.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
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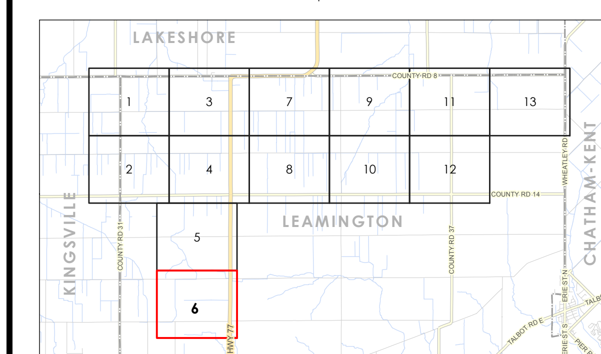


Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

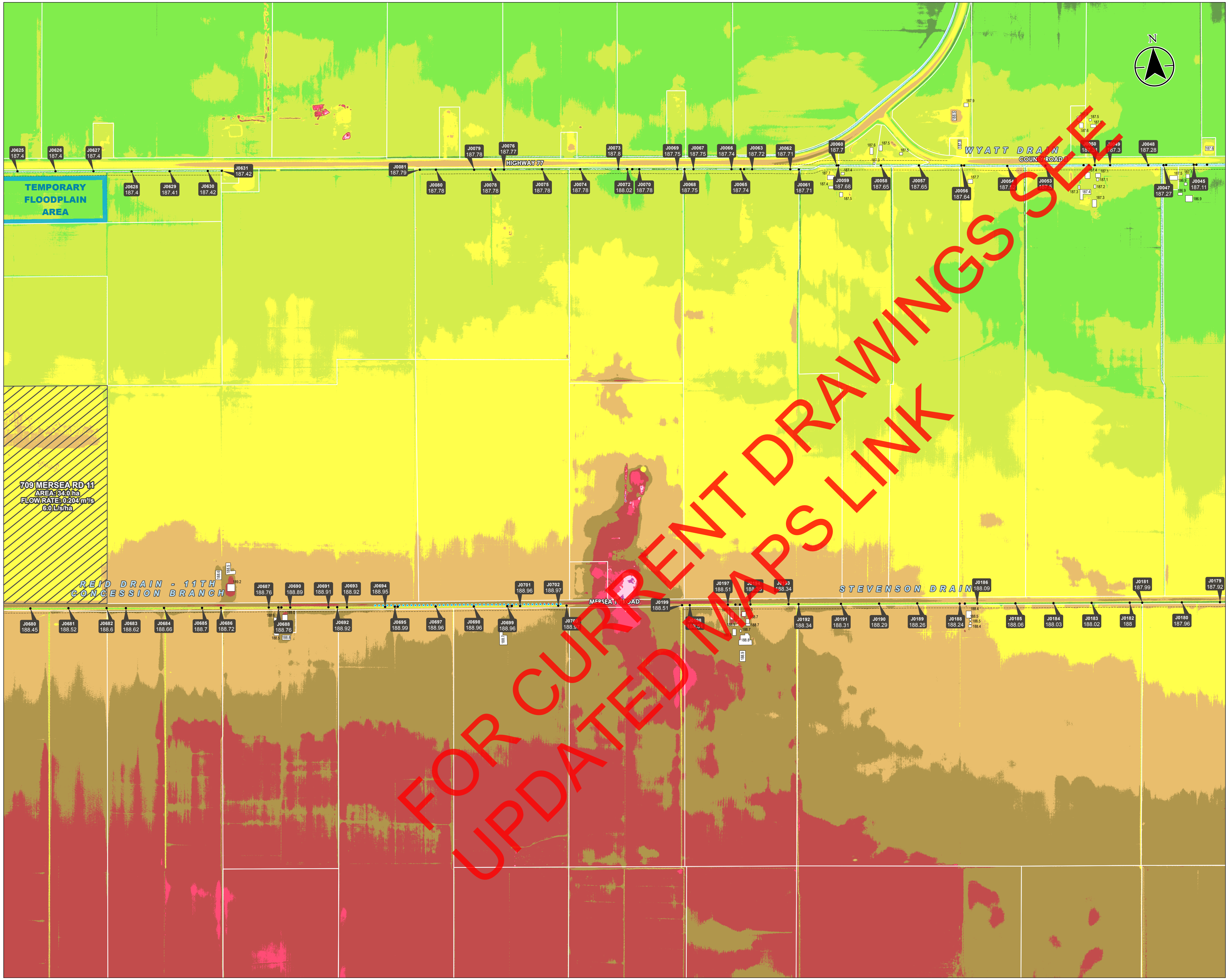
Figure No.

6

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_6.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)

Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

191.51 - 192.00
191.01 - 191.50
190.51 - 191.00
190.01 - 190.50
189.51 - 190.00
189.01 - 189.50
188.51 - 189.00
188.01 - 188.50
187.51 - 188.00
187.01 - 187.50
186.51 - 187.00
186.01 - 186.50
185.51 - 186.00
185.01 - 185.50
184.51 - 185.00

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
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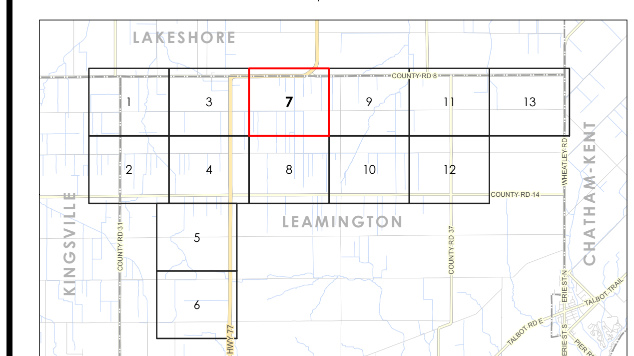


Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

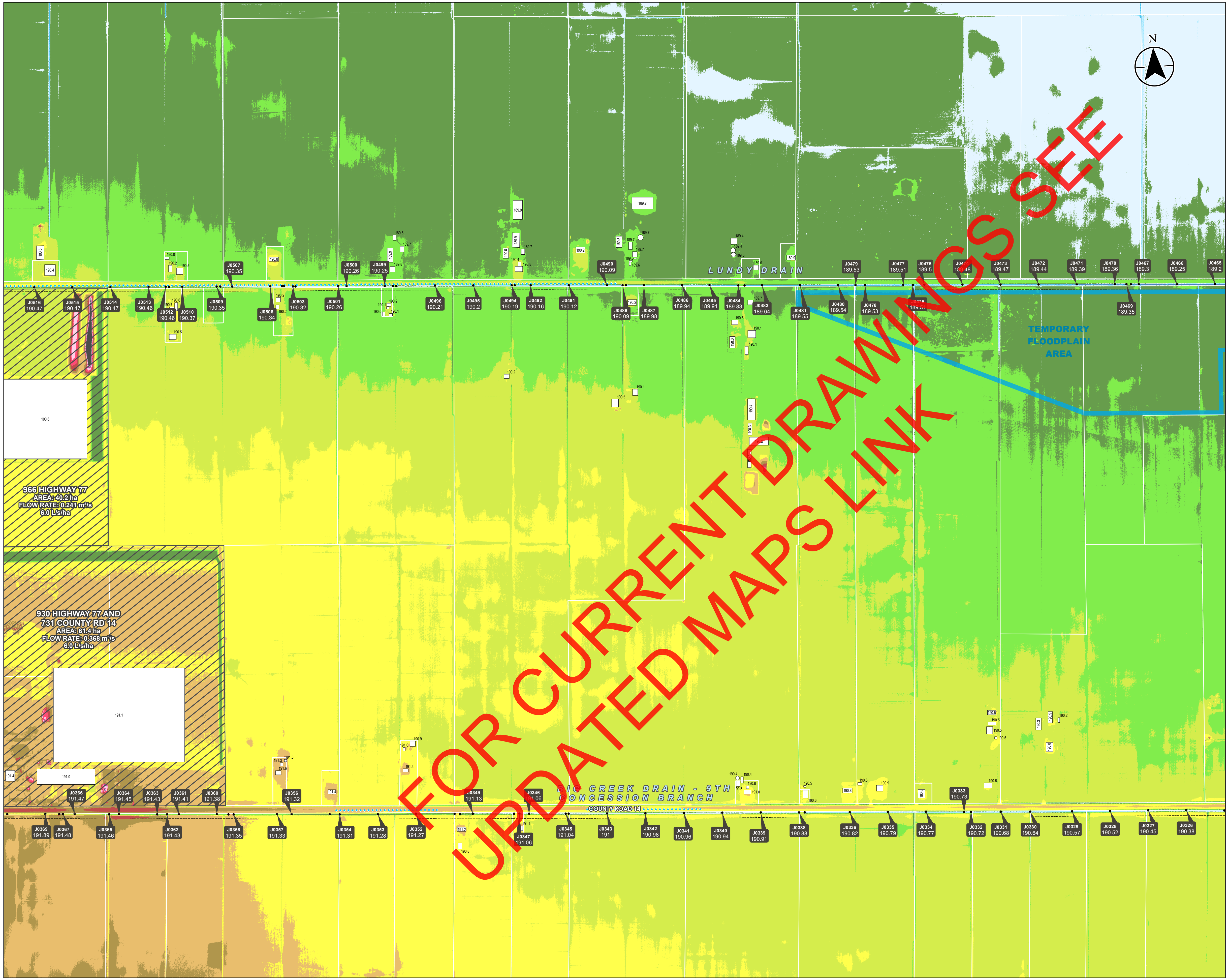
MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

Figure No.

7

Title

Projected Flood Elevations
1:100 Year Event



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)

Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

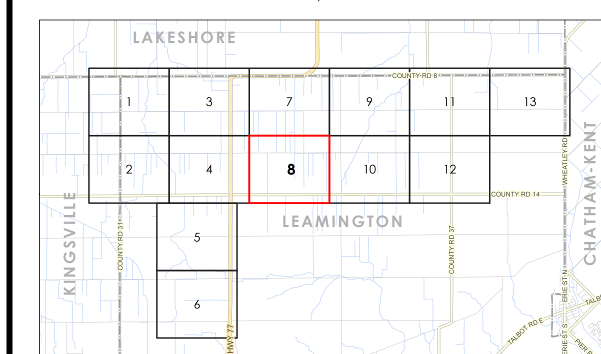
- ≥ 194.51
- 194.01 - 194.50
- 193.51 - 194.00
- 193.01 - 193.50
- 192.51 - 193.00
- 192.01 - 192.50
- 191.51 - 192.00
- 191.01 - 191.50
- 190.51 - 191.00
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- ≤ 187.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location

Municipality of Leamington

165620134 REVB

Prepared by KDB on 2019-05-22

Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON

STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

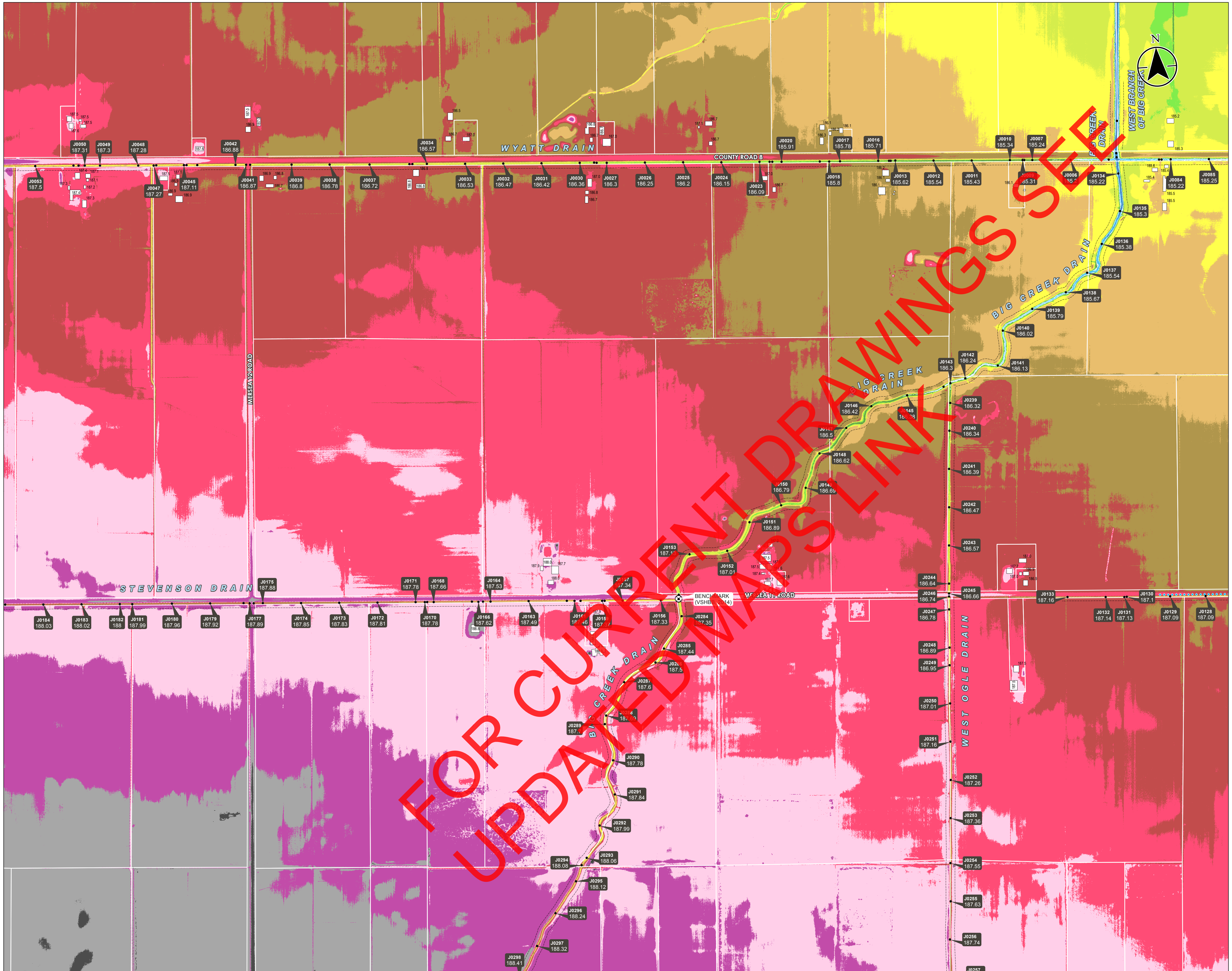
Figure No.

8

Title

Projected Flood Elevations 1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_8.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m) [3]

Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

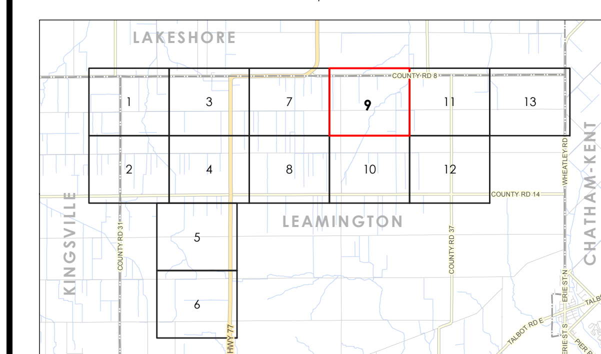
- ≥ 189.01
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- 185.01 - 185.50
- 184.51 - 185.00
- 184.01 - 184.50
- 183.51 - 184.00
- 183.01 - 183.50
- 182.51 - 183.00
- 182.01 - 182.50
- ≤ 182.00

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location

Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

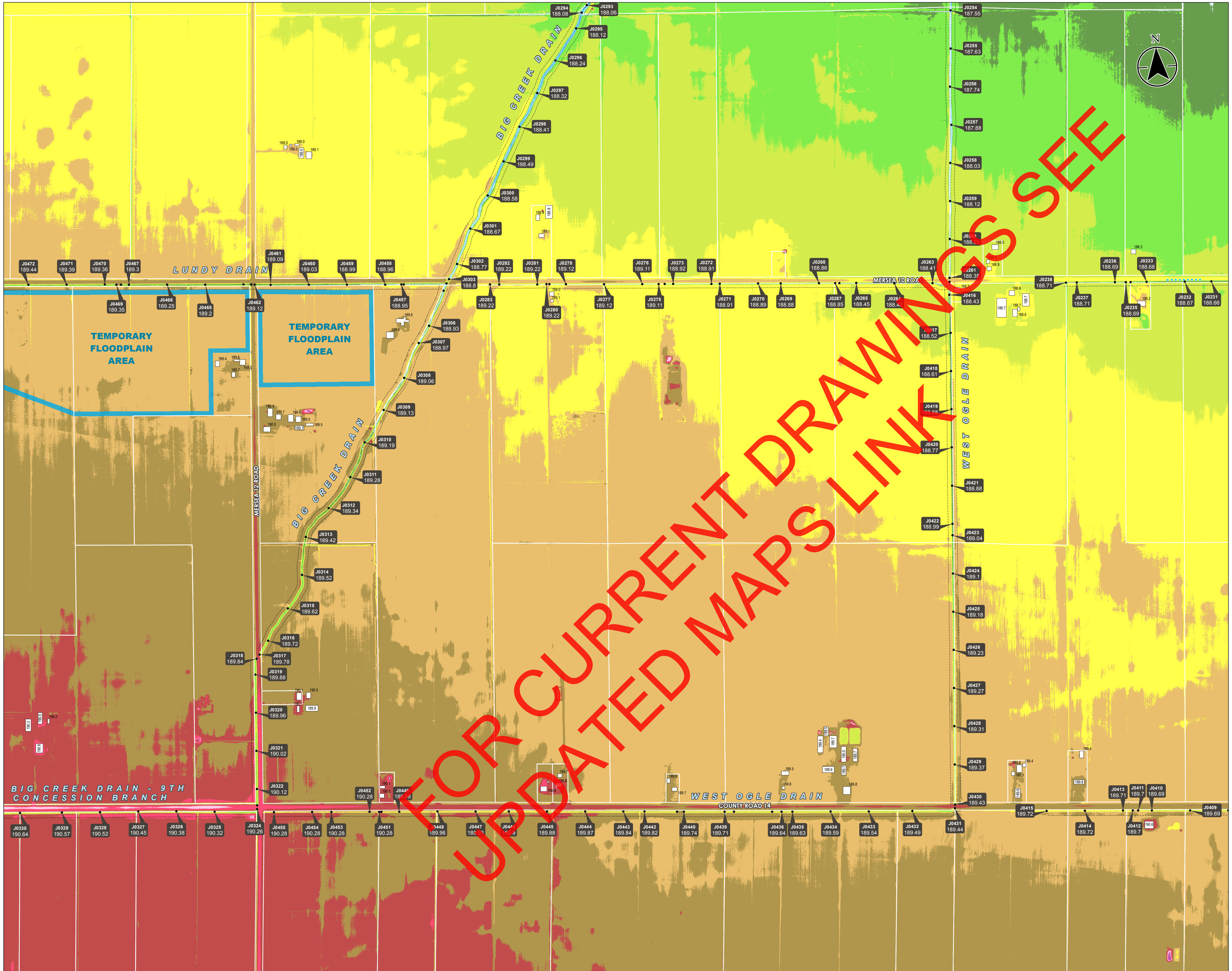
Figure No.

9

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_9.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)
Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

- 0 - 30 cm at Pavement Edge
- > 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

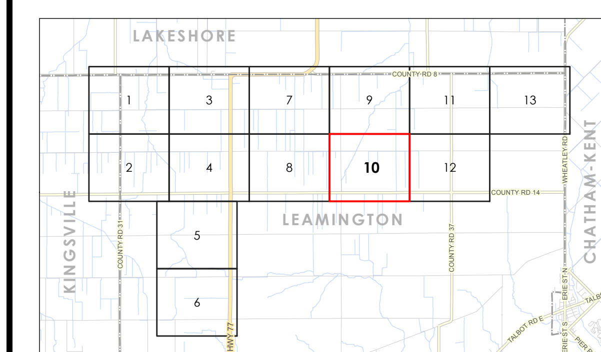
- 192.01 - 192.50
- 191.51 - 192.00
- 191.01 - 191.50
- 190.51 - 191.00
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- ≤ 185.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location

Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

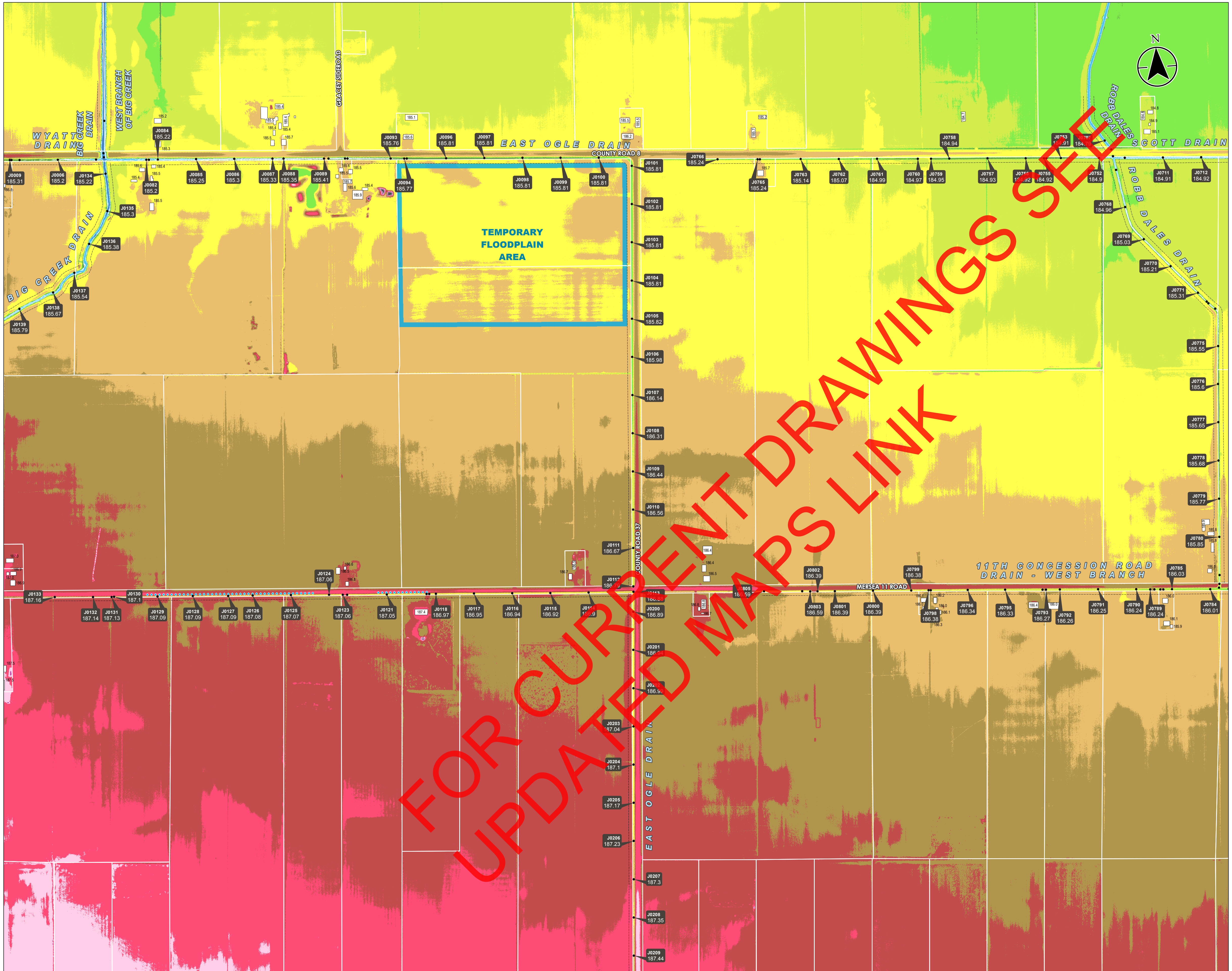
MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

Figure No.

10

Title

Projected Flood Elevations
1:100 Year Event



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m) [3]
Modeled Node

Proposed Floodway [4]

Designated Temporary Floodplain Area

Ponding Above Road

0 - 30 cm at Pavement Edge

> 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)

Buildout Area

Existing Ground Elevation (m)

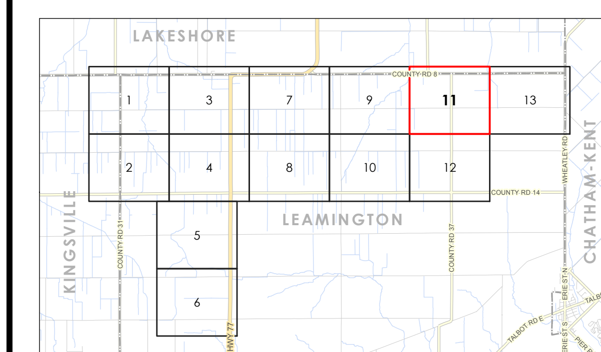
- ≥ 189.01
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- 185.01 - 185.50
- 184.51 - 185.00
- 184.01 - 184.50
- 183.51 - 184.00
- 183.01 - 183.50
- 182.51 - 183.00
- 182.01 - 182.50
- ≤ 182.00

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location
Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

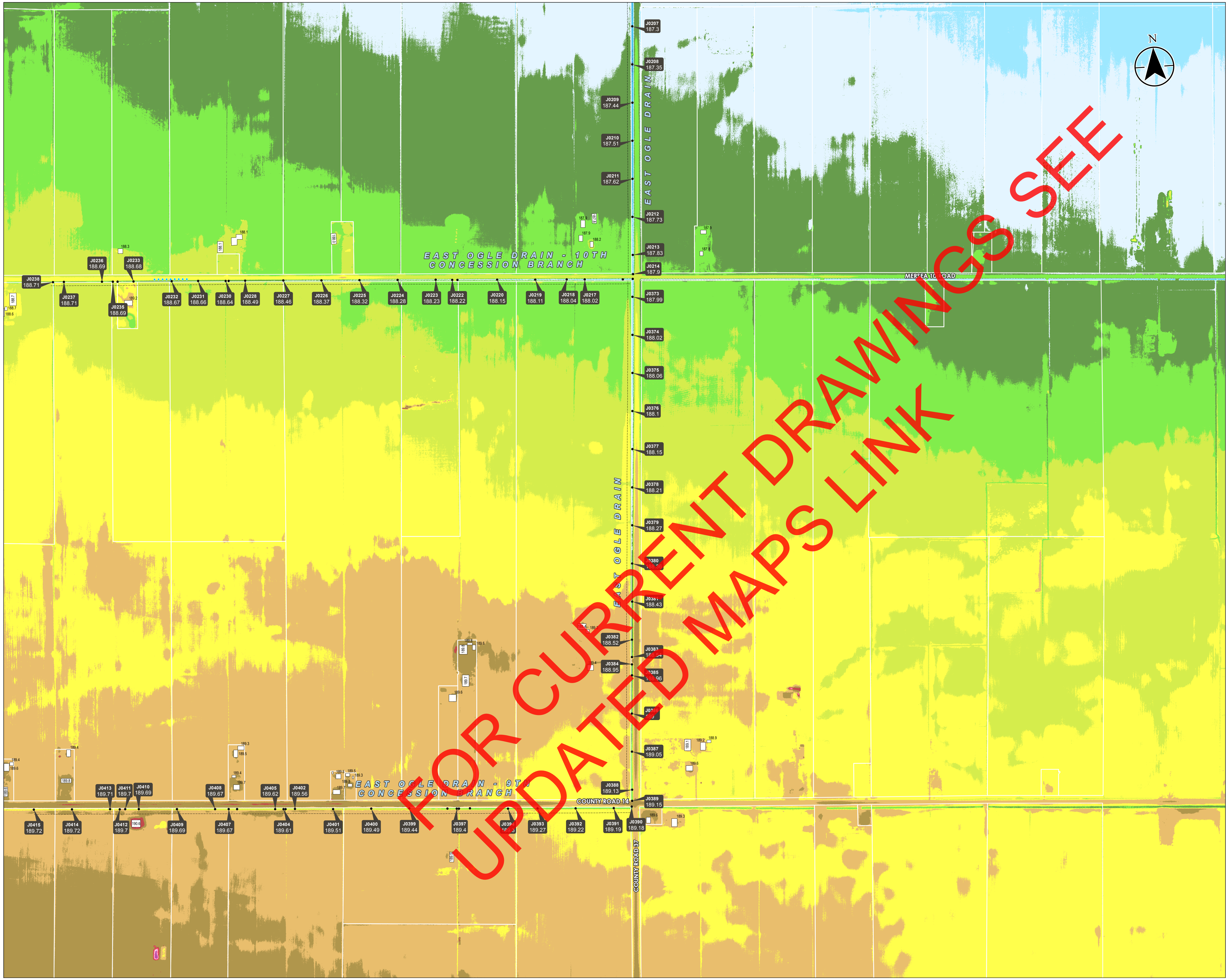
Figure No.

11

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_11.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

Node ID
1:100 Year Regulatory Flood Elevation (m)
Modeled Node
Proposed Floodway [4]
Designated Temporary Floodplain Area

Ponding Above Road

- 0 - 30 cm at Pavement Edge
- > 30 cm at Pavement Edge

Existing Building and Approximate Existing Grade Elevation (m)
Buildout Area

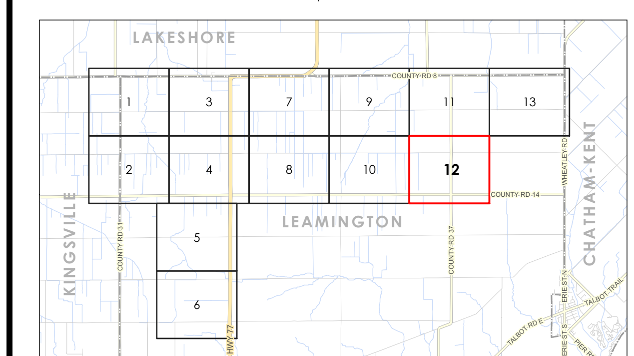
Existing Ground Elevation (m)

- 192.01 - 192.50
- 191.51 - 192.00
- 191.01 - 191.50
- 190.51 - 191.00
- 190.01 - 190.50
- 189.51 - 190.00
- 189.01 - 189.50
- 188.51 - 189.00
- 188.01 - 188.50
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- ≤ 185.50

0 200 400 metres
1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location

Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

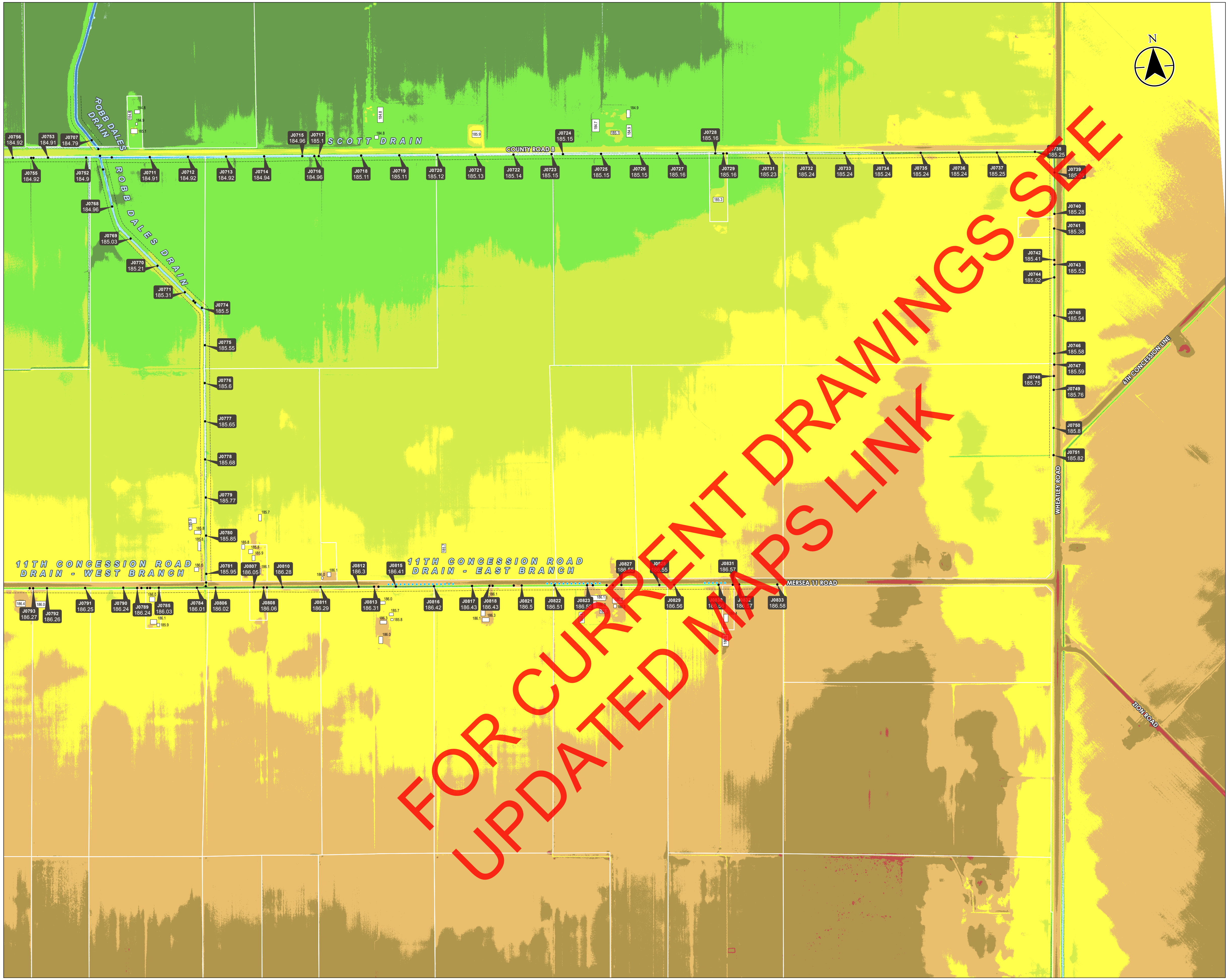
Figure No.

12

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_12.mxd Revised: 2019-05-22 By: kbuchanan



Stantec

Legend

- Node ID / 1:100 Year Regulatory Flood Elevation (m)
- Modeled Node
- Proposed Floodway [4]
- Designated Temporary Floodplain Area

Ponding Above Road

- 0 - 30 cm at Pavement Edge
- > 30 cm at Pavement Edge
- Existing Building and Approximate Existing Grade Elevation (m)
- Buildout Area

Existing Ground Elevation (m)

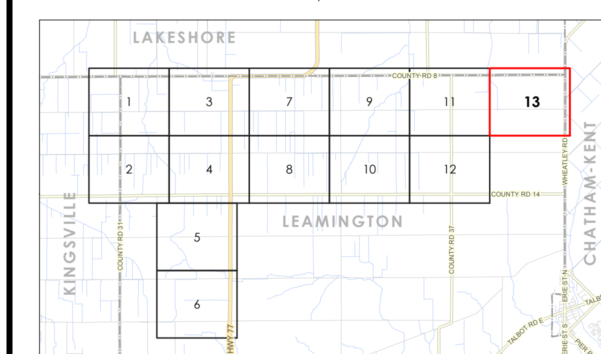
- 187.51 - 188.00
- 187.01 - 187.50
- 186.51 - 187.00
- 186.01 - 186.50
- 185.51 - 186.00
- 185.01 - 185.50
- 184.51 - 185.00
- 184.01 - 184.50
- 183.51 - 184.00
- 183.01 - 183.50
- 182.51 - 183.00
- ≤ 182.50

0 200 400 metres

1:5,000 (At original document size of 22x34)

Notes

1. Horizontal Coordinate System: NAD 1983 UTM Zone 17N
2. Vertical Coordinate System: CGVD 1928 (1978 Adjustment)
3. Regulatory Storm defined herein as 100-Year 6-Hour Storm with rainfall amount of 99 milimetres, distributed using Probable Maximum Precipitation distribution.
4. Proposed floodway limits shown are for illustration purposes only and have been depicted as an 8 metre offset from approximate top of bank alignments. Actual limits of floodway are to be a minimum horizontal setback of 8 metres plus depth of drain. Development is prohibited within the floodway limits and the designated floodway area within these limits shall remain unencumbered of any obstruction or fill.
5. Contains information licensed under the Open Government License - Ontario.



Project Location

Municipality of Leamington

165620134 REVB
Prepared by KDB on 2019-05-22
Technical Review by AM on 2019-05-21

Client/Project

MUNICIPALITY OF LEAMINGTON
STORMWATER MASTER DRAINAGE STUDY FOR REID DRAIN, SILVER CREEK AND BIG CREEK

Figure No.

13

Title

Projected Flood Elevations
1:100 Year Event

V:\01656\active\165620134\floodline\MXD\165620134_BandedElevation_13.mxd Revised: 2019-05-22 By: kbuchanan

APPENDIX H

ERCA Floodline Information

ESSEX REGION CONSERVATION AUTHORITY FILL & FLOOD LINE MAPPING

36

RUSCOM RIVER

REGULATION MADE UNDER
THE CONSERVATION AUTHORITIES ACT
FILL, CONSTRUCTION AND ALTERATION
TO WATERWAYS

ONTARIO REGULATION NO. ______________

SCHEDULE NO. ______________

NO.	REVISIONS	DATE	BY
1	MAX OBS FLOOD	FEB.85	ERCA

- ········ MAX OBS FLOODLINE
- — — — FLOOD LINE BASED ON 100 YEAR STORM
- ——— FLOOD LINE BASED ON REGIONAL STORM
- - - - - FILL LINE
- (●) FLOOD LEVELS FOR REGIONAL STORM
- ● FLOOD LEVELS FOR 100 YEAR STORM
- 582.5 SURVEYED VERTICAL CONTROL POINT. CANADIAN GEODETIC DATUM
- ■602.07 MAX OBS FLOOD LEVEL

THIS MAP IS PREPARED FOR USE IN CONJUNCTION WITH THE FLOOD PLAIN MAPPING REPORT DATED JAN. 1981 PREPARED BY ESSEX REGION CONSERVATION AUTHORITY AND FORMS PART THEREOF.

PHOTO MAPPING COMPILED AND DRAWN BY KENTING EARTH SCIENCES LIMITED. FROM AERIAL PHOTOGRAPHS TAKEN MAY 1979.

S. R. TAYLOR

ESSEX REGION CONSERVATION AUTHORITY

KENTING EARTH SCIENCES LIMITED OTTAWA, TORONTO, CALGARY

MAP NO. ER3-36

ESSEX REGION CONSERVATION AUTHORITY FILL & FLOOD LINE MAPPING

45

RUSCOM RIVER

REGULATION MADE UNDER
THE CONSERVATION AUTHORITIES ACT
FILL, CONSTRUCTION AND ALTERATION
TO WATERWAYS

ONTARIO REGULATION NO. ____________

SCHEDULE NO. ____________

KEY PLAN

NO.	REVISIONS	DATE	BY
1	MAX OBS FLOOD	FEB.85	ERCA

FLOOD LINE BASED ON 100 YEAR STORM
FLOOD LINE BASED ON REGIONAL STORM
FILL LINE
(●) FLOOD LEVELS FOR REGIONAL STORM
● FLOOD LEVELS FOR 100 YEAR STORM
582.5 SURVEYED VERTICAL CONTROL POINT, CANADIAN GEODETIC DATUM
MAX OBS FLOOD LINE
■612.0 MAX OBS FLOOD LEVEL

THIS MAP IS PREPARED FOR USE IN CONJUNCTION WITH THE FLOOD PLAIN MAPPING REPORT DATED JAN. 1981 PREPARED BY ESSEX REGION CONSERVATION AUTHORITY AND FORMS PART THEREOF.

PHOTO MAPPING COMPILED AND DRAWN BY KENTING EARTH SCIENCES LIMITED. FROM AERIAL PHOTOGRAPHS TAKEN MAY 1979.

S. R. TAYLOR

Scale 1:5000

ESSEX REGION CONSERVATION AUTHORITY

KENTING EARTH SCIENCES LIMITED

MAP NO. ER3-45

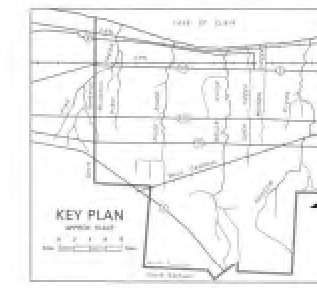
ESSEX REGION CONSERVATION AUTHORITY FILL & FLOOD LINE MAPPING

45

RUSCOM RIVER

REGULATION MADE UNDER
THE CONSERVATION AUTHORITIES ACT
FILL, CONSTRUCTION AND ALTERATION
TO WATERWAYS

ONTARIO REGULATION NO.__________
SCHEDULE NO.__________



NO.	REVISIONS	DATE	BY
1	MAX OBS FLOOD	FEB.85	ERCA

FLOOD LINE BASED ON 100 YEAR STORM
FLOOD LINE BASED ON REGIONAL STORM
FILL LINE
FLOOD LEVELS FOR REGIONAL STORM
FLOOD LEVELS FOR 100 YEAR STORM
582.5 SURVEYED VERTICAL CONTROL POINT. CANADIAN GEODETIC DATUM
MAX OBS FLOOD LINE
612.0 MAX OBS FLOOD LEVEL

THIS MAP IS PREPARED FOR USE IN CONJUNCTION WITH THE FLOOD PLAIN MAPPING REPORT DATED JAN. 1981 PREPARED BY ESSEX REGION CONSERVATION AUTHORITY AND FORMS PART THEREOF.

PHOTO MAPPING COMPILED AND DRAWN BY KENTING EARTH SCIENCES LIMITED. FROM AERIAL PHOTOGRAPHS TAKEN MAY 1979.

S. R. TAYLOR

ESSEX REGION CONSERVATION AUTHORITY

KENTING EARTH SCIENCES

MAP NO. ER3-45

24.20	50.00	0.0	0.0	579.10	3950.00	590.28	0.0	590.60	84.00	6.25	1.92	924.07
24.30	28.00	591.20	591.00	579.10	3950.00	590.30	0.0	590.61	84.00	6.24	1.92	924.63
24.40	50.00	0.0	0.0	579.20	3950.00	590.63	0.0	590.71	687.17	3.57	1.93	926.47
25.00	3900.00	0.0	0.0	582.60	4100.00	592.80	0.0	593.27	221.68	12.10	2.13	1069.39
25.10	10.00	0.0	0.0	582.60	4100.00	592.81	0.0	593.28	222.06	12.05	2.13	1069.59
25.20	10.00	0.0	0.0	582.60	4100.00	592.83	0.0	593.29	222.65	11.98	2.13	1069.79
25.30	50.00	0.0	0.0	582.80	4100.00	593.19	0.0	593.41	474.62	5.58	2.13	1071.15
25.40	50.00	0.0	0.0	582.80	4100.00	593.13	0.0	593.54	80.00	8.70	2.14	1072.47
25.50	100.00	602.70	598.60	582.90	4100.00	593.22	0.0	593.63	80.00	8.74	2.14	1074.31
25.60	25.00	0.0	0.0	582.90	4100.00	593.51	0.0	593.71	499.37	4.94	2.14	1075.00
25.70	50.00	0.0	0.0	582.90	4100.00	593.56	0.0	593.74	457.91	5.64	2.15	1076.85
26.00	4000.00	0.0	0.0	584.40	4050.00	596.51	0.0	596.93	442.35	11.12	2.38	1202.91

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	EG	TOPWID	10K*S	TIME	VOL
27.00	1150.00	0.0	0.0	584.40	3400.00	597.56	0.0	597.72	445.34	3.68	2.47	1233.74
27.10	50.00	0.0	0.0	584.40	3400.00	597.53	0.0	597.80	76.00	5.48	2.48	1234.90
27.20	30.00	604.50	600.50	584.40	3400.00	597.54	0.0	597.81	76.00	5.47	2.48	1235.47
27.30	50.00	0.0	0.0	584.50	3400.00	597.70	0.0	597.87	480.10	3.62	2.48	1236.65
28.00	500.00	0.0	0.0	584.00	3450.00	597.94	0.0	598.07	843.67	4.04	2.54	1254.56
28.10	50.00	0.0	0.0	584.00	3450.00	597.81	0.0	598.25	57.00	8.99	2.54	1256.01
28.20	22.00	597.70	599.50	584.00	3450.00	598.09	0.0	598.33	646.20	5.32	2.54	1256.57
28.30	50.00	0.0	0.0	584.10	3450.00	598.28	0.0	598.39	888.87	3.34	2.55	1258.68
29.00	4050.00	0.0	0.0	586.10	3800.00	599.63	0.0	599.77	1998.26	3.39	2.96	1478.33
29.10	50.00	0.0	0.0	586.10	3800.00	599.56	0.0	599.88	64.00	6.12	2.97	1480.31
29.20	28.00	601.30	600.90	586.20	3800.00	599.58	0.0	599.90	64.00	6.25	2.97	1480.85
29.30	50.00	0.0	0.0	586.30	3800.00	599.82	0.0	599.97	1998.26	3.69	2.97	1482.82
30.00	1850.00	0.0	0.0	586.30	3950.00	600.67	0.0	600.85	1623.23	6.03	3.14	1587.02
31.00	450.00	0.0	0.0	586.30	2300.00	600.98	0.0	600.99	3982.20	0.66	3.36	1630.85
31.10	200.00	0.0	0.0	586.30	2300.00	600.99	0.0	601.00	4034.89	0.56	3.46	1659.80
32.00	1850.00	0.0	0.0	588.60	2300.00	601.05	0.0	601.53	54.86	14.91	3.55	1805.35
32.10	50.00	0.0	0.0	588.60	2300.00	601.14	0.0	601.60	55.16	14.45	3.55	1805.83
32.20	50.00	0.0	0.0	588.60	2300.00	601.30	0.0	601.69	40.00	10.03	3.56	1806.34
32.30	30.00	603.00	602.70	588.60	2300.00	601.33	0.0	601.72	40.00	9.95	3.56	1806.65

PROFILE FOR RIVER LES BRANCH

PLOTTED POINTS (BY PRIORITY)-E-ENERGY,W-WATER SURFACE,I-INVERT,C-CRITICAL W.S.,L-LEFT BANK,R-RIGHT BANK,X-LOWER END STA

```
ELEVATION-FT    590.      595.      600.      605.      610.      615.      620.      625.      630.      635.      640.

     SECNO   CUMDIS-FT
     37.10  7200.  C        .         .    I    .         WEMR  L   .
     37.20  7300.  C        .         .    I    .         .EMR  L   .
     37.30  7400.  C        .         .    I    .         .E R  L   .
            7500.  C        .         .    I    .         .E MR L   .
            7600.  C        .         .    I    .         .WEMR L   .
            7700.  C        .         .    I    .         .WEM RL   .
            7800.  C        .         .     I   .         . EM RL   .
     38.00  7900.  C        .         .     I   .         . WEM L   .
     38.10  8000.  C        .         .     I   .         .   EM L  .
     38.20  8100.  C        .         .     I   .         .   WE L  .
     38.30  8200.  C        .         .     I   .         .   WE L  .
```

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

LES BRANCH -R

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	EG	TOPWID	10K*S	TIME	VOL
32.20	40.00	0.0	0.0	591.60	685.00	606.00	0.0	606.06	26.00	1.78	0.0	0.0
33.00	50.00	0.0	0.0	595.30	685.00	605.99	0.0	606.09	28.00	3.37	0.01	0.37
33.10	26.00	605.30	606.50	595.30	685.00	606.01	0.0	606.10	788.95	3.20	0.01	0.57
33.20	50.00	0.0	0.0	595.40	685.00	606.03	0.0	606.11	1229.11	3.50	0.02	1.10
33.30	100.00	0.0	0.0	595.40	685.00	606.07	0.0	606.15	1348.64	3.30	0.03	2.37
37.00	6800.00	0.0	0.0	602.50	700.00	610.11	0.0	610.38	32.31	14.37	0.48	60.77
37.10	50.00	0.0	0.0	602.50	700.00	610.22	0.0	610.45	25.00	11.36	0.49	60.97
37.20	30.00	612.30	612.40	602.50	700.00	610.26	0.0	610.49	25.00	11.20	0.49	61.09
37.40	60.00	0.0	0.0	602.60	700.00	610.30	0.0	610.56	32.60	13.60	0.49	61.30
38.00	650.00	0.0	0.0	602.90	700.00	611.23	0.0	611.53	57.51	15.74	0.53	63.78
38.10	50.00	0.0	0.0	602.90	700.00	611.28	0.0	611.67	20.00	21.80	0.54	63.95
38.20	50.00	612.30	612.30	602.90	700.00	611.40	0.0	611.78	20.00	20.77	0.54	64.11
38.30	50.00	0.0	0.0	603.00	700.00	611.66	0.0	611.90	320.40	12.74	0.54	64.32

SECTION NUMBER	DISCHARGE CFS	CWSEL	CWSEL DIFF EACH Q	CWSEL DIFF EACH SECTION	CWSEL-WSELK	TOPWID	T.W. DIFF	LENGTH
32.200	685.001	606.000	0.0	0.0	0.0	26.000	0.0	40.000
33.000	685.001	605.994	0.0	-0.006	0.0	28.000	0.0	50.000

University of Windsor

SUMMARY PRINTOUT FOR MULTIPLE PROFILES

BR (SILVER CREEK) -R

SECTION NUMBER	CHANNEL LENGTH	MIN EL OF ROADWAY	MAX EL OF LOW CHORD	MIN EL GROUND	DISCHARGE (CFS)	CWSEL	CRIWS	EG	TOPWID	10K*S	TIME	VOL
10.00	1850.00	0.0	0.0	586.30	1800.00	600.70	0.0	600.74	1641.40	1.27	0.0	0.0
12.00	300.00	0.0	0.0	586.70	1800.00	600.75	0.0	600.77	2429.02	1.05	0.09	20.78
14.00	2000.00	0.0	0.0	589.60	1800.00	601.08	0.0	601.36	54.50	8.61	0.22	114.55
14.10	100.00	0.0	0.0	589.80	1800.00	601.18	0.0	601.45	54.76	8.33	0.22	115.52
14.20	50.00	0.0	0.0	589.80	1800.00	601.16	0.0	601.57	32.00	13.15	0.23	115.97
14.30	20.00	602.90	603.40	589.80	1800.00	601.19	0.0	601.60	32.00	13.05	0.23	116.13
14.40	50.00	0.0	0.0	590.00	1800.00	601.43	0.0	601.69	55.16	7.98	0.23	116.58
30.00	1700.00	0.0	0.0	592.00	1800.00	603.14	0.0	603.57	66.67	14.56	0.32	131.74
30.10	150.00	0.0	0.0	592.00	1800.00	603.38	0.0	603.78	170.48	13.10	0.33	132.97
30.20	50.00	0.0	0.0	591.60	1800.00	603.33	0.0	604.01	24.00	25.24	0.33	133.35
30.30	19.00	603.60	605.10	591.60	1800.00	603.39	0.0	604.06	24.00	24.87	0.33	133.46
30.40	50.00	0.0	0.0	592.10	1800.00	603.91	0.0	604.24	347.21	10.49	0.34	133.89
31.00	1800.00	0.0	0.0	592.00	1800.00	606.44	0.0	605.66	54.71	5.87	0.47	153.56
32.00	1800.00	0.0	0.0	594.90	1800.00	606.66	0.0	606.93	55.17	8.29	0.59	172.30
32.10	50.00	0.0	0.0	591.60	1800.00	606.66	0.0	607.02	26.00	10.86	0.59	172.76
32.20	40.00	604.50	605.60	591.60	1800.00	606.64	0.0	607.19	26.00	37.67	0.59	173.07
32.30	50.00	0.0	0.0	595.00	1800.00	607.34	0.0	607.37	1127.02	1.68	0.60	174.56
34.00	2000.00	0.0	0.0	597.30	1600.00	607.87	0.0	608.28	47.00	15.16	0.71	234.48
34.10	150.00	0.0	0.0	597.30	1600.00	608.12	0.0	608.50	47.82	13.69	0.72	235.58
34.20	50.00	0.0	0.0	594.70	1600.00	608.18	0.0	608.57	26.00	12.51	0.72	235.95
34.30	40.00	608.10	609.30	594.70	1600.00	608.21	0.0	608.68	26.00	24.58	0.73	236.23
34.40	50.00	0.0	0.0	597.40	1600.00	608.46	0.0	608.81	48.57	12.50	0.73	236.59
35.00	500.00	0.0	0.0	598.10	1600.00	609.08	0.0	609.48	42.27	13.63	0.76	240.33
36.00	1700.00	0.0	0.0	599.90	1600.00	611.00	0.0	611.24	54.78	7.74	0.88	254.38
36.10	50.00	0.0	0.0	599.90	1600.00	611.04	0.0	611.28	54.95	7.59	0.88	254.85
36.20	50.00	0.0	0.0	599.70	1600.00	611.04	0.0	611.38	32.00	11.06	0.88	255.28
36.30	36.00	611.80	611.60	599.70	1600.00	611.08	0.0	611.42	32.00	10.93	0.88	255.56
36.40	500.00	0.0	0.0	600.00	1600.00	611.77	0.0	611.99	865.02	12.75	0.92	259.61

APPENDIX I

Culvert Inventory

Culvert Name	WATERSHED	DRAIN NAME	BY-LAW	NORTHING	EASTING	LENGTH (DWGS.) (m)	LENGTH (G.I.S) (m)	LENGTH (FIELD) (m)	SIZE (mm)	OBVERT TO TOP (m)	Inlet Node	Outlet Node	Ground Elev. Inlet (m)	Ground Elev. Outlet (m)	Culvert Inlet Depth (m)	Culvert Outlet Depth (m)	Inlet Inv. Elev. (m)	Outlet Inv. Elev. (m)	Comments
C178	SILVER CREEK	IRWIN DRAIN	5642	4670121	364892		18.94	19	2x5.7	0.6	J001	J002	187.475	187.655	2.6	2.6	184.875	185.055	
C170	SILVER CREEK	IRWIN DRAIN	5642	4666431	364625		10.23	12	375		J004	J003	194.255	194.255	0.905	0.855	193.35	193.4	
C171	SILVER CREEK	IRWIN DRAIN	5642	4666953	364661		6.85	6.6	1200	0.8	J006	J005	191.485	191.585	2	2	189.485	189.585	
C274	SILVER CREEK	IRWIN DRAIN	5642	4667573	364707		24.99		1x1.85	1.4	J007	J289	189.755	-1	2.4	2.5	187.355	187.623	
C173	SILVER CREEK	IRWIN DRAIN	5642	4667746	364719		15.9	16	2400	0	J011	J010	190.425	190.485	2.4	2.4	188.025	188.085	
C174	SILVER CREEK	IRWIN DRAIN	5642	4668096	364743		4.94	4.9	1.7x3	0.4	J013	J012	189.835	189.735	2.1	2.1	187.735	187.635	
C175	SILVER CREEK	IRWIN DRAIN	5642	4668439	364766		8.39	8.9	2400	0.8	J015	J014	189.205	189.185	3.2	3.2	186.005	185.985	
C270	SILVER CREEK	IRWIN DRAIN	5642	4668959	364804		24.48		1x1.65	1.3	J018	J291	187.085	-1	2.3	1.9	184.785	184.015	
C177	SILVER CREEK	IRWIN DRAIN	5642	4669276	364826		8.94	9.4	3800	0	J020	J019	187.455	187.445	3.8	3.8	183.655	183.645	
C276	SILVER CREEK	IRWIN DRAIN	5642	4670086	365338		7.31	7.4	2x3	0.5	J022	J021	186.805	186.785	2.5	2.5	184.305	184.285	
C266	SILVER CREEK	IRWIN DRAIN	5642	4670071	365644		6.82	6.7	2X4.3	0.3	J024	J023	187.085	187.115	2.3	2.3	184.785	184.815	*Open bottom
C181	SILVER CREEK	REID DRAIN - WEST PART	3171	4670023	366410	6.6	8.98	8.5	1200	0.8	J025	J026	186.645	186.545	2	2	184.645	184.545	
C182	SILVER CREEK	REID DRAIN - WEST PART	3171	4669993	366864	6	7.41	6.7	900	0.4	J027	J028	186.575	186.555	1.3	1.3	185.275	185.255	
C182E	SILVER CREEK	REID DRAIN - WEST PART	3171	4669979	367049		8.22	11	700	0	J030	J029	186.935	186.935	1.61	1.61	185.325	185.325	
C153	REID	REID DRAIN - WEST BRANCH	3514	4669774	367903		7.75	7.7	2.4 x 4.9	0.9	J031	J032	187.595	187.585	3.3	3.3	184.295	184.285	
C156	REID	REID DRAIN - TOWNLINE BRANCH	3119	4669733	368536		15.29	15	2 x 4.3	0.3	J033	J301	187.305	-1	2.3	2.4	185.005	185.035	
C155	REID	REID DRAIN - TOWNLINE BRANCH	3119	4669812	369475	45	56.15	56	900	0.5E 0.6W	J036	J037	187.145	187.315	1.4	1.5	185.745	185.815	
C154	REID	REID DRAIN - TOWNLINE BRANCH	3119	4669802	369591	11.4	12.15	12	750	0	J038	J039	186.735	186.575	0.75	0.75	185.985	185.825	
C123	BIG CREEK	WYATT DRAIN	3448	4669765	370154		12.64	12.5	750	0	J041	J040	186.615	186.625	0.75	0.75	185.865	185.875	
C124	BIG CREEK	WYATT DRAIN	3448	4669741	370512		12.93	13	1200	0	J043	J042	186.455	186.445	1.2	1.2	185.255	185.245	
C125	BIG CREEK	WYATT DRAIN	3448	4669720	370807		8.89	9	1050	0.6	J045	J044	186.725	186.985	1.65	1.65	185.075	185.335	
C126	BIG CREEK	WYATT DRAIN	3448	4669713	371058	4.4	4.42	4.4	1.7x2.4	0.3E 0.5W	J047	J046	187.485	187.435	2.2	2	185.285	185.435	
C127	BIG CREEK	WYATT DRAIN	3448	4669689	371386		7.13	7	1800	1.3	J049	J048	187.535	187.575	3.1	3.1	184.435	184.475	
C128	BIG CREEK	WYATT DRAIN	3448	4669667	371723		16.02	16	1800	0	J051	J050	186.615	186.565	1.8	1.8	184.815	184.765	
C129	BIG CREEK	WYATT DRAIN	3448	4669655	371915		6.94	7	1800	1	J053	J052	187.405	187.395	2.8	2.8	184.605	184.595	
C130	BIG CREEK	WYATT DRAIN	3448	4669649	371986		7.05	7	1800	1.2	J055	J054	187.295	187.335	3	3	184.295	184.335	
C131	BIG CREEK	WYATT DRAIN	3448	4669637	372156	10.5	10.93	10.5	2x4.4	0.6	J057	J056	187.255	187.245	2.6	2.6	184.655	184.645	
C132	BIG CREEK	WYATT DRAIN	3448	4669610	372584		7.7	8	2200	0.8	J059	J058	187.025	187.075	3	3	184.025	184.075	
C133	BIG CREEK	WYATT DRAIN	3448	4669579	373066	6.5	6.52	6.5	2.3x4.1	0.5	J061	J060	186.975	187.125	2.8	2.8	184.175	184.325	
C134	BIG CREEK	WYATT DRAIN	3448	4669551	373525		7.32	7	2200	1.5	J063	J062	186.795	186.755	3.7	3.7	183.095	183.055	
C135	BIG CREEK	WYATT DRAIN	3448	4669532	373835	4.4	4.37	4.4	2.1x3.6	0.5	J065	J064	186.325	186.325	2.6	2.6	183.725	183.725	
C136	BIG CREEK	WYATT DRAIN	3448	4669509	374184	4.5	4.5	4.5	2.2x3.6	0.6	J067	J066	186.295	186.215	2.8	2.8	183.495	183.415	
C033	BIG CREEK	BIG CREEK DRAIN	3707	4669504	374429		10.32	10.5	6 X 14	0.4	J069	J068	186.275	186.255	6	6	180.275	180.255	
C101	BIG CREEK	(East Ogle Drain West Bound)		4669488	374542	6.1	6.46	6.5	3.4 x 5.6	0.6	J070	J071	185.985	185.915	4	4	181.985	181.915	
C102	BIG CREEK	(East Ogle Drain West Bound)		4669456	375008	5.4	10.71	11.6	2400	0.5	J072	J073	185.805	185.735	2.9	2.9	182.905	182.835	
C103	BIG CREEK	(East Ogle Drain West Bound)		4669452	375061	4.8	6.31	6.5	2.5 x 4.8	0.6	J074	J075	186.175	186.235	3.1	3.1	183.075	183.135	
C104	BIG CREEK	(East Ogle Drain West Bound)		4669442	375216		6.41	6.5	2.6 x 4.8	0.6	J076	J077	186.045	186.055	3.2	3.2	182.845	182.855	
C009_RD	BIG CREEK	STRAUSS LAND COMPANY DRAIN	2823	4669374	376138	6.1	6.18	6.1	1650	0.9	J079_RD	J078_RD	185.615	185.695	2.55	2.55	183.065	183.145	
C010_RD	BIG CREEK	STRAUSS LAND COMPANY DRAIN	2823	4669344	376584	34.14	34.25	34.4	1650	1	J081_RD	J080_RD	185.025	185.455	2.65	2.65	182.375	182.805	
C010E_RD	BIG CREEK	STRAUSS LAND COMPANY DRAIN	2823	4669325	376887			6.2	1650	1.2	J083_RD	J082_RD	185.285	185.215	2.85	2.85	182.435	182.365	
C008_RD	BIG CREEK	ROBB DALES DRAIN	3524	4669326	377063		18.31	18.3	2.2 X 4.8	0.4	J085_RD	J084_RD	184.915	184.955	2.6	2.6	182.315	182.355	
C007_RD	BIG CREEK	ROBB DALES DRAIN	3524	4668918	377285	6.1	6.41	6.1	1.65x4	0.5	J087_RD	J086_RD	185.215	185.055	2.15	2.15	183.065	182.905	arch culvert
C024_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668084	378625	34	36.18	37	750	0	J088_RD	J089_RD	185.685	185.425	0.75	0.75	184.935	184.675	
C023_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668101	378321		16.5	16.5	1300	0	J090_RD	J091_RD	185.635	185.595	1.3	1.3	184.335	184.295	
C022_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668103	378269		15.07	15.2	1500	0.5	J092_RD	J093_RD	186.215	186.225	2	2	184.215	184.225	
C021_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668116	378079		20.3	20.5	1600	0	J094_RD	J095_RD	185.625	185.615	1.6	1.6	184.025	184.015	
C020_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668121	378009	8.5	8.56	8.5	1600	0.8	J096_RD	J097_RD	186.295	186.265	2.4	2.4	183.895	183.865	
C019_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668139	377710	8.5	11.7	11.5	2000	0	J098_RD	J099_RD	185.795	185.785	2	2	183.795	183.785	
C47_3								11	3.45x10.5	0.9	J099	J107	0	0	0	0	183.388	183.344	
C018_RD	BIG CREEK	11TH CONCESSION - EAST BRANCH	3753	4668159	377419	8.5	9.03	8.9	1800	0.9	J100_RD	J101_RD	186.115	185.985	2.7	2.7	183.415	183.285	
C006_RD	BIG CREEK	ROBB DALES DRAIN	3524	4668176	377264		9.59	9.5	2.1 X 4.4	0.8	J102_RD	J103_RD	186.685	186.725	2.9	2.9	183.785	183.825	
C016_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668179	377088		11.04	11	1800	0	J105_RD	J104_RD	185.805	185.795	1.8	1.8	184.005	183.995	
C015_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668198	376806		9.31	9	1600	0.5	J107_RD	J106_RD	186.165	186.195	2.1	2.1	184.065	184.095	
C014_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668217	376507	6.1	5.92	5.9	1.6 X 1.6	0.3	J109_RD	J108_RD	186.535	186.485	1.9	1.9	184.635	184.585	
C148	REID	REID DRAIN - WEST BRANCH	3788	4668381	368411		11.86	12	2.5x4.9	0.7	J1103	J294	189.335	189.315	3.2	3.2	186.135	186.115	*Steel round box
C013_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668236	376204		18.4	19	1000	0	J111_RD	J110_RD	185.525	185.445	1	1	184.525	184.445	
C138	REID	REID DRAIN - 10TH CONCESSION	3662	4667378	367770		16.1	16	700	1	J1124	J646	190.655	190.675	1.7	1.7	188.955	188.975	
C072	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665799	370690		13.93	14.9	1800	0	J1128	J1230	190.045	189.935	1.8	1.8	188.245	188.135	
C012_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668246	376047	9.15	11.55	12	750	0	J113_RD	J112_RD	185.625	185.545	0.75	0.75	184.875	184.795	
C005_RD	BIG CREEK	SCOTT DRAIN	3803	4669276	377632	16	11.57	16	1650	0	J1132_RD	J1278_RD	184.215	184.215	1.65	1.65	182.565	182.565	Top of culvert
C120	BIG CREEK	STEVENSON DRAIN	3262	4668454	372687		11.46	11.7	2100	0	J1145	J1240	187.385	187.315	2.1	2.1	185.285	185.215	
C011_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668257	375894		6.28	6.1	600	0.8	J115_RD	J114_RD	186.485	186.705	1.4	1.4	185.085	185.305	
CCC								13.5	2.1x4.5	0.8	J1153	J084	187.115	187.065	2.9	2.9	184.215	184.165	
C017_RD	BIG CREEK	11TH CONCESSION - WEST BRANCH	4342	4668177	377113		7.57	7.7	1800	0.7	J1160_RD	J1213_RD	186.205	186.275	2.5	2.5	183.705	183.775	
C026	BIG CREEK	EAST OGLE DRAIN - 11TH CONCESSION	2065	4668299	375195	4.88	7.15	7.1	1200	1	J117	J116	186.925	186.985	2.2	2.2	184.725	184.785	
C047	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664443	370735		7.42	7.3	1400	0	J1174	J1216	191.075	191.005	1.4	1.4	189.675	189.605	*West of culvert damaged
C068	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665898	369193		13.13	13.6	1200	0	J1180	J1218	190.605	190.505	1.2	1.2	189.405	189.305	
C038	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4665057	371857		13.93	13.95	1800	0	J1187	J1280	190.195	190.235	1.8	1.8	188.395	188.435	
C040	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664399	371430		17.08	17.4	1200	0	J1188	J1186	190.775	190.785	1.2	1.2	189.575	189.585	
C027	BIG CREEK	EAST OGLE DRAIN - 11TH CONCESSION	2065	4668312	374978		11.48	11.5	1200	0.6	J119	J118	186.835	186.795	1.8	1.8	185.035	184.995	
C028	BIG CREEK	EAST OGLE DRAIN - 11TH CONCESSION	2065	4668349	374372		6.11	6.1	900	W0.6 - E0.4	J121	J120	187.035	186.855	1.5	1.3	185.535	185.555	
C042	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664406	371327		15.31	14.75	1800	0	J1215	J1283	190.625	190.525	1.8	1.8	188.825	188.725	
C046	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664430	370921		11.96	12.1	1500	0	J1217	J1214	190.795	190.835	1.5	1.5	189.295	189.335	
C069	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665859	369787		13.84	13.9	1400	0	J1219	J1228	190.385	190.265	1.4	1.4	188.985	188.865	
C064	BIG CREEK	BIG CREEK - 9TH CONCESSION BRANCH	2767	4665952	368429		14.92	13.45	900	0	J1221	J1222	191.225	191.235	0.9	0.9	190.325	190.335	
C066	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665943	368567		9.46	9.4	900	0	J1223	J1224	191.885	191.845	1.7	1.7	190.185	190.145	
C067	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665930	368749		9.82	9.65	900	0	J1225	J1179	191.945	191.885	1.81	1.8	190.135	190.085	
C071	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665839	370076		7.44	7.6	1800	0	J1227	J1127	189.975	189.915	1.8	1.8	188.175	188.115	
C070	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665850	369943		13.86	13.9	1400	0	J1229	J1226	190.235	190.235	1.4	1.4	188.835	188.835	
C029	BIG CREEK	EAST OGLE DRAIN - 11TH CONCESSION	2065	4668370	374068	6.1	6.11	6.1	525	1.3	J123	J122	187.575	187.485	1.825	1.825	185.75	185.66	
C099	BIG CREEK	(East Ogle Drain North Bound)		4665856	375564		19.02	19	1600	0	J1236	J1165	188.385	188.305	1.6	1.6	186.785	186.705	
C121	BIG CREEK	STEVENSON DRAIN	3262	4668440	372940		16.28	16	2200	0	J1237	J1238	187.175	187.135	2.2	2.2	184.975	184.935	
C034	BIG CREEK	BIG CREEK DRAIN	3707	4668431	373204		11.1	11.3	2.8 X 6.8	0.8	J124	J1149	187.875	187.885	3.6	3.6	184.275	184.285	
C122	BIG CREEK	STEVENSON DRAIN	3262	4668436	373007		6.56	6.5	2.5x3.6	0.5	J126	J125	188.245	188.195	3	3	185.245	185.195	
C003_RD	BIG CREEK	SCOTT DRAIN	3803	4668972	379551	38.1	37.44	38.1	900	1.2	J1271_RD	J1272_RD	185.885	185.885	2.1	2.1	183.785	183.785	
C002_RD	BIG CREEK	SCOTT DRAIN	3803	4668864	379544	21.96	12.28	21.96	900	0	J1273_RD	J1274_RD	185.085	185.095	0.9	0.9	184.185	184.195	
C001_RD	BIG CREEK	SCOTT DRAIN	3803	4668582	379524	30	31.67	30	900	0	J1275_RD	J1276_RD	186.015	186.015	1.54	1.55	184.475	184.465	
C004_RD	BIG CREEK	SCOTT DRAIN	3803	4669210	378702	6.1	8.65	9	1200	N0.6 - E0.4	J1279_RD	J1131_RD	185.025	185.085	1.65	1.8	183.375	183.285	
C119	BIG CREEK	STEVENSON DRAIN	3262	4668463	372543	6.3	6.04	6	1900	0.6	J128	J127	187.485	187.585	2.5	2.5	184.985	185.085	
C055	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664521	369568		11.41	11.9	1400	0	J1282	J1173	191.445	191.555	1.4	1.4	190.045	190.155	
C041	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664402	371378		46.36	46.4	1600	0	J1284	J1285	190.845	190.785	1.6	1.6	189.245	189.185	
C146W		REID DRAIN - WEST BRANCH	3788	4667336	368437		21.89	21.7	1200	0.9	J1290	J1172	190.695	190.825	2.1	2.1	188.595	188.725	
C118	BIG CREEK	STEVENSON DRAIN	3262	4668493	372087	9.9	9.79	10	2x4.5	0.8	J130	J129	188.575	188.645	2.8	2.8	185.775	185.845	
C117	BIG CREEK	STEVENSON DRAIN	3262	4668544	371304	13.8	12.42	13.5	1375	0.6	J132	J131	188.325	188.225	1.975	1.975	186.35	186.25	
C116	BIG CREEK	STEVENSON DRAIN	3262	4668581	370715	10.8	12.26	12	900	1.3	J134	J133	188.805	188.735	2.2	2.2	186.605	186.535	
C157	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4668618	370118	14.6	12.34	12	900	1.1	J135	J136	188.695	188.675	2	2	186.695	186.675	
C158	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4668636	369821	6.9	8.08	8	1200	1	J137	J138	188.715	188.735	2.2	2.2	186.515	186.535	
C159	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4668657	369516		7.88	8.2	1500	0.7	J139	J140	188.515	188.585	2.2	2.2	186.315	186.385	*Obvert to driveway
C160	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4668734	368469		18.45	17.2	2x2.5	0.25	J141	J312	188.245	188.255	2.25	2.25	185.995	186.005	
C161	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4669022	368486		4.48	5	2.5x2.5	0.5	J142	J143	188.205	188.265	3	3	185.205	185.265	
C162	REID	REID DRAIN - 11TH CONCESSION BRANCH	2826	4669449	368518		7.79	8	2x4	0	J144	J145	187.085	187.015	2	2	185.085	185.015	
C151	REID	REID DRAIN - WEST BRANCH	3788	4669592	368496	6.1	6.29	6.2	2 x 4.5	0.6	J146	J147	187.705	187.745	2.6	2.6	185.105	185.145	
C150	REID	REID DRAIN - WEST BRANCH	3788	4669083	368460	6.2	5.97	6.1	2 x 3.9	0.6	J149	J148	188.305	188.415	2.6	2.6	185.705	185.815	
C149	REID	REID DRAIN - WEST BRANCH	3788	4668734	368437	16.9	16.79	16.9	2.5x3.6	0.3	J150	J151	188.565	188.515	2.8	2.8	185.765	185.715	
C147	REID	REID DRAIN - WEST BRANCH	3788	4668188	368400	24.4	29.88	24.4	2.5x3.7	0.7	J153	J152	189.605	189.495	3.2	3.2	186.405	186.295	
C146	REID	REID DRAIN - WEST BRANCH	3788	4667349	368340		37.43	37.5	2.5x3.4	0.7	J155	J154	190.885	191.015	3.2	3.2	187.685	187.815	
C212	SILVER CREEK	BAILEY DRAIN	2767	4668778	367682		14.97	15	1100		J156	J157	187.655	187.635	1.1	1.1	186.555	186.535	
C211	SILVER CREEK	BAILEY DRAIN	2767	4668817	367081	6.6	11.36	10.5	1200		J158	J159	188.205	188.205	1.8	1.9	186.405	186.305	
C210	SILVER CREEK	BAILEY DRAIN	2767	4668888	366018		14.7	15	1800	0	J160	J161	187.535	187.425	1.8	1.8	185.735	185.625	
C209	SILVER CREEK	BAILEY DRAIN	2767	4668907	365721	7.8	11.69	11.9	1600	0	J162	J163	187.115	187.175	1.6	1.6	185.515	185.575	
C184	SILVER CREEK	SILVER CREEK DRAIN	2091	4667512	365876		8.64	8.5	3x7.3	0.4	J165	J164	190.695	190.625	3.4	3.4	187.295	187.225	*Surface of the road
C183	SILVER CREEK	SILVER CREEK DRAIN	2091	4668917	365666		8.56	8.5	4x8	0	J167	J166	188.685	188.685	4	4	184.685	184.685	
C236	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665565	364577	7.2	6.23	6.3	450		J170	J169	197.685	197.685	1.25	1.25	196.435	196.435	
C237	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665617	364569	80.7	80.65	82	450		J171	J172	197.765	197.765	1.45	1.45	196.315	196.315	
C238	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665740	364591	27.3	35.24	36.2	450	1N 0.8S	J173	J174	197.405	197.385	1.25	1.45	196.155	195.935	
C239	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665847	364597	50.1	52.22	52.3	450	1.2N	J175	J176	197.615	197.375	1.65	1.65	195.965	195.725	
C240	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665924	364605	28.5	29.45	29.5	525	1.2	J177	J178	197.275	197.325	1.725	1.725	195.55	195.6	
C234	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4666009	364613	46.2	45.74	48	600	1.2S	J179	J180	197.245	-2	1.8	0.6	195.445	196.365	*North not visible
C233	SILVER CREEK	CHASE DRAIN	3864	4665978	364794		12.2	12.5	750	1.35	J182	J181	195.075	195.175	0.75	0.75	194.325	194.425	*PRIVATE PROPERTY
C232	SILVER CREEK	CHASE DRAIN	3864	4666024	365063	6.1	6.26	6.1	900	1.2	J184	J183	195.545	195.485	2.1	2.1	193.445	193.385	*PRIVATE PROPERTY
C231	SILVER CREEK	CHASE DRAIN	3864	4666156	365266	30	28.03	30	1200	1W	J186	J185	194.445	193.295	2.2	1.2	192.245	192.095	
C230	SILVER CREEK	CHASE DRAIN	3864	4666509	365395		11.05	11.3	1000	0.3	J188	J187	191.705	191.855	1	1	190.705	190.855	HDPE
C229	SILVER CREEK	CHASE DRAIN	3064	4667114	365553	6	4.89		950		J190	J189	190.065	190.025	0.95	0.95	189.115	189.075	*PRIVATE PROPERTY
C228	SILVER CREEK	CHASE DRAIN	3064	4667325	365577	6	5.93		900		J192	J191	190.405	190.505	1.3	1.3	189.105	189.205	*PRIVATE PROPERTY
C227	SILVER CREEK	CHASE DRAIN	3064	4667522	365604	6	7.64	7.3	1800	0.7	J193	J194	190.165	190.145	2.5	2.5	187.665	187.645	
C226	SILVER CREEK	CHASE DRAIN	3064	4667512	365744		13.52	14	1600	1	J195	J196	190.245	190.205	2.6	2.6	187.645	187.605	
C186	SILVER CREEK	SILVER CREEK DRAIN	2091	4666083	366441		10.07	9.6	2.5x7.6	0	J197	J198	192.555	192.565	2.5	2.5	190.055	190.065	
C185	SILVER CREEK	SILVER CREEK DRAIN	2091	4667285	366068		8.19	8.5	1.8x3.8	0.8	J199	J200	189.975	190.085	1.8	1.8	188.175	188.285	Arch Culvert
C224	SILVER CREEK	SILVER CREEK - 10TH CONCESSION	2800	4667490	366082		18.19	18	1400	0	J202	J201	189.405	189.335	1.4	1.4	188.005	187.935	
C223	SILVER CREEK	SILVER CREEK - 10TH CONCESSION	2800	4667470	366382	6	18.14	18	1400	0	J204	J203	189.635	189.555	1.4	1.4	188.235	188.155	
C222	SILVER CREEK	SILVER CREEK - 10TH CONCESSION	2800	4667451	366688	6	14.13	14.2	1400	0	J205	J206	189.795	189.725	1.4	1.4	188.395	188.325	
C221	SILVER CREEK	SILVER CREEK - 10TH CONCESSION	2800	4667441	366841	6.6	14.06	14	1400	0	J208	J207	189.865	189.845	1.4	1.4	188.465	188.445	
C220	SILVER CREEK	SILVER CREEK - 10TH CONCESSION	2800	4667400	367445	7.8	14.26	14	800	0	J209	J210	189.715	189.685	0.8	0.8	188.915	188.885	
C141	REID	REID DRAIN - WEST BRANCH	3788	4665973	368248	19.4	19.43	19.3	2.7x3.8	0	J211	J212	192.335	192.315	2.9	2.9	189.435	189.415	
C142	REID	REID DRAIN - WEST BRANCH	3788	4666323	368272	6.1	6.94	6	2.5x2.9	0.7	J214	J213	192.205	192.205	3.2	3.2	189.005	189.005	
C143	REID	REID DRAIN - WEST BRANCH	3788	4666496	368285	27.2	27.03	27.4	2x2.7	0.7	J216	J215	191.895	191.925	2.7	2.7	189.195	189.225	
C144	REID	REID DRAIN - WEST BRANCH	3788	4666866	368309		13.46	15	1400	1	J218	J217	190.985	190.975	2.4	2.4	188.585	188.575	
C145	REID	REID DRAIN - WEST BRANCH	3788	4666982	368316	6	6.13	6	2.5x2.9	0.6	J220	J219	191.835	191.795	3.1	3.1	188.735	188.695	
C085	BIG CREEK	LUNDY DRAIN	3820	4667290	369124	8.5	9.18	8.4	1200	0.8	J222	J221	190.245	190.285	2	2	188.245	188.285	
C086	BIG CREEK	LUNDY DRAIN	3820	4667281	369258	8.5	8.94	9.5	1450	0.3	J224	J223	189.995	190.025	1.75	1.75	188.245	188.275	
C087	BIG CREEK	LUNDY DRAIN	3820	4667271	369428	4.9	4.95	4.7	1.7 x 1.7	0.4	J226	J225	190.295	190.315	2.1	2.1	188.195	188.215	
C44_2								16.5	2.85x6	0.5	J232	J44	0	0	3.35	3.35	183.965	183.965	
C203b	SILVER CREEK	SILVER CREEK DRAIN	2091	4664857	366499			5	2.2x3.4	0.5	J236	J241	0	0	2.7	2.7	191.9	191.9	
C235	SILVER CREEK	CHASE DRAIN - TOWNLINE BRANCH	3107	4665525	364550	45.6	48.95	47.5	450		J254	J168	198.135	198.135	0.45	0.45	197.685	197.685	*Pipe somewhat buried
C218	SILVER CREEK	SILVER CREEK - 9TH CONCESSION	3315	4666045	366859		14.31	12.1	1800		J261	J1121	192.355	192.385	2.9	2.9	189.455	189.485	
C249	SILVER CREEK	SILVER CREEK DRAIN - 6TH CONCESSION	2802	4661914	366070		50.15	49.1	900	0	J277	J522	200.745	200.815	1.3	2.5	199.445	198.315	
C172	SILVER CREEK	IRWIN DRAIN	5642	4667572	364706		24.25	24.4	2500	0	J289	J009	-1	190.015	2.5	2.5	187.623	187.515	
C176	SILVER CREEK	IRWIN DRAIN	5642	4668960	364803		25.1	24.7	3800	0	J291	J016	-1	187.855	1.9	1.9	184.015	185.955	
C152	REID	REID DRAIN - WEST BRANCH	3788	4669731	368525		26.68	26	2 x 4.9	0.4	J301	J035	-1	187.345	2.4	2.4	185.035	184.945	
C197	SILVER CREEK	SILVER CREEK DRAIN	2091	4663277	366935		12.56	12.2	2X2.4	0	J311	J483	197.585	197.145	2.7	2.2	194.885	194.945	
C087E	BIG CREEK	LUNDY DRAIN	3820	4667268	369457		6.86	6.7	1575	0.4	J314	J227	190.435	190.115	1.975	1.975	188.46	188.14	*East of culvert 87
C087E(i)	BIG CREEK	LUNDY DRAIN	3820	4667251	369718		9.13	8.4	1500	0.5	J316	J315	190.025	190.015	2	2	188.025	188.015	*East of culvert 87
C087E(ii)	BIG CREEK	LUNDY DRAIN	3820	4667231	370030		8.74	8.2	1600	0.5	J318	J317	190.035	190.035	2.1	2.1	187.935	187.935	*East of culvert 87
C087E(iii)	BIG CREEK	LUNDY DRAIN	3820	4667211	370321		9.51	8.5	1900	0.9	J320	J319	190.195	190.145	2.8	2.8	187.395	187.345	*East of culvert 87

Culvert Name	WATERSHED	DRAIN NAME	BY-LAW	NORTHING	EASTING	LENGTH (DWGS.) (m)	LENGTH (G.I.S) (m)	LENGTH (FIELD) (m)	SIZE (mm)	OBVERT TO TOP (m)	Inlet Node	Outlet Node	Ground Elev. Inlet (m)	Ground Elev. Outlet (m)	Culvert Inlet Depth (m)	Culvert Outlet Depth (m)	Inlet Inv. Elev. (m)	Outlet Inv. Elev. (m)	Comments
C087E(iv)	BIG CREEK	LUNDY DRAIN	3820	4667188	370629		16.34	16.4	1950	0	J322	J321	189.565	189.575	1.95	1.95	187.615	187.625	*East of culvert 87
C087E(v)	BIG CREEK	LUNDY DRAIN	3820	4667120	371643		13.13	12	2450	0	J323	J324	189.235	189.255	2.45	2.45	186.785	186.805	*East of culvert 87
C087E(vi)	BIG CREEK	LUNDY DRAIN	3820	4667097	371994		8.75	8.5	2.5x3.5	0.5	J325	J326	190.005	190.035	3	3	187.005	187.035	*East of culvert 87
C087E(vii)	BIG CREEK	LUNDY DRAIN	3820	4667073	372385		6.08	6.2	1.7x2.7	0.5	J328	J327	189.615	189.705	3.2	3.2	186.415	186.505	*East of culvert 87
C035	BIG CREEK	BIG CREEK DRAIN	3707	4667070	372503		7.88	13	3 X 4.5	0.4	J330	J329	189.235	189.375	3.4	3.4	185.835	185.975	
C036	BIG CREEK	BIG CREEK DRAIN	3707	4666126	371939		12.02	22	2.5 X 3.8	0.5	J332	J331	190.615	190.565	3	3	187.615	187.565	
C037	BIG CREEK	BIG CREEK DRAIN	3707	4665730	371909		9.51	9.8	2.5 X 2.5	0.6	J333	J334	190.645	190.675	3.1	3.1	187.545	187.575	
C088	BIG CREEK	WEST OGLE DRAIN - 10TH CONCESSION	3415	4667045	372763	6.1	7.62	7.8	800	0.9	J336	J335	189.155	189.175	1.7	1.7	187.455	187.475	
C090	BIG CREEK	WEST OGLE DRAIN - 10TH CONCESSION	3415	4666994	373519	6.1	10.62	10.6	900	1.1	J338	J337	188.765	188.705	2	2	186.765	186.705	
CAA								9	1050	0.75	J339	J340	186.515	186.455	1.8	1.8	184.715	184.655	
C089	BIG CREEK	WEST OGLE DRAIN - 10TH CONCESSION	3415	4661024	373061	6.1	15.92	16	1000	0.8	J341	J342	188.905	188.925	1.8	1.8	187.105	187.125	
C032	BIG CREEK	WEST OGLE DRAIN	3340	4666981	373812	10.36	10.58	10.4	2 X 3.6	N0.3 - S0.8	J344	J343	189.245	188.855	2.8	2.3	186.445	186.555	
C091	BIG CREEK	EAST OGLE DRAIN - 10TH CONCESSION	3157	4666963	373989	6.1	12.2	12	600	1	J345	J1154	188.685	188.735	1.6	1.6	187.085	187.135	
C092	BIG CREEK	EAST OGLE DRAIN - 10TH CONCESSION	3157	4666945	374279	6.1	12.47	12.4	900	0.7	J347	J346	188.545	188.525	1.6	1.6	186.945	186.925	
C093	BIG CREEK	EAST OGLE DRAIN - 10TH CONCESSION	3157	4666926	374574	6.1	7.81	7.6	1300	0.3	J355	J356	188.295	188.325	1.6	1.6	186.695	186.725	
C217	SILVER CREEK	SILVER CREEK - 9TH CONCESSION	3315	4666050	366783		62.47	61.4	900		J357	J231	192.255	192.205	1.99	1.98	190.265	190.225	
C094	BIG CREEK	EAST OGLE DRAIN - 10TH CONCESSION	3157	4666886	375169		13.26	13.5	2200	0	J359	J358	188.205	188.315	2.2	2.2	186.005	186.115	
C100	BIG CREEK	(East Ogle Drain North Bound)		4666863	375636		12.73	12.4	2 x 3.5	0.6	J361	J360	188.165	188.205	2.6	2.6	185.565	185.605	
C098	BIG CREEK	(East Ogle Drain North Bound)		4665483	375537	15.2	15.36	15.2	1.5 x 3.7	0.4	J363	J362	189.395	189.295	1.9	1.9	187.495	187.395	
C097	BIG CREEK	EAST OGLE DRAIN - 9TH CONCESSION	3760	4665502	375081	5.6	5.46	5.5	1.5 x 2.5	0.8	J365	J364	189.715	189.585	2.3	2.3	187.415	187.285	
C096	BIG CREEK	EAST OGLE DRAIN - 9TH CONCESSION	3760	4665533	374627	5.5	5.31	5.6	1.5 x 2.25	0.6	J367	J366	189.915	189.985	2.1	2.1	187.815	187.885	
C095	BIG CREEK	EAST OGLE DRAIN - 9TH CONCESSION	3760	4665562	374201		13.72	14.3	1200	0	J369	J368	189.145	189.135	1.2	1.2	187.945	187.935	
C031a	BIG CREEK	WEST OGLE DRAIN	3340	4665605	373731			9.6	2 x 4.6	0.7	J371	J370	190.305	190.215	2.7	2.7	187.605	187.515	*Crossing Essex Rd 14
C031	BIG CREEK	WEST OGLE DRAIN	3340	4665641	373014		18.03	18	1800	0	J373	J372	189.695	189.665	1.8	1.8	187.895	187.865	
C030	BIG CREEK	WEST OGLE DRAIN	3340	4665697	372229	6.1	6.2	6.1	750	0.9	J375	J374	190.215	190.245	1.65	1.65	188.565	188.595	
C038S	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664696	371828			7.36	1800	0	J377	J376	190.445	190.595	1.8	1.8	188.645	188.795	*South of Culvert 38
C063	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664561	368915		7.99	8.2	600	0	J379	J378	192.875	192.875	1.14	1.15	191.735	191.725	
C062	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664560	368927		8.76	8.7	400	0.56E	J381	J380	192.985	192.705	0.96	0.96	192.025	191.745	*West of culvurt not visible
C061	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664556	368975		29.5	29.3	700	).4E - W0.6	J383	J382	192.725	192.355	1.33	1.1	191.395	191.255	
C060	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664554	369021		12.86	12.1	900	0	J385	J384	192.715	192.715	1.24	1.31	191.475	191.405	
C059	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664551	369033		13.62	13.3	900	0	J387	J386	192.255	192.235	0.9	0.9	191.355	191.335	
C057	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664543	369227		7.41	7.2	1200	0.55 - W0.4	J389	J388	192.425	192.415	1.65	1.75	190.775	190.665	
C058	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664538	369281		4.51	6.1	1200	0	J391	J390	192.195	192.185	1.2	1.2	190.995	190.985	
C056	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664523	369526		11.1	11.2	1200	:0.3 - W0.2	J393	J392	192.015	192.125	1.45	1.5	190.565	190.625	
C054	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664516	369677		59.72	60.15	1400	0	J395	J394	191.795	191.745	1.4	1.4	190.395	190.345	
C053	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664505	369832		7.36	7.4	1400	E0.4 - W0	J397	J396	191.795	191.715	1.4	1.4	190.395	190.315	
C052	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664496	369969		6.11	6.2	1200	:0.45 - W0.	J399	J398	191.875	191.885	1.5	1.65	190.375	190.235	
C051	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664484	370130		7.56	7.3	1200	E0 - W0.3	J401	J400	191.655	191.845	1.5	1.5	190.155	190.345	
C050	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664464	370431		64.41	64.7	1200	0	J403	J402	191.325	191.295	1.2	1.2	190.125	190.095	
C049	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664460	370495		8.72	8.6	1400	0	J405	J404	191.205	191.195	1.4	1.4	189.805	189.795	
C048	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664452	370623		8.96	8.5	1500	0	J407	J406	191.155	191.075	1.5	1.5	189.655	189.575	
C045	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664424	371037		7.56	7.4	1500	0	J409	J408	191.005	190.975	1.6	1.6	189.405	189.375	
C044	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	4664422	371062		12.06	12.1	1500	0	J411	J410	190.845	190.865	1.5	1.5	189.345	189.365	
C043	BIG CREEK	BIG CREEK - 8TH CONCESSION BRANCH	2710	466414	371191		7.91	7.4	1600	0	J413	J412	190.845	190.815	1.6	1.6	189.245	189.215	
C065	BIG CREEK	(SOUTH OF COUNTY RD 14)		4665952	367447		4	3.9	900	0	J415	J414	191.525	191.455	0.9	0.9	190.625	190.555	
C084W(ii)	BIG CREEK	(NORTH OF COUNTY RD 14)		4665952	368735			26.6	400	0	J417	J416	191.835	191.815	0.4	0.4	191.435	191.415	*West of culvert 84
C084W(i)	BIG CREEK	(NORTH OF COUNTY RD 14)		4665943	368839			27.2	400	0	J419	J418	191.445	191.455	0.4	0.4	191.045	191.055	*West of culvert 84
C084	BIG CREEK	(NORTH OF COUNTY RD 14)		4665920	369168		21.71	21.6	400	0	J421	J420	191.325	191.325	1.37	1.37	189.955	189.955	
C083W	BIG CREEK	(NORTH OF COUNTY RD 14)		4665918	369200			8.8	400	0	J423	J422	191.175	191.175	1.23	1.2	189.945	189.975	* East of culvert 84
C083	BIG CREEK	(NORTH OF COUNTY RD 14)		4665908	369333		5.6	9.05	400	0	J425	J424	191.175	191.175	1.17	1.22	190.005	189.955	
C082	BIG CREEK	(NORTH OF COUNTY RD 14)		4665900	369468		8.29	9.3	450	0.83W	J427	J426	190.145	190.725	0.45	1.28	189.695	189.445	*East culvert not visible
C081	BIG CREEK	(NORTH OF COUNTY RD 14)		4665888	369639		6.89	9.7	600	0	J429	J428	190.965	190.965	1.22	1.33	189.745	189.635	
C080	BIG CREEK	(NORTH OF COUNTY RD 14)		4665838	370394		15.87	17.7	900	0	J431	J430	190.075	190.005	0.9	0.9	189.175	189.105	
C079	BIG CREEK	(NORTH OF COUNTY RD 14)		4665828	370537		9.98	11.8	900	0.7E 0W	J433	J432	190.645	190.645	1.6	1.6	189.045	189.045	
C078	BIG CREEK	(NORTH OF COUNTY RD 14)		4665819	370687		8.77	9.9	800	0	J435	J434	190.685	190.685	1.55	1.65	189.135	189.035	*West culvurt damaged
C076	BIG CREEK	(NORTH OF COUNTY RD 14)		4665807	370872		12.48	11.85	700	0	J437	J436	189.835	189.815	0.7	0.7	189.135	189.115	
C077	BIG CREEK	(NORTH OF COUNTY RD 14)		4665807	370872		8.89	9.8	750	0	J439	J438	190.805	190.805	1.82	1.86	188.985	188.945	
C075	BIG CREEK	(NORTH OF COUNTY RD 14)		4665799	370991		9.28	9.4	900	0.65E 0W	J441	J440	190.495	190.495	1.55	1.55	188.945	188.945	
C074	BIG CREEK	(NORTH OF COUNTY RD 14)		4665785	371210		11	11.8	900	0.6E W0	J443	J442	189.975	190.475	0.9	1.5	189.075	188.975	
C073	BIG CREEK	(NORTH OF COUNTY RD 14)		4665779	371324		12.78	11.4	1050	1.1	J445	J444	190.385	190.385	2.15	2.15	188.235	188.235	
C139	REID	REID DRAIN - WEST BRANCH	3788	4665308	368199	27.5	28.15	27.5	900	0	J447	J446	192.665	192.435	1.95	1.7	190.715	190.735	
C140	REID	REID DRAIN - WEST BRANCH	3788	4665774	368235	6.2	6.28	6.2	1200	0.85N 0.7S	J449	J448	192.455	192.335	1.9	2.05	190.555	190.285	
C214	SILVER CREEK	LORNE E. JACKSON DRAIN	2957	4666101	365981	30	30.12	28.6	900		J451	J450	191.845	191.805	0.9	0.9	190.945	190.905	
C215	SILVER CREEK	LORNE E. JACKSON DRAIN	2957	4666081	366309	30	30.71	30.6	1.2x1.9		J453	J452	192.065	192.045	1.7	1.7	190.365	190.345	
C204	SILVER CREEK	SILVER CREEK DRAIN	2091	4666064	366590		24.32	24.3	2.2x4.6	0	J454	J455	192.445	192.455	2.2	2.2	190.245	190.255	
C168	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4666036	367021	12.5	12.08	12.1	900	0	J457	J458	191.435	191.525	0.9	0.9	190.535	190.625	
C167	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4666001	367583		13.01	12.9	1200	0	J460	J459	191.545	191.685	1.2	1.2	190.345	190.485	
C165	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4665998	367641		6.17	12	900	0	J462	J461	191.495	191.545	0.9	0.9	190.595	190.645	
C164	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4665988	367797	5.9	6.13	15.8	900	0	J468	J467	192.035	192.035	1.8	1.7	190.235	190.335	
C163	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4665965	368165		18	20.8	900	0	J470	J469	191.055	191.015	0.9	0.9	190.155	190.115	
C201	SILVER CREEK	SILVER CREEK DRAIN	2091	4664716	366197		9.73	8.9	2.4x3.8	0	J472	J471	195.995	195.975	3	3	192.995	192.975	
C202	SILVER CREEK	SILVER CREEK DRAIN	2091	4664778	366297		6.75	6.7	1800	0.7	J474	J473	194.865	194.885	2.5	2.5	192.365	192.385	*PRIVATE PROPERTY
C203	SILVER CREEK	SILVER CREEK DRAIN	2091	4664833	366432		7.36	6.7	1800	0.75	J476	J475	194.865	194.555	2.55	2.55	192.315	192.005	old culvert
C200	SILVER CREEK	SILVER CREEK DRAIN	2091	4664564	366232		7.01	6.7	1900	0.35	J478	J477	195.595	195.525	2.25	2.25	193.345	193.275	
C199	SILVER CREEK	SILVER CREEK DRAIN	2091	4664323	366439		5.07	4.8	2.4x4.2	0.3	J480	J479	195.925	196.005	2.7	2.7	193.225	193.305	Box culvert
C198	SILVER CREEK	SILVER CREEK DRAIN	2091	4663716	366716		8.53	7.3	1650	0.2	J482	J481	-2	-2	1.85	1.85	194.835	194.865	*PRIVATE PROPERTY
C196	SILVER CREEK	SILVER CREEK DRAIN	2091	4663284	366685		10.68	10.1	1750	0.55E 0.6W	J485	J484	197.415	197.495	2.35	2.3	195.065	195.195	
C195	SILVER CREEK	SILVER CREEK DRAIN	2091	4663293	366540		62.89	61.5	2000	0.7E 0.05W	J487	J486	197.525	197.335	2.05	2.3	195.475	195.035	
C194	SILVER CREEK	SILVER CREEK DRAIN	2091	4663303	366383		6.4	6.3	1400	0.9E0.8W	J489	J488	197.825	197.885	2.2	2.3	195.625	195.585	
C193	SILVER CREEK	SILVER CREEK DRAIN	2091	4663309	366280		10.77	11.1	1200	0	J491	J490	196.845	196.775	0.86	0.73	195.985	196.045	
C192	SILVER CREEK	SILVER CREEK DRAIN	2091	4663312	366243		9.1	9.1	1200	0	J493	J492	197.415	197.465	1.6	1.6	195.815	195.865	
C246	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663321	366085		13.33	12.7	900	0.75W	J494	J495	197.795	197.695	1.8	1.65	195.995	196.045	*Damaged bad
C245	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663335	365852		10.95	9.65	300	0	J497	J496	197.695	197.305	1.5	1.05	196.195	196.255	*Damaged
C244	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663333	365893		10.88	10.6	600	0	J499	J498	197.705	197.815	1.7	1.7	196.005	196.115	
C243	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663338	365932		9.66	9.3	1850	0.8N 0.6S	J501	J500	198.265	198.325	2.45	2.65	195.815	195.675	
C242	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663665	366107		10.05	9.5	900	0.75	J503	J502	196.725	196.725	1.65	1.65	195.075	195.075	half submerged, poor flow
C241	SILVER CREEK	SILVER CREEK DRAIN - WEST BRANCH	3628	4663804	366407		22.12		900	0.5	J505	J504	196.435	196.435	1.4	1.4	195.035	195.035	half submerged, poor flow, two culverts in a row
C191	SILVER CREEK	SILVER CREEK DRAIN	2091	4662586	366123		19.38	18.1	1200	0.65	J507	J506	197.415	197.455	1.2	1.2	196.215	196.255	*PRIVATE PROPERTY
C190	SILVER CREEK	SILVER CREEK DRAIN	2091	4662268	366200		8.82	9.2	900	1.5	J509	J508	198.015	197.915	0.9	0.9	197.115	197.015	*PRIVATE PROPERTY
C189	SILVER CREEK	SILVER CREEK DRAIN	2091	4661922	366051		12.46	11.8	2.1X2.5	0	J511	J510	201.065	200.675	2.1	2.1	198.965	198.575	
C187	SILVER CREEK	SILVER CREEK DRAIN	2091	4661934	365557		8.24	7.75	550	0	J513	J512	200.625	200.595	1.6	1.6	199.025	198.995	
C188	SILVER CREEK	SILVER CREEK DRAIN	2091	4661931	365681		13.78	30.8	700	1.1N 0.8S	J515	J514	200.705	200.625	1.8	1.5	198.905	199.125	
C247W	SILVER CREEK	SILVER CREEK DRAIN - 6TH CONCESSION	2802	4661890	366424		7.47	6.78	200	0	J517	J516	202.095	202.095	0.4	0.4	201.695	201.695	*West of culvert 247
C247	SILVER CREEK	SILVER CREEK DRAIN - 6TH CONCESSION	2802	4661903	366237		12.03	12.6	450	0	J518	J519	201.255	201.255	1.45	1.45	199.805	199.805	
C248	SILVER CREEK	SILVER CREEK DRAIN - 6TH CONCESSION	2802	4661909	366134		19.1	21	550	0	J520	J276	199.965	199.825	0.55	0.55	199.415	199.275	
C257	SILVER CREEK	SLOAN DRAIN	2804	4664181	364463		18.37	18.1	2.2x5.4	0	J523	J524	197.285	197.295	2.5	2.5	194.785	194.795	
C278	SILVER CREEK	EAST-TOWNLINE DRAIN	2633	4663434	364399		16.3	15.7	2300	0	J526	J525	197.975	197.765	2.3	2.3	195.675	195.465	
C258	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION	1008	4663430	364446		13.38	9	450	0	J528	J527	198.445	198.445	0.85	1.05	197.595	197.395	
C259	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION	1008	4663389	365039		10.07	9.8	1200	0	J530	J529	197.765	197.715	1.8	1.8	195.965	195.915	
C256	SILVER CREEK	SLOAN DRAIN	2804	4663387	365169		11.2	10.7	1.8x3.8	0	J531	J532	198.125	197.745	2.4	2.1	195.725	195.645	
C260	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION EAST	-	4663374	365253		17.87	18.3	800	0	J534	J533	196.495	196.645	0.8	0.8	195.695	195.845	
C261	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION EAST	-	4663374	365290		11.11	10.8	700	0	J535	J536	197.715	197.715	1.77	1.73	195.945	195.985	
C262	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION EAST	-	4663369	365354		60.18	60.5	600	0	J537	J538	197.565	197.605	1.6	1.6	195.965	196.005	
C263	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION EAST	-	4663362	365445		7.22	7.15	800	0	J539	J540	197.645	197.595	1.6	1.6	196.045	195.995	
C264	SILVER CREEK	SLOAN DRAIN - 7TH CONCESSION EAST	-	4663360	365475		5.99	5.7	550	1.25W	J541	J542	197.845	197.795	1.65	1.8	196.195	195.995	
C255	SILVER CREEK	SLOAN DRAIN	2804	4662681	365270		9.98	9.9	1800	0.3	J544	J543	198.385	198.335	1.8	1.8	196.585	196.535	*PRIVATE PROPERTY
C254	SILVER CREEK	SLOAN DRAIN	2804	4661974	365223		8.84	8.9	1.7x2.4	0	J546	J545	200.385	200.205	2.4	2.4	197.985	197.805	
C250	SILVER CREEK	SLOAN DRAIN - 6TH CONCESSION (EAST)	1632	4661963	365230		11.98	12.5	1200	0.48N	J547	J548	199.525	199.015	1.2	1.68	198.325	197.335	
C251	SILVER CREEK	SLOAN DRAIN - 6TH CONCESSION (WEST)	3534	4661969	365133		9.33	9.18	850	0	J550	J549	199.705	199.765	1.65	1.65	198.055	198.115	
C252	SILVER CREEK	SLOAN DRAIN - 6TH CONCESSION (WEST)	3534	4661982	364938		5.37	26.8	900	0.4	J553	J552	199.805	199.725	1.3	1.3	198.505	198.425	
C253	SILVER CREEK	SLOAN DRAIN - 6TH CONCESSION (WEST)	3534	4661999	364667		6.56	5.85	450	0	J560	J554	200.635	200.605	1.65	1.65	198.985	198.955	
CBB								8	2.7x3	0.6	J609	J610	187.805	187.885	3.3	3.3	184.505	184.585	
C137	REID	REID DRAIN - 10TH CONCESSION	3662	4667345	368268		22.07	22	700	1.3	J647	J1122	190.575	190.595	2	2	188.575	188.595	
D166	REID	REID DRAIN - 9TH CONCESSION BRANCH	3789	4665999	367615		13.56	14.75	1200	W0 E0.97	J864	J279	191.425	192.275	1.2	2.17	190.225	190.105	