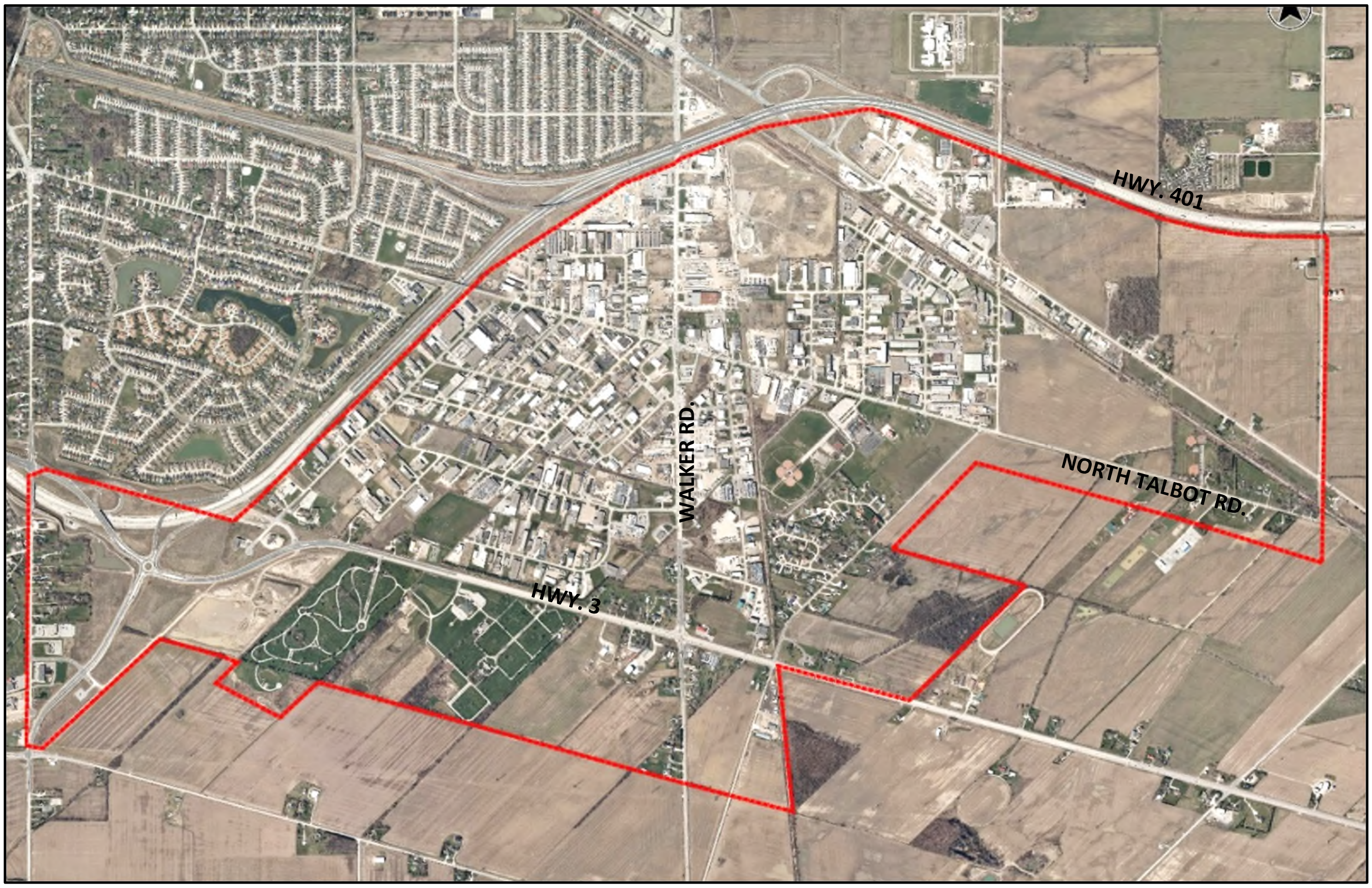
OLDCASTLE STORMWATER MASTER PLAN
FINAL REPORT



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Landmark
Engineers Inc.

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EXECUTIVE SUMMARY

INTRODUCTION

In recent years, the issue of flooding has increasingly become a major concern in the Town of Tecumseh and the Windsor-Essex Region. Extreme rainfall events in September 2016 and August 2017 each caused significant flooding of local roads, homes, and businesses – with hundreds of reports of flooding received by the Town as a result of each event. In response, the Town of Tecumseh successfully applied for funding through the *National Disaster Mitigation Program* and subsequently commissioned the *Storm Drainage Master Plan* for the northern portion of the Town that was most affected by the flooding. That study was completed in June 2019.

Landmark Engineers was subsequently retained by the Town of Tecumseh in June 2019 to develop a Stormwater Master Plan for the Oldcastle Hamlet area, in the southwest corner of the Town. The drainage infrastructure in this area (also known as the Oldcastle Business Park) has been developed over the years in fragmented manner – generally in response to individual developments, dating back to pre-amalgamation. Given the economic importance of this business park and the drainage issues that are known to exist in the area, an updated, holistic planning approach to stormwater management was deemed to be warranted.

Based on the above, the Landmark Engineers has prepared this *Oldcastle Stormwater Master Plan* on behalf of the Town of Tecumseh. It was the purpose of this report to:

- Inventory, assess, and confirm the capacities of the existing stormwater drainage system;
- Identify and define local drainage issues and areas of concern;
- Review and assess the stormwater management needs for future development;
- Identify and assess potential drainage improvements; and,
- Prepare a prioritized strategy for implementing the proposed drainage improvements.

It should be noted that this *Oldcastle Stormwater Master Plan* has been developed in accordance with the procedures set out in the MEA's *Municipal Class Environmental Assessment*. Although this report has been prepared as a standalone technical document, for broader context and details regarding the accompanying public consultation process, it should be read in conjunction with the *Environmental Assessment (EA) Project File*.

STUDY AREA / EXISTING DRAINAGE SYSTEM

The study area for this Stormwater Master Plan generally encompasses the Oldcastle Business Park in the southwest quadrant of the Town of Tecumseh, and is generally bounded by Highway 401 to the north and west. The southern and eastern limits of the study area are more variable, but generally extend southerly just beyond Highway 3 and as far east as 9th Concession Road.

The current study area is located at the headwaters of three separate watersheds: with stormwater draining westerly toward Turkey Creek; northerly and easterly toward Little River; and southwesterly toward the Canard River. The drainage divide separating these three watersheds consists of a low ridge that generally runs along the Walker Road and Highway 3 rights-of-way.

Stormwater generated from within the study area is generally conveyed to the downstream drainage systems (located within the neighbouring municipalities of Windsor and Lasalle) via local storm sewers, roadside ditches, and open-channel drains. Each of the downstream receiving bodies within the Turkey Creek and Little River watersheds have recently been subject to hydrologic and/or hydraulic analyses via the *Turkey Creek Watershed Study* (ongoing), the *Upper Little River Master Drainage and Stormwater Management Plan* (2017), and the *Little River Floodplain Mapping project* (ongoing). The information compiled via these parallel studies was used to help model the overall drainage system.

STORMWATER MODELLING METHODS

In order to analyze and assess the performance of the existing (and future) drainage system, Landmark Engineers created a detailed hydrologic and hydraulic model of the study area and its downstream receiving bodies using PCSWMM Professional 2D software. Information from the Town of Tecumseh's Geographic Information System (GIS), archived as-built sewer design drawings, municipal drain reports, and the Ontario Ministry of Natural Resources and Forestry's *LiDAR-Derived Digital Terrain Model* were all used in constructing the model, with hydrologic inputs based on the *Windsor/Essex Regional Stormwater Management Standards Manual* (ERCA, 2018).

The dual-drainage model (incorporating both the minor drainage system of sewers, drains & culverts and the major drainage system of overland surface flow routes) was then calibrated based on actual field observations from five separate flow-monitoring locations during six separate rainfall events over the course of the study - measuring both water levels and flow velocities. The model's hydrologic and hydraulic parameters were carefully adjusted to validate the predicted water levels and flows - accounting for variables such as: the antecedent moisture condition in the soil; and the level of overgrowth/vegetation in the primary drains.

EXISTING DRAINAGE ISSUES

In identifying problems with the existing system, it was noted that the current drainage infrastructure within the study area was generally designed and constructed to a lesser standard than that which would be prescribed today. While perhaps not ideal, these systems can still provide an adequate level-of-service in conveying stormwater from most rainfall events. It was also noted that a full upgrade of the system to conform with modern standards would be highly impractical, disruptive and expensive.

Thus, rather than focusing on strict compliance with current standards, the model constructed for this Stormwater Master Plan was first used to identify and address the parts of the existing stormwater system that are significantly undersized and have deficient drainage capacity – where frequent and prolonged nuisance ponding will typically result.

Based on our review of the drainage model, our observations in the field, and our consultations with both local residents and Town of Tecumseh maintenance staff, existing drainage problems were identified at the following locations:

- Deficient drainage capacity has been noted in the minor drainage system (i.e., sewers, culverts & open drains) along Fasan Drive, Blackacre Drive (particularly near the intersection with Outer Drive), Halford Drive, Webster Drive, Del Duca Drive and Ure Street;

- The existing culvert on the Wolfe Drain crossing Outer Drive and the drain section along Outer Drive are substantially undersized, limiting outflow capacity for the entire upstream subwatershed (approx. 233 hectares);
- The open-channel segment of the Wolfe Drain immediately downstream of the Outer Drive culvert is excessively steeply graded, resulting in significant erosion and downcutting due to high flow velocities;
- A low-lying road sag was noted on Blackacre Drive just east of Outer Drive, resulting in frequent ponding due to the above-noted drainage deficiencies;
- Heavy brush, overgrowth and sediment accumulations have been noted on the Hurley Relief Branch Drain and on the Washbrook Drain, substantially restricting their flow capacities;
- Substantial sediment accumulations and standing water have been noted on the culvert enclosure of the 6th Concession Drain between North Talbot Road and the Highway 401 corridor;
- Castlewood Court has been observed to be very slow to drain, likely due to a suspected blockage in the culvert enclosure feeding the Wolfe Drain; and,
- Frequent and prolonged nuisance ponding has been observed at many locations within the study area (including Fasan Drive, Blackacre Drive, Del Duca Drive, Ure Street, and Oldcastle Road) due to blockages in the driveway access culverts along the roadside ditches.

In addition to the above, our review of the dual-drainage model for the study area revealed the following deficiencies with the major (i.e., overland) storm drainage system for conveying infrequent heavy storm events within the study area:

- Roadway sags lacking a proper overland flow outlet were identified along Fasan Drive, Blackacre Drive, Halford Drive, Webster Drive, Del Duca Drive, Ure Street, Dumouchelle Street, Moro Drive, Rossi Drive, Roscon Drive, Olympia Drive, Brendan Lane, and DiCocco Court;
- The existing Wolfe Drain along Outer Drive and east of Walker Road does not have sufficient capacity to convey stormwater from a 100-year flow event;
- The existing cross-section of the Washbrook Drain between North Talbot Road and 9th Concession Road does not have sufficient capacity to convey stormwater from a 100-year flow event; and,
- The existing roadside drain along North Talbot Road between Weston Park and 9th Concession Road does not have sufficient grade and is very slow to drain.

RECOMMENDED DRAINAGE IMPROVEMENTS

In order to address the known issues with the existing stormwater system (as outlined above), the following drainage improvements are recommended:

- New storm sewers along Fasan Drive, Blackacre Drive, Del Duca Drive, Ure Street, Castlewood Court and Oldcastle Road;
- Wolfe Drain improvements, including:
    - a new auxiliary Wolfe Drain, combined with storage via a new Blackacre Pond;
    - a 1200mm-diameter (dia.) enclosure of the Wolfe Drain along Outer Drive;
    - replacement of the existing culvert adjacent to Olympia Drive;
    - replacement of the storm sewer immediately east of Walker Road; and,

    - remedial works along the steep segment of the Wolfe Drain between Outer Drive and Highway 401;
- Deepening of the Collins Drain from Outer Drive to the Fasan Drive storm sewer outlet, combined with storage via a new Collins Pond - including replacement of all affected culverts;
- Replace (enlarge) existing storm sewer outlets to Wolfe Drain for Moro Drive, Rossi Drive, Olympia Drive and Brendan Lane;
- Replace (enlarge) existing storm sewer outlet to 6th Concession Drain for Halford Drive;
- Replace and re-route the Hurley Relief Branch Drain enclosure to a new Hurley Pond located along the south side of the railway;
- Washbrook Drain improvements, including:
    - immediate maintenance to remove blockages; and,
    - replacement of culvert through Weston Park;
- New Washbrook-Downing Pond to attenuate flows from Washbrook Drain, immediately upstream of the North Talbot Road crossing;
- Demonte Drain improvements, including:
    - replacement of existing storm sewer and culverts;
    - cleaning of the open-channel segments of the drain, as required to provide a reasonable level of service; and,
    - the establishment of a new overland flow route toward the 8th Concession Drain;
- Establish/secure/maintain overland flow routes at specific locations.

STORMWATER MANAGEMENT FOR FUTURE DEVELOPMENTS

In order to address the stormwater management needs for future developments within the current study area, the stormwater ponds noted above (i.e., the Oldcastle Heights Pond, the Downing Acres Pond, and the 9th Concession Pond) have all been sized to address both the stormwater quality and quantity requirements of the adjacent designated development blocks on a regional scale. Other large undeveloped areas within the study area will require individual stormwater management plans to address these requirements as set out in the *Windsor/Essex Region Stormwater Management Standards Manual* (ERCA, 2018).

For new infill developments located within the existing built-up sections of the study area, a set of simplified stormwater management criteria have been established as part of the overall study. These criteria establish clear and concise storage volume and release rate requirements for 4 separate categories of infill developments, based on the practical objective of not adversely impacting the existing drainage conditions.

ESTIMATED COSTS & IMPLEMENTATION

Based on the outcomes of our drainage model assessments, we recommend that the following measures be implemented to address the known drainage issues, and facilitate development within the study area:

Short-Term Improvements: $5.8 Million

We recommend that the Town endeavor to complete the following improvements as soon as possible - preferably within a 1- to 2-year timeframe:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
W.1	Wolfe Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	$3,550,000
8C.1	Demonte Drain Improvements	Drainage Act	Little River	9th Conc. Drain	$100,000
H.1	Hurley Relief Branch Drain Improvements	Drainage Act	Little River	Hurley Drain	$50,000
H.2	New Storm Sewer along Del Duca Drive	Schedule B	Little River	Hurley Drain	$1,000,000
H.3	New Storm Sewer along Ure Street	Schedule B	Little River	Hurley Drain	$450,000
9C.1	Washbrook Drain Improvements	Drainage Act	Little River	9th Conc. Drain	$620,000

Medium-Term Improvements: $11.2 Million

We recommend that the Town endeavor to complete the following improvements within a 10-year timeframe, or in conjunction with planned sanitary sewer improvements for the affected roadways:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
W.2	Collins Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	$1,130,000
W.3	New Storm Sewer along Fasan Drive	Schedule B	Turkey Creek	Wolfe Drain	$1,340,000
W.5	New Storm Sewer along Blackacre Drive	Schedule A	Turkey Creek	Wolfe Drain	$1,870,000
W.6	Replace Storm Outlets to Wolfe Drain	Schedule B	Turkey Creek	Wolfe Drain	$1,080,000
6C.1	Replace Halford Drive Storm Outlet	Schedule B	Little River	6th Concession Drain	$60,000
7C.1	New Storm Sewers along O'Neil Dr. & Moyhanan St.	Schedule A	Little River	7th Concession Drain	$230,000
H.4	Enlarge & Re-route Hurley Drain to New Hurley Pond	Schedule B	Little River	Hurley Drain	$3,320,000
9C.2	New Washbrook-Downing Pond	Schedule B	Little River	9th Concession Drain	$2,200,000

Long-Term Improvements: $6.4 Million

We recommend that the Town endeavor to complete the following improvements within a 20-year timeframe, or in conjunction with planned sanitary sewer improvements for the affected roadways:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
7C.2	New Storm Sewer along Hennin Street	Schedule A	Little River	7th Concession Drain	$370,000
9C.3	New Storm Sewer along Oldcastle Road, Castlewood Court and O'Neil Drive	Schedule A	Little River	9th Concession Drain	$1,880,000
9C.4	Extension of Washbrook Drain Enclosure	Drainage Act	Little River	9th Concession Drain	$4,170,000

Development-Driven Works: $8.6 Million

The following projects are stormwater ponds which serve to address stormwater management requirements of future development:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
9C.5	Oldcastle Heights Pond	Schedule B	Little River	9th Concession Drain	$1,310,000
9C.6	Downing Acres Pond	Schedule B	Little River	9th Concession Drain	$1,630,000
9C.7	9th Concession Pond	Schedule B	Little River	9th Concession Drain	$5,660,000

1.0 INTRODUCTION

1.1 BACKGROUND

On June 7th, 2019 the Town of Tecumseh retained Landmark Engineers Inc. to carry out a stormwater study and develop a Stormwater Master Plan (SMP) for the Oldcastle Hamlet area. This study area is located in the southwest corner of the Town of Tecumseh – commonly known as the Oldcastle Business Park. It is bound by Highway 401 to the north. Walker Road bisects the study area in the north-south direction, and North Talbot Road and Highway 3 serve as the main east-west roads. A key plan and site plan depicting the limits of the study area is provided in Figure A1.

It is our understanding that this study was commissioned in response to a pair of extreme rainfall events that affected the Windsor-Essex region in September 2016 and August 2017. These storms resulted in significant basement flooding along the south shoreline of Lake St. Clair – the Riverside neighbourhood of the City of Windsor and the northern part of the Town of Tecumseh, in particular. Due to the significant flood damage that was caused by these extreme events, the Town of Tecumseh qualified for financial assistance through the provincial *National Disaster Mitigation Program*. The Town proceeded first with the *Storm Drainage Master Plan* study of the northern portion of the Town (i.e., the area north of County Road 42), which was most affected by the extreme events. That study was carried out by Dillon Consulting and was completed in June 2019. This current study pertains to the Oldcastle Hamlet Settlement Area.

With flood mitigation as a catalyst, this study also provides the opportunity to take a comprehensive look at the existing drainage system. The Oldcastle Hamlet area drainage system has generally been developed in a fragmented fashion, in response to individual developments dating back to pre-amalgamation. The area will benefit from the holistic approach of this Stormwater Master Plan, which will consider improvement opportunities and constraints on a watershed scale.

This SMP report has been developed in general accordance with the procedures set out in the *Municipal Class Environmental Assessment (MCEA)*. Nevertheless, this report is intended as a standalone document that is part of, and may be read in conjunction with, the *Environmental Assessment (EA) Project File*.

1.2 OBJECTIVES

The main objectives of the Oldcastle Stormwater Master Plan (OSMP) were: to evaluate the capacity of the existing stormwater system in the Oldcastle Hamlet area; to identify the capacities needed for existing and projected future demands; and, to develop a prioritized strategy for implementing proposed improvements.

To achieve these objectives, the following tasks were undertaken:

- An assessment and review of the capacity of the existing stormwater system;
- Identifying local drainage issues and areas of concern;
- An assessment and review of the stormwater needs for future development;
- Identifying potential stormwater management improvement alternatives; and,

- Creation of a strategy for implementing the proposed improvements.

2.0 STUDY AREA CHARACTERISTICS & OVERALL CONTEXT

The following section describes the general characteristics of the study area and provides some overall context in terms of the existing land use, topography, soils, and drainage characteristics.

2.1 LAND USE

Figure A2 depicts the designated Land Use Plan for the Oldcastle Hamlet area of the Town of Tecumseh, which covers approximately 890 hectares (ha) – including approximately 220 hectares of impervious land cover (i.e., building roofs and paved surfaces), consisting primarily of Business Park, Hamlet Residential and Community Facility uses. Figure A3 depicts areas where future development blocks are intended / anticipated to occur.

2.2 TOPOGRAPHY

The topographic map provided in Figure A4 illustrates a clearly defined ridge bisecting the study area from north to south. This ridge is generally aligned with Walker Road through the study area. Elevations within the study area range between 185.0 and 192.0 metres above mean sea level, generally sloping away from the Walker Road ridge toward the southwest and northeast.

2.3 SOILS

According to the *Essex County Soil Map (Dominion Dept. of Agriculture & Ontario Agricultural College, 1949)*, the study area predominantly consists of Brookston Clay soil with a small area of Burford Loam (Shallow Phase). Brookston Clay is known to have a high runoff potential and very low infiltration rates when thoroughly wetted.

Given the scale of the study area, a geotechnical investigation was not deemed to be warranted for the purposes of this SMP. Geotechnical investigations are recommended for individual projects that stem from the recommendations of this report.

2.4 DRAINAGE PATTERNS

As illustrated by the ridge depicted in the topographic mapping, there is a drainage divide within the study area that results in the minor stormwater system draining to 3 separate watersheds: Turkey Creek to the west, Little River to the northeast, and Canard River to the southwest. Figure A5 depicts these watershed boundaries. Thus, the study area represents the upstream lands, or headwaters, for each of these three watersheds. The following subsections generally describe drainage characteristics of the subwatersheds that are contributing to the each of the three watersheds.

2.4.1 Turkey Creek Watershed

There is one subwatershed within the study area that contributes to the Turkey Creek watershed: the Wolfe Drain subwatershed area, which includes tributary drainage from the Collins Drain. Downstream of the study area limits, this area drains westerly along the north limit of the Windsor-Essex Parkway where the Wolfe Drain converges into the Cahill Drain at Cousineau Road. The Cahill Drain then crosses the Parkway approximately 1,000 metres downstream of Cousineau Road and flow continues westerly through the Town of LaSalle, until the Cahill Drain ultimately converges with Turkey Creek approximately 750 metres west of Malden Road.

The overall contributing area from Tecumseh lands is approximately 233 hectares (ha), with an overall existing impervious area of 118 ha (51% imperviousness).

2.4.2 Little River Watershed

There are six subwatersheds within the study area that contribute to the Little River watershed. All of these subwatersheds drain northerly and easterly through the City of Windsor, ultimately all converging into Little River at Baseline Road and between 9th Concession Road and County Road 17.

The overall contributing area from Tecumseh lands within the study area is approximately 755 ha, with an overall existing imperviousness of 21%. A summary of each subwatershed and its characteristics is provided in Table 1, below:

Table 1 – Subwatershed Characteristics

SUBWATERSHED	AREA (Hectares)			
	Total	Developed	Impervious	Agricultural
6th Concession Drain	53.7	53.7	31.8	0
7th Street Drain	29.4	29.4	20.6	0
7th Concession Drain	67.1	67.1	25.8	0
8th Concession Drain	22.0	22.0	15.6	0
Hurley Relief Drain	101.6	51.9	32.6	49.7
9th Concession Drain	480.9	95.7	31.9	385.2
OVERALL	**754.7**	**319.8**	**158.3**	**434.9**

It should be noted that the 8th Concession Drain subwatershed includes tributary drainage from the Demonte Drain. The 9th Concession Drain subwatershed includes tributary drainage from the Washbrook Drain, the Wellwood Drain, the Talbot-McCarthy Drain, the Downing Drain, the Beehan Drain and the Shuttleworth Drain.

2.4.3 Canard River Watershed

There is one subwatershed within the study area that contributes to the Canard River: the 3rd Concession Drain subwatershed area. The 3rd Concession Drain receives tributary drainage from the Dickson Drain, the Burke Drain, the Shreve Drain and the Benson Drain. Downstream of the study area limits, this area drains westerly through the Town of LaSalle from the Town limits at Howard Avenue (i.e., the Tecumseh-LaSalle boundary), to the East Branch of the Cahill Drain, approximately 490 metres west of Disputed Road. Here the flow turns southerly toward the Canard River, located approximately 300 metres south of Kelly Road.

The overall contributing area from Tecumseh lands is approximately 211 hectares (ha), which predominantly consists of undeveloped lands from both cemetery and agricultural land use, as well as a relatively small amount of commercial, suburban residential and roadway drainage.

2.5 DESCRIPTION OF EXISTING DRAINAGE SYSTEM

This section provides a general description of the existing drainage system for each subwatershed area.

2.5.1 Wolfe Drain Area (Turkey Creek Watershed)

The Wolfe Drain is an open channel that collects a significant portion of the study area west of Walker Road. It acts as the main artery for the local drainage system, collecting flows from the local storm sewers. The Collins Drain is also an open channel that conveys flows from Highway 3 as well as a few local roadways within the subwatershed. A significant portion of this area is serviced by relatively new storm sewers, whereas Blackacre Drive and Fasan Drive are still drained via shallow roadside ditches with driveway culverts and older perforated subdrains.

2.5.2 6th Concession Drain Area (Little River Watershed)

The 6th Concession Drain is an enclosed sewer within the study area, collecting flows from the tributary local storm sewers. The drain becomes an open channel with culverts through the Highway 401 corridor and outlets to a trunk storm sewer as it enters the City of Windsor residential development to the north of the highway, ultimately draining into the North Roseland stormwater facility.

2.5.3 7th Street Drain Area (Little River Watershed)

The 7th Street Drain is an enclosed sewer within the study area, draining Walker Road and its adjacent properties. This sewer turns easterly north of Provincial Road and outlets at a controlled rate to the 7th Concession Drain, with a stormwater pond adjacent to the drain for storage and flow attenuation.

2.5.4 7th Concession Drain Area (Little River Watershed)

The 7th Concession Drain is an enclosed sewer along North Talbot Road. As it turns northerly it becomes an open channel, which collects flows from roadside drains with driveway culverts and subdrains.

2.5.5 8th Concession Area (Little River Watershed)

The 8th Concession Drain is an open channel which collects flow from local storm sewers and open drains.

2.5.6 Hurley Relief Drain Area (Little River Watershed)

The Hurley Relief Drain is an open channel which collects flow from the Hurley Relief Branch Drain (enclosed) and the upper part of the Hurley Relief Drain (open channel). The former collects flow from shallow roadside drains with driveway culverts and older perforated subdrains, while the latter collects tile drainage and surface flow from the adjacent agricultural lands.

2.5.7 9th Concession Drain Area (Little River Watershed)

The 9th Concession Drain is an open channel that collects a significant portion of the study area east of Walker Road. Approximately 80% of the subwatershed consists of undeveloped agricultural lands which are drained via tile drainage and surface flow. One of the main tributary drains to the 9th Concession Drain is the Washbrook Drain, which consists of an enclosed section from Walker Road to 8th Concession Road. This section collects flows from North Talbot Road and its adjacent properties.

2.6 RELEVANT BACKGROUND STUDIES

A number of recent studies have evaluated the available capacity of the downstream drainage corridors with due consideration to the flows coming from the headwaters in the Oldcastle Hamlet area. These have included:

- The *Upper Little River Master Drainage and Stormwater Management Plan* (Stantec, 2017);
- The *Sandwich South Master Servicing Plan, Little River Floodplain Mapping* (Dillon, Ongoing);
- The *Wolfe, Cahill and Talbot Drains Stormwater Management Report* for Windsor-Essex Parkway Project (Dillon, 2012); and,
- The Howard/Bouffard Master Drainage Study (Dillon, Ongoing).

The following subsections generally summarize the information from the foregoing studies that is most relevant to the current stormwater master plan.

2.6.1 Upper Little River Master Drainage and Stormwater Management Plan

The Upper Little River watershed is located in the southeast part of the City of Windsor and the westernmost part of the Town of Tecumseh. The main branch of Little River originates south of Highway 401 and generally flows in a northerly direction toward the Detroit River. The drainage area of the Upper Little River watershed contributing to flows in Little River at the downstream limit of the study area (i.e., at the culvert under E.C. Row Expressway) is approximately 45 square kilometres (4,500 hectares). The portion of the Upper Little River watershed located within the Oldcastle Hamlet area is 755 hectares.

The *Draft Upper Little River Master Plan* (ULRMP) (Stantec, September 2017) included recommendations for 'Grouped Off-line Stormwater Management (SWM) Ponds' within specified SWM corridors. A SWM corridor was recommended to extend into the Oldcastle Hamlet study area along the 9th Concession Drain, the Washbrook Drain and the Downing Drain. A copy of Drawing No. 3 from the ULRMP showing the SWM corridors and proposed catchment areas has been included in Appendix A for reference purposes.

In reviewing Drawing No. 3 and the proposed ULRMP model, it was our interpretation that the Hurley Relief Drain was proposed to be re-routed to connect with the 9th Concession Drain through the proposed SWM corridor adjacent to the southern limit of Highway 401. The 6th Concession Drain, the 7th Street Drain, the 7th Concession Drain and the 8th Concession Drain were all considered to flow uncontrolled from the Oldcastle Hamlet area into the City of Windsor.

2.6.2 Sandwich South Master Servicing Report, Little River Floodplain Mapping

This ongoing study includes the preparation of updated floodplain mapping for the Upper Little River and its tributaries within the City of Windsor's Sandwich South lands. This study was initiated in June 2019 and is scheduled to be completed in 2022. The results of the current OSMP, specifically the estimated peak flow rates for each drain within the Oldcastle Hamlet area subwatersheds into the City of Windsor (see Section 5.4.8 of this report), were provided to the City for consideration in preparing the above-noted floodplain mapping.

2.6.3 Wolfe, Cahill and Talbot Drains Stormwater Management Report for Windsor-Essex Parkway Project

It is our understanding that the above-titled report (hereafter: *the Parkway Report*) supported the design and construction of the improved Wolfe Drain and Cahill Drain through the Herb Gray Parkway corridor. The Wolfe Drain begins in the Oldcastle Hamlet area of the Town of Tecumseh, and extends into the City of Windsor where it converges into the Cahill Drain at Cousineau Road along the north side of the Parkway. The Cahill Drain then continues westerly alongside the Parkway before turning southerly through submerged culverts under the Parkway and into the Town of LaSalle. The hydrologic and hydraulic analysis results presented in the October 2012 report identified the peak flow rate allocated to the Wolfe Drain subcatchment area within the current OSMP study area.

2.6.4 Howard/Bouffard Master Drainage Study

This ongoing study was initiated by the Town of LaSalle in order to: build on the stormwater solutions developed through the *Howard/Bouffard Planning Districts EA Addendum* (Dillon March 2017); define local flood mapping under existing conditions; establish long-term buildout conditions; and develop an implementation strategy for recommended drainage improvements. This study area is located in the northeast area of the Town of LaSalle and includes the aforementioned Cahill Drain as one of its main drainage channels. The study effectively considers the Cahill Drain flows from the Herb Gray Parkway up to Turkey Creek.

It is our understanding that the study relied upon the flows estimated in the aforementioned Parkway report. We note that questions have been raised regarding the approach taken to define these flows and the subsequent impacts to the downstream receivers through the Town of LaSalle. It has recently been acknowledged that the Town of LaSalle receivers may not currently have sufficient capacity to convey the Parkway's 100-year peak flow rate to a sufficient outlet. In response, the Essex Region Conservation Authority, in cooperation with the Town of LaSalle, the City of Windsor and the Town of Tecumseh, has engaged Landmark Engineers Inc. and Dillon Consulting Ltd. to undertake a coordinated hydrologic and hydraulic modelling study of the Turkey Creek watershed (hereafter: *the Turkey Creek Watershed Study*).

2.6.5 Turkey Creek Watershed Study

The primary objective of the ongoing *Turkey Creek Watershed Study* is to update the hydrologic and hydraulic models for the main channels within the Turkey Creek watershed. These are needed to better represent the current watershed and stream characteristics, to identify the residential, commercial and industrial areas that are at risk of flooding, and to facilitate the prediction of future water levels affected by climate change, future land-use changes, and future channel improvements (including the infill of existing floodplain areas under a two-zone floodway concept).

Part of the analyses for the *Turkey Creek Watershed Study* will be used to determine if a greater outlet capacity exists for the Oldcastle Hamlet area via the Wolfe Drain, as compared to what had previously been allocated through the *Parkway Report* and the subsequent design of the Herb Gray Parkway. It is anticipated that there is additional capacity available - primarily resulting from consideration of the existing stormwater management ponds in the nearby Southwood Lakes subdivision (located within the neighbouring City of Windsor). The current OSMP has considered several improvement options for the Wolfe Drain, for which the preferred option is dependant on the outcome of the *Turkey Creek Watershed Study* with regards to outlet capacity.

Notwithstanding the above, it is presumed that the City of Windsor may also want to utilize any additional downstream outlet capacity that is identified through the *Turkey Creek Watershed Study*. It was also noted that the costs of any new conveyance improvements on Turkey Creek through the Town of LaSalle are unknown at this time, and that establishing additional storage in the Oldcastle Hamlet area may be preferable to providing additional conveyance through LaSalle when evaluating potential improvement alternatives holistically at the watershed scale.

3.0 METHODOLOGY – HYDROLOGIC & HYDRAULIC MODELLING

To evaluate the capacity of the existing drainage system in the Oldcastle Hamlet area as well as to assess the impact of proposed improvements, a detailed hydrologic and hydraulic model was created using PCSWMM Professional 2D software (version 5.1.014). This section discusses the model setup, approach and input parameters.

3.1 MODEL SETUP

The model setup consisted of a detailed inventory and input of storm sewer information compiled from the Town's Geographic Information System (GIS) information and various as-built drawings. Municipal drain reports were also reviewed to identify open channel characteristics, culvert sizing, and vertical profile information.

After completing our review of the foregoing, a number of data gaps were identified, particularly with regard to municipal drain and culvert profile information that was often based on an arbitrary vertical datum. Thus, a significant amount of field work was undertaken to resolve these data gaps and complete the detailed model setup. Over the course of our survey work, we surveyed culvert inverts as well as drainage report benchmarks in order to correlate the arbitrary datums with proper geodetic elevations. The results of this benchmarking exercise are summarized in Appendix B.

With regard to the vertical drain profiles, it was deemed appropriate to use 2017 LiDAR-derived Digital Terrain Model (DTM) data to obtain drain cross-sections. LiDAR-derived sections are reasonably accurate to depict a cross-section within a tolerance of about 0.1 metres along the banks of a drain, as compared to actual surveyed sections. This tolerance is sometimes slightly larger (i.e., up to approx. 0.3 metres) at the bottom of the drain due to the potential for standing water and/or thick-matted vegetation. Nevertheless, the LiDAR data typically gives a representative, albeit slightly smaller (conservative), cross-section.

3.2 MODEL APPROACH

A dual-drainage system model was created; wherein the minor system was represented by sewers, drains and culverts; and the major system (i.e., surface flow) was represented by typical roadway cross-sections and overland flow swales. This approach allowed us to simulate the interaction between pipe flow and surface flow/ponding.

With regard to representing surface flow/ponding, the LiDAR data and GIS tools were used to clearly illustrate localized sags at varying depths. It was evident from the sag maps (see Figures A6 through A8) that some undeveloped or partially-developed properties currently have low-lying areas that are prone to collecting surface water. Accounting for these depressions would unreasonably reduce design surface water levels, since this localized depression storage cannot be expected to remain with future development and re-grading of these lands. Thus, for the purposes of our model we ignored any incidental storage capacity located on private properties (i.e., the surface flow corridor and ponding extents was limited to the Town's right-of-way for the purpose of our model analysis).

3.2.1 Model Input Parameters

The hydrologic model inputs generally followed the *Windsor/Essex Region Stormwater Management Standards Manual* (ERCA, December 2018), with minor deviations to the infiltration parameters as described below.

Based on the observations from our model calibration, it was apparent that the actual hydrologic response for high-intensity thunderstorms during dry summer conditions was significantly dampened and runoff volumes were much lower than what the standard design infiltration parameters were producing. We found that adjusting clay conductivity rates to a relatively high value of 5 mm/hr provided a good fit under the foregoing conditions. While this rate is 10 times that for a typical, conservative standard design, it is very reasonable to expect that very dry clay will experience shrinking and exhibit fissures that would significantly increase infiltration rates - as compared to swelling clays under saturated conditions. Appendix C provides a more detailed discussion and summary of our calibration efforts as well as the specific inputs used in the modelling.

With regard to hydrologic flow estimation for agricultural lands, the PCSWMM groundwater routine was utilized to more closely mimic the observed hydrologic response within this region. We leveraged the hydrologic methodology which was used on a recent model calibration effort on the Ruscom River watershed. Details of the model calibration are included in Appendix C.

4.0 EXISTING STORMWATER SYSTEM CAPACITY

Once we were confident that the model was reliably simulating the hydrologic and hydraulic responses of the study area, we proceeded to evaluate the capacity of the existing system under various design storms - which considered the appropriate level of service and flood risk mitigation for the study area.

4.1 LEVEL OF SERVICE AND RISK

Modern stormwater standards, as prescribed in the *Windsor/Essex Region Stormwater Management Standards Manual*, outline specific design criteria for stormwater systems - including criteria related to drainage element sizing and allowable surface ponding depths. These criteria aim to provide a minimum standard for drainage capacity, which results in limiting nuisance ponding to infrequent rainfall events and further limiting the risk of flooding to extreme events.

The existing system was constructed to lesser standards than those specified in today's modern standards. Nevertheless, this SMP does not recommend replacement of the overall existing drainage system in order to conform with current standards, as this would be very impractical, disruptive and costly. Rather, this plan is intended to address the parts of the existing stormwater system that are deemed to be problematic and/or are found to have deficient drainage capacity.

It is important to make the distinction between what is sub-standard versus what would be considered deficient. In the context of this SMP, sub-standard describes a drainage system that is somewhat less efficient than a drainage system designed to modern standards. Regardless, these systems can still be effective and provide a sufficient amount of drainage to convey stormwater from most storm events. Deficient systems, however, create frequent and prolonged nuisance ponding as a result of issues such as (but not limited to): crushed driveway culverts, drain blockages, or significantly undersized drainage elements.

4.2 MINOR STORM SYSTEM CAPACITY

The minor or "convenience" system generally consists of designed drainage works, such as open drains and closed drains (i.e., culverts and sewer pipes) that convey stormwater flows from frequent events to limit the inconvenience of local ponding. Our model analyzed the existing minor storm system to confirm its conveyance capacities when subject to Standard design storms, as listed below:

- Water Quality Storm (32mm) with Chicago distribution – 20 minute timestep
- 2-year, 4-hour storm with Chicago distribution – 20 minute timestep

Our modelling confirms that a significant proportion of the minor system can adequately convey a 2-year design storm. In certain areas, however, the existing level of service is more in line with a water quality storm. Some capacity issues were revealed as illustrated in the modelling result figures presented in Appendix D; with the key minor system capacity deficiencies summarized (by drain subwatershed area) below:

4.2.1 Wolfe Drain Subwatershed

- The existing drainage capacity is deficient along Blackacre Drive and Fasan Drive.
- There is a notable drainage deficiency at Blackacre Drive near Outer Drive, resulting in excessive roadway ponding and access issues.

4.2.2 6th Concession Drain Subwatershed

- The existing drainage capacity is deficient along Halford Drive.

Landmark

4.2.3 8th Concession Drain Subwatershed

- The drainage along Webster Drive and across the private property to 8th Concession Drain is insufficient and in need of improvements.

4.2.4 Hurley Relief Drain Subwatershed

- The existing drainage capacity is deficient along Del Duca Drive and Ure Street.

4.3 OBSERVED DRAINAGE ISSUES

Over the duration of the two-year study, there were a few storm events with short-duration rainfall intensities that were comparable to that of a standard 5-year minor design storm. the two such examples occurred on 20 September 2018 and on 28 August 2020. We were able to validate our modelling findings through field observations of the actual drainage system's performance during and/or shortly following these significant rainfall events.

Several other drainage issues were also identified via our field work to resolve data gaps; through discussions with Town staff; and through comments provided by residents at the Public Information Centres that were convened as part of the Class Environmental Assessment of this project. These observations and discussions highlighted the following problematic issues:

1) The Wolfe Drain culvert crossing Outer Drive is significantly undersized, resulting in limited outflow capacity for the Wolfe Drain subwatershed area.
2) The Wolfe Drain open channel section between Outer Drive and Highway 401 is steeply graded (i.e., > 1%) and is experiencing notable downcutting and erosion from high flow velocities.
3) A number of local roadways, designed with subdrains, shallow ditches and culvert drainage systems, are experiencing varying levels of deficient drainage. While some culverts are in good condition, many others are crushed and/or filled with sediments - which is significantly limiting the flow capacity of the roadside drainage systems. In most instances, the resultant nuisance ponding is frequent and prolonged. This issue was observed along: Blackacre Drive, Fasan Drive, Del Duca Drive, Ure Street, and Oldcastle Road.
4) Blackacre Drive has a low-lying road sag between Outer Drive and Roscon Industrial Drive that is prone to deep ponding and restricted access as result of deficient drainage.
5) The Hurley Relief Branch Drain along the north side of the abandoned CASO rail right-of-way is significantly sedimented in - to the extent that it has plugged a significant portion of the 900mm-diameter culvert pipe crossing under the railway. This is significantly restricting flow capacity. The slope of the drain through this segment is very flat due to a lack of fall between the railway crossing and the County Road 46 culvert crossing. Consequently, the drain is prone to rapid sedimentation – with a corresponding need for frequent cleaning.
6) The Washbrook Drain has a significant blockage (~0.5m depth) located immediately north of North Talbot Road. Moreover, heavy brush and sedimentation is evident along the drain from North Talbot Road to County Road 46.
7) The 6th Concession Drain enclosure between North Talbot Road and the Highway 401 corridor is a chronic maintenance issue with substantial sedimentation and standing water in the pipe.

8) Castlewood Court has been observed by residents to take a long time to drain. It is suspected that the existing enclosure from Castlewood to Wolfe Drain may be partially blocked.

The foregoing issues are illustrated in Figure A9.

4.3.1 Conditional Assessment of Driveway Access Culverts

The scope of this SMP did not include a conditional assessment of the existing drainage infrastructure. However, based on the foregoing drainage issues with driveway access culverts, it was deemed warranted to undertake a more comprehensive assessment of these culverts throughout the study area. Appendix E provides a detailed inventory of our assessment (including photographs), as well as summary figures of our findings.

4.4 MAJOR STORM SYSTEM CAPACITY

The major system drainage consists of drainage features that convey flows from infrequent storms. These typically consist of surface features, such as roadways and swales, but can sometimes consist of larger underground pipes and drains. The major system supports the minor system by providing a pathway to safely convey excess runoff that the minor system cannot handle. The major system always exists, regardless of whether or not it is planned for.

4.4.1 Coarse Surface Flow Assessment

As a tool to provide a preliminary screening of potential surface flooding issues, a coarse surface flow model was created using GeoHECRAS 2D software. The model made the following simplifying conservative assumptions:

- Rainfall = Standard 100-year 4-hour design storm;
- Rainfall = Runoff (i.e., no rainfall is lost by infiltration or evaporation);
- Assumed 50% blockage of drain culverts; and,
- Drainage capacity limited to open drains, culverts and a few key storm sewer sections.

Appendix F depicts maximum flood depths and flood extents in four (4) main areas of concern. Deep ponding depths such as surface storage on roadways and parking lots, or ponding extents shown to encroach upon buildings do not necessarily mean that these areas are flood prone. These maps are intended only to highlight the potential for flood damage under an extreme rainfall event.

4.4.2 Dual-Drainage Model Assessment

A more detailed dual-drainage PCSWMM model, which considers the drainage capacity of both the minor (sewer) and major (surface) systems, was developed to more reasonably assess flood risk based on a standard 100-year level of service. The model analyzed the major storm system capacity under standard design storms, as listed below:

- For conveyance assessment: 100-year 4-hour storm with Chicago distribution and 20-minute timestep;
- For storage assessment: 100-year 24-hour storm with SCS distribution and 2-hour timestep;

- For peak flow assessment on larger watersheds: 100-year 12-hour storm with AES distribution and 1-hour timestep;
- For comparison with Wolfe Drain hydrology undertaken for the Parkway: 100-year 6-hour storm with Chicago distribution and 5-minute timestep (Infiltration based on Curve Number (CN) method with pervious CN of 82); and,
- For new stormwater pond assessments: Stress Test storm.

Our dual-drainage modelling revealed several areas of concern where the system's conveyance is limited and surface ponding is excessive (i.e., risk of flood damage and limited access). These areas are illustrated in the modelling result figures presented in Appendix G, with the key major system capacity issues summarized by drain subwatershed area below:

4.4.3 Wolfe Drain Subwatershed

- This subwatershed includes several roadway sag areas that lack a proper overland flow route (i.e., a surface water flow path that directs runoff away from buildings to a sufficient outlet). There is a need for major system improvements to mitigate excessive surface ponding throughout the area, particularly at the following roadway locations:
  - Moro Drive and Rossi Drive, approximately midway between Outer Drive and Pulleyblank Drive;
  - Roscon Drive at the cul-de-sac;
  - Blackacre Drive near Outer Drive;
  - Walker Road near Blackacre Drive;
  - Brendan Lane at its south limit;
  - Di Cocco Court at its north limit; and,
  - Fasan Drive at its west limit.
- The Wolfe Drain does not have sufficient capacity to convey the 100-year flow. The open drain section along Outer Drive and the enclosed section east of Walker Road are not sufficiently sized for the design 100-year flow, resulting in substantial surface ponding in the low-lying upstream lands.

4.4.4 6th Concession Drain Subwatershed

- Halford Drive and Dumouchelle Street each lack a proper overland flow route. There is a need for major system improvements to mitigate excessive surface ponding.

4.4.5 8th Concession Drain Subwatershed

- There is a need for major system improvements to mitigate excessive surface ponding on Webster Drive and the private property to the east.

4.4.6 Hurley Relief Drain Subwatershed

- Del Duca Drive and Ure Street each have the potential for significant surface ponding under a major storm event. While the topography provides some overland relief by directing flows toward the open field east of 8th Concession Road, it currently would have to do so by flowing in between existing buildings and across private properties in an unplanned manner. Significant roadway ponding would occur and relief would be limited to a relatively narrow stretch of 8th Concession Road that is low enough to provide a drainage outlet.

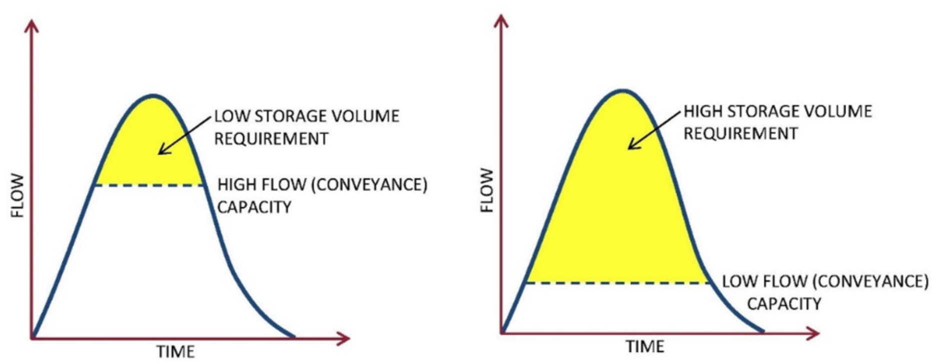
4.4.7 9th Concession Drain Subwatershed

- The drainage along North Talbot Road between Weston Park and 9th Concession Road has a very limited gradient (i.e., the roadside drain is very flat and consequently water can be very slow to drain until water levels in the downstream receiver (Washbrook Drain) subside).
- The Washbrook Drain between North Talbot Road and 9th Concession Road cannot convey the calculated 100-year flows. Consequently, a significant amount of storage occurs in the low-lying agricultural lands south of North Talbot Road as well as low-lying lands in (and adjacent to) Weston Park.

It is noteworthy that the potential access issues on Trafalgar Court and Piccadilly Avenue (as illustrated from our coarse surface flow assessment) would only occur under an extreme rainfall event that is well beyond the 100-year standard design storm.

4.5 OVERALL CAPACITY ASSESSMENT

It is evident from our model assessment that the existing system is in need of stormwater capacity improvements. There are two ways to improve the system’s ability to handle stormwater: an increase in conveyance and/or an increase in storage. The graphs below depict the relationship between conveyance and storage. The blue line conceptually illustrates how flow varies with time over the duration of a major storm event. The left graph illustrates that when flow capacity of the receiving drainage system is high, the corresponding storage volume needed during this event is low. Conversely, the right graph illustrates that when flow capacity at the outlet is low, the corresponding storage volume requirement is high.



When considering issues of low conveyance capacity, the potential solution that typically first comes to mind is to increase this capacity with larger infrastructure. While this often can be a reasonable approach, the current study area is limited as to how much flow it can direct to receiving drains in the neighbouring municipalities. These limitations are summarized in the following section.

4.6 DOWNSTREAM RECEIVER CAPACITY & EXISTING FLOWS

4.6.1 Wolfe Drain

The Wolfe Drain flows leave the current study area at the Highway 401 culvert crossing, where they enter the City of Windsor and continue along the Wolfe Drain to the Cahill Drain and ultimately through the Town of LaSalle to Turkey Creek. The *Wolfe & Cahill Drain Stormwater Report* (Dillon Consulting, October 2012) that was undertaken in support of the Herb Gray Parkway project included a hydrologic analysis wherein the peak flow rate on the Wolfe Drain at the downstream end of the Highway 401 culvert crossing was estimated to be 6.1 m^3/s. It is our understanding that this report served as the design basis of the constructed drain improvements through the Parkway corridor. It is also our understanding that this report is being relied upon for the current Howard/Bouffard Master Drainage Study, and serves as the current design basis for the proposed improvements being contemplated as part of that study.

By comparison, the estimated 100-year peak flow rate from the current OSMP dual-drainage modelling is 7.7 m^3/s. It should be noted that without accounting for existing overland relief flow, the peak flow was estimated to be 5.5 m^3/s.

4.6.2 6th Concession Drain

The 6th Concession Drain flows leave the current study area through the Highway 401 corridor at the interchange with Dougall Parkway. Once across the highway, flows are collected by a trunk storm sewer that runs through the North Roseland development in the City of Windsor. It is our understanding that this sewer was designed to accept an external flow (from Tecumseh and the Highway 401 corridor) based on a lumped subcatchment with the following hydrologic parameters:

- Area = 53.78ha
- Slope = 3%
- % Impervious = 37.2
- N Impervious = 0.011
- N Pervious = 0.24
- Dstore Imperv = 1.9mm
- Dstore Perv = 3.8mm
- Zero Imperv = 25%
- CN = 74 (pervious)

Presumably, the original design for the downstream trunk sewer would have used a 100-year 6-hour storm with 1-hour timestep, which would yield a peak flow rate of 4.4 m^3/s. In comparison, the estimated 100-year peak flow rate from the current OSMP modelling is 3.2 m^3/s.

4.6.3 7th Street Drain

The 7th Street Drain (enclosed sewer) flows leave the current study area at the City of Windsor boundary on Walker Road. These flows continue northerly along Walker Road and north of Provincial Road before being diverted easterly to the 7th Concession Drain. From our review of the *7th Street Drain Outlet Diversion Report* (Dillon, 2007) it appears that the 7th Concession Drain was designed to accommodate the peak flows from a 5-year storm for “current” (i.e., current at the time of the report) land uses within the Town of Tecumseh.

The *Upper Little River Master Plan* (ULRMP) accounted for 100-year flow rates of 6.8 m^3/s and 7.7 m^3/s coming from Tecumseh along the 7th Street Drain for the existing and proposed (i.e., future, fully-developed) condition, respectively. Our model extended this drain downstream of the study area, up to the future SWM corridor along the proposed east-west arterial (approximately midway between County Road 42 and Highway 401). By comparison, the estimated existing 100-year peak flow rate from the current OSMP modelling is 2.9 m^3/s.

4.6.4 7th Concession Drain

Flow from the 7th Concession Drain leaves the current study area through the Highway 401 corridor at the interchange with County Road 46. The *Upper Little River Master Plan* (ULRMP) accounted for 100-year flow rates of 8.1 m^3/s and 10.1 m^3/s coming from Tecumseh along the 7th Concession Drain for the existing and proposed condition, respectively. Our model extended this drain downstream of the study area, up to the aforementioned future SWM corridor. By comparison, the estimated existing 100-year peak flow rate from the current OSMP modelling is 2.0 m^3/s.

4.6.5 8th Concession Drain

Flow from the 8th Concession Drain leaves the current study area through the Highway 401 corridor along the 8th Concession Road right-of-way. The *Upper Little River Master Plan* (ULRMP) accounted for 100-year flow rates of 3.8 m^3/s and 3.6 m^3/s coming from Tecumseh along the 8th Concession Drain for the existing and proposed condition, respectively. Our model extended this drain downstream of the study area, up to the aforementioned future SWM corridor. By comparison, the estimated existing 100-year peak flow rate from the current OSMP modelling is 0.7 m^3/s.

4.6.6 Hurley Relief Drain

Flow from the Hurley Relief Drain leaves the current study area through the Highway 401 corridor at a point approximately halfway between 8th Concession Road and 9th Concession Road. The *Upper Little River Master Plan* accounted for an existing-condition 100-year flow rate of 6.6 m^3/s coming from Tecumseh along the Hurley Relief Drain. While not explicitly identified, our interpretation of the ULRMP suggests that the Hurley Relief Drain should be re-routed to the 9th Concession via the proposed SWM corridor along the south side of Highway 401. It should be acknowledged that the Hurley Relief Drain currently converges with the 9th Concession Drain approximately 300 metres downstream (i.e., north) of Highway 401. Based on the foregoing, a proposed-condition 100-year flow rate is not specified for this drain. By comparison, the estimated existing 100-year peak flow rate from the current OSMP modelling is 3.2 m^3/s.

4.6.7 9th Concession Drain

The 9th Concession Drain flows leave the current study area through the Highway 401 corridor at 9th Concession Road. The Upper Little River Master Plan accounted for 100-year flow rates of 9.6 m^3/s and 6.9 m^3/s coming from Tecumseh along the 9th Concession Drain for the existing and proposed condition, respectively. By comparison, the estimated existing 100-year peak flow rate from the current OSMP modelling is 5.4 m^3/s.

4.6.8 Canard River Drains

The local drains that flow toward the Canard River leave the current study area along the southern limit of the Oldcastle Hamlet (i.e., south of Highway 3). These drains include: the Shreve Drain, the Dickson Drain, the Benson Drain and the Burke Drain. To the best of our knowledge, the capacities of these receivers from the current study area limits to a sufficient outlet (i.e., the Canard River) have not been assessed to date. By default, the capacity of these receivers has been assumed to be limited to typical agricultural drainage rates as specified in the *Windsor/Essex Region Stormwater Management Standards Manual* (ERCA, December 2018).

4.6.9 Flow Discrepancies between ULRMP and OSMP

In several instances, the foregoing comparisons between the ULRMP and OSMP flows show a significant discrepancy. This can be explained by the fact that the ULRMP model estimated peak flows based on the hydrologic response from a lumped catchment area that was assumed to be 60% impervious. In analyzing the subject catchment at a much smaller scale, the OSMP model approach represented the drainage area using several individual subcatchments, with an overall measured imperviousness of 38%. The OSMP model also considered the hydraulic routing limitations of the existing drainage system. By accounting for these details, in is our opinion that the OSMP inherently provides a more realistic representation of the peak flows generated by the drainage area.

5.0 STORMWATER MASTER PLAN

5.1 APPROACH

The Stormwater Management Plan (SMP) outlined herein has attempted to strike a balance between improved conveyance capacity and corresponding storage requirements, with the ultimate goal of improving drainage capacity and mitigating flood risk to the extent that is practical. While the existing stormwater system in the Oldcastle Hamlet area does not typically meet modern standards, the recommendations of this SMP do not advocate achieving these standards without due regard for the associated costs. As such, this SMP is intended to provide a practical strategy for flood risk mitigation and to substantially improve the level of service without overburdening the Town of Tecumseh by mandating marginally-warranted drainage improvements amidst many other competing priorities.

5.2 PROPOSED IMPROVEMENTS

The following subsections provide a general discussion of the drainage improvements we recommend, based on our analysis and review of the dual-drainage system model. The recommended improvements have been grouped here by drainage area, and further separated into more manageable components that could be undertaken as individual projects. The recommended projects have also been listed in a priority sequence and labelled for easy reference to the plans provided in Appendix H and the cost estimates provided in Appendix I. For example, "W.1" represents the improvements within the Wolfe Drain subwatershed that should be undertaken as the 1st priority project in the area.

5.2.1 Wolfe Drain Subwatershed

The recommended improvements for the Wolfe Drain subwatershed area are depicted in Figure H2 and summarized herein. A number of options are recommended within the lower reaches of the Wolfe Drain and Collins Drain, providing the Town with the flexibility to determine the preferred solution at a later date based upon the findings of the ongoing *Turkey Creek Watershed Study*. These options are presented in Figures H2.1 to H2.4 – as well as a summary matrix, identifying the specific improvements associated with each option.

W.1 As an initial improvement measure, construction of a new auxiliary Wolfe Drain is recommended, combined with the construction of the Blackacre Pond to provide additional storage capacity and to offset the increased flows from the conveyance improvements planned for Blackacre Drive and from various storm outlet upgrades within the subwatershed. More specifically, the new Auxiliary Wolfe Drain will convey a significant portion of Wolfe Drain flows (attenuated by the new Blackacre Pond) to alleviate the flows being directed to the Wolfe Drain section along Outer Drive. In addition, the new Auxiliary Wolfe Drain will provide a primary drainage outlet for the new Blackacre Drive storm sewer. This work will include:

- A 1200mm-diameter enclosure of the Wolfe Drain along Outer Drive;
- replacement of the existing culvert adjacent to Olympia Drive;
- replacement of the storm sewer immediately east of Walker Road;
- remedial works to address the erosion concerns in the existing steep segment of the Wolfe Drain between Outer Drive and Highway 401; and,
- a high-stage spillway from the Wolfe Drain to the Blackacre Pond.

Alternatively:

- The Blackacre Pond is not required and a larger new auxiliary Wolfe Drain will convey higher flows under potential Option 4.

W.2 To accommodate improved conveyance from Fasan Drive, the Collins Drain needs to be lowered and additional storage capacity is needed to offset the increased flows. More specifically, the recommended improvements consist of the following:

- a deepening (and corresponding enlargement) of the Collins Drain from Outer Drive to the Fasan Drive storm sewer outlet - including replacement of all affected culverts;
- construction of the Collins Pond; and,
- re-grading of overland routes as designated in Figure H2.

Alternatively:

- The Collins Drain deepening is not required under Option 2; and,
- The Collins Pond is not required under potential Options 3 & 4.

W.3 To address deficient drainage on Fasan Drive, a new storm sewer is recommended - including the establishment of a new overland flow route from Fasan Drive to the Collins Drain, as specified. Interim improvements may also be necessary, as discussed in section 5.3.1.

W.4 To address deficient drainage on Blackacre Drive, a new storm sewer is recommended. Interim improvements may also be necessary, as discussed in section 5.3.1.

W.5 To address deficient major storm routing areas, enlarging existing storm sewer outlets to the Wolfe Drain will improve major storm conveyance. More specifically, these sewers will replace existing storm sewer outlet sewers for Moro Drive, Rossi Drive, Olympia Drive and Brendan Lane, including re-grading to implement specified overland routes.

Consideration should also be given to raising the Blackacre road sag (near Outer Drive) as part of any future infrastructure improvements.

5.2.2 6th Concession Drain Subwatershed

The recommended 6th Concession Drain subwatershed area improvements are depicted in Figure H3 and summarized as follows:

6C.1 To address deficient major storm routing, replacement of the Halford Drive storm sewer is recommended; including the establishment of new overland flow routes to 6th Concession Drain, as specified. With regard to the identified sedimentation issue in the 6th Concession Drain enclosure at the Highway 401 corridor, a re-alignment of the drainage ditch that converges with the enclosure outlet is recommended. This re-alignment should effectively redirect flows so that they enter the open drain segment of the 6th Concession Drain, flowing in the northerly direction.

It should be noted that more substantial routing improvements were considered for this area. However, the lack of gradient and the backwater conditions imposed by the receiving storm sewer (i.e., north of the Highway 401 corridor) would limit the effectiveness of installing larger storm sewers. Thus, the option of replacing all existing storm sewers in this area with larger storm sewers would have a disproportionate impact on reducing high water levels, and is therefore not deemed to be worthy of the added cost.

5.2.3 7th Concession Drain Subwatershed

The recommended 7th Concession Drain subwatershed area improvements are depicted in Figure H4 and are summarized as follows:

7C.1 To address deficient drainage, new storm sewers are recommended on Moynahan Drive & O'Neil Drive.

7C.2 The existing drainage along Hennin Street consists of drainage ditches and culverts that are generally in good condition. This drainage is currently providing a sufficient level of service. That being said, consideration should be given to replacing this rural type of drainage system with enclosed storm sewers, in conjunction with future sanitary sewer improvements.

5.2.4 8th Concession Drain Subwatershed

The recommended 8th Concession Drain subwatershed area improvements are depicted in Figure H3 and are summarized as follows:

8C.1 To address drainage deficiencies, improvements to the Demonte Drain are recommended. More specifically, we recommend:

- the replacement of existing storm sewer and culverts;
- the cleaning of the open-channel segments of the drain, as required to provide a reasonable level of service; and,
- the establishment of a new overland flow route toward the 8th Concession Drain.

5.2.5 Hurley Relief Drain Subwatershed

The recommended Hurley Relief Drain subwatershed area improvements are depicted in Figure H4 and are summarized as follows:

H.1 Immediate maintenance is needed on the Hurley Relief Branch Drain to remove the sedimentation along the north side of the railway and to remove the blockage of the culvert crossing the rail right-of-way. The sewers upstream of the culvert crossing should also be inspected and cleaned as required. (Note: an interim solution to clean the drain has been approved under the *Hurley Relief Branch Drain & Upper Part of the Hurley Relief Drain* report prepared by Rood Engineering Inc., dated November 20, 2019).

H.2 To address drainage deficiencies on Del Duca Drive, a new storm sewer is recommended - including a new storm outlet for future re-routing of flows toward the future Hurley Pond. (Note: Detail design is currently in progress as part of the *Del Duca Sanitary Sewer Improvements* project).

H.3 To address deficient drainage on Ure Street, a new storm sewer is recommended.

H.4 To accommodate the proposed conveyance improvements along Del Duca Drive and Ure Street, downstream conveyance improvements and corresponding storage capacity are recommended. More specifically, it is recommended to replace and re-route the Hurley Relief Branch Drain enclosure to a new Hurley Pond located along the south side of the railway.

5.2.6 9th Concession Drain Subwatershed

The recommended 9th Concession Drain subwatershed area improvements are depicted in Figures H4/H5 and are summarized as follows:

9C.1 Immediate maintenance is required on the Washbrook Drain to remove significant blockages. More specifically, the needed maintenance includes clearing & grubbing of overgrown vegetation and sediment removal along the Washbrook Drain between North Talbot Road and County Road 46. As part of this work, the drain should be re-graded, the drain enclosure through Weston Park should be replaced, and new berming should be installed to contain emergency floodplain storage from the Hurley Relief Branch Drain catchment area. The scope of work should also include the replacement of the Washbrook Drain field access culvert located between County Road 46 and 9th Concession Road.

9C.2 Additional storage capacity is needed to dampen existing flows from the Washbrook Drain enclosure and to accommodate flow increases from conveyance capacity improvements. This will be achieved with the construction of the new Washbrook Pond. The storage and corresponding flow attenuation provided by the pond will reduce flows on the downstream reach of the Washbrook Drain, which will correspondingly reduce the water levels in the drain and improve the conveyance capacity of the 'gradient limited' drainage along North Talbot Road (i.e., the Talbot / McCarthy Drain). Concurrently, the Downing Drain should be deepened by approximately 1.0m, starting from North Talbot Road to a point approximately 630m upstream, in order to accommodate a gravity outlet from the potential future Downing Acres Pond.

Alternatively:

- The Downing Drain deepening could be undertaken as part of item 9C.6; or
- The Downing Drain deepening and proposed Downing Acres Pond could be abandoned in favor of a single regional stormwater facility serving both the Washbrook Drain as well as the future Downing Acres development. In this case, the Downing Acres development would be expected to provide compensation for the benefit derived from off-site stormwater management.

9C.3 The existing storm sewer along Castlewood Court provides a reasonable level of service. However, the drainage along this local road is currently divided into two watersheds – as part of the development drains to Washbrook Drain and the other part drains to the Wolfe Drain via an enclosed sewer that currently drains across the rear yards of Trafalgar Court properties. It is recommended to re-route the eight properties nearest the cul-de sac from the Wolfe Drain to the Washbrook Drain via a new storm sewer along Castlewood Court. A new storm sewer is also suggested (but not strictly necessary) along Oldcastle Road to replace the rural type of drainage (i.e., roadside ditches and culverts) with enclosed sewer drainage. Notwithstanding the ultimate decision to maintain an open ditch or to enclose the ditch with a storm sewer, interim improvements are necessary in the short-term as discussed in section 5.3.1.

9C.4 It is anticipated that future development will result in a desire to extend the Washbrook Drain enclosure from 8th Concession Road to the North Talbot Road crossing. This work is not required from a conveyance capacity perspective.

The following 9th Concession Drain area improvements (9C.5 to 9C.7) would establish new storage capacity to accommodate future development and as such, the priority of each of these projects will be largely development-driven and may or may not precede the foregoing projects.

9C.5 Construction of the new Oldcastle Heights Pond to accommodate the proposed 21.4-hectare Oldcastle Heights Development. This pond is ultimately intended to be integrated as a regional stormwater facility consisting of two ponds (i.e., the Hurley Pond and the Oldcastle Heights Pond), connected by a linear drain as well as an emergency storage floodplain in the Weston Park baseball diamond area.

9C.6 Construction of the new Downing Acres Pond to accommodate 31.2 hectares of potential future residential development, located east of Oldcastle Road and north of Highway 3.

9C.7 Construction of the new 9th Concession Pond to accommodate 86 hectares of potential future industrial development generally bounded by: Highway 401 to the north, County Road 46 to the south, 8th Concession Road to the west and 9th Concession Road to the east. This pond will also accept and attenuate flows from the re-routed Hurley Relief Drain, with an additional catchment area of approximately 75.7 hectares. The future industrial development will require conveyance to pond by means of new infrastructure and road grading. Alternatively, consideration could potentially be given to improving the 9th Concession Drain, albeit this would require a re-routing of the 9th Concession Drain through the 9th Concession Pond and consideration to potential impacts on fish habitat.

5.3 PHASING & PROJECTED COSTS

5.3.1 Phasing

The previous section of this report generally outlines the scope of recommended drainage improvements in a priority sequence, sorted by drainage area. This section provides additional guidance regarding which projects should take precedence – as well as the timeframes recommended for completing the improvements. The following provides a summary of our recommendations, broken down into short-term, medium-term, and long-term projects. Refer to Appendix I for project listings and associated cost estimates. The estimates listed in this section under the Wolfe Drain subwatershed are based on Option 1b.

Irrespective of the timeframe for undertaking these improvements, we recommend that the Town proceed as soon as possible to secure the lands required for the improvements. Refer to Appendix M for details.

Short-Term Improvements: $5.8 Million

Based on our review and assessment of the dual-drainage model for the Oldcastle Hamlet area, we recommend that the Town endeavor to complete the following improvements as soon as possible - preferably within a 1- to 2-year timeframe:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate[1]
W.1	Wolfe Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	$3,550,000
8C.1	Demonte Drain Improvements	Drainage Act	Little River	9th Conc. Drain	$100,000
H.1	Hurley Relief Branch Drain Improvements	Drainage Act	Little River	Hurley Drain	$50,000
H.2	New Storm Sewer along Del Duca Drive	Schedule B	Little River	Hurley Drain	$1,000,000
H.3	New Storm Sewer along Ure Street	Schedule B	Little River	Hurley Drain	$450,000
9C.1	Washbrook Drain Improvements	Drainage Act	Little River	9th Conc. Drain	$620,000

The following discusses projects identified as medium-term to long-term where interim short-term measures should be considered:

- *W.3 (New Storm Sewer along Fasan Drive) & W.4 (New Storm Sewer along Blackacre Drive):*

  These new storm sewers are recommended to address problematic local drainage and would ideally be completed in the short-term. There is, however, a substantial number of improvements recommended within the Wolfe Drain subwatershed - and proper sequencing of these improvements will be necessary to accommodate the increase in conveyance capacity resulting from the new storm sewers. Thus, it is anticipated that the recommended timeframe will not be achievable for these two projects. As such, we have provided an interim recommendation to replace existing culverts that are in poor to very poor condition – as presented and summarized in Appendix E.

- *6C.1 (Replace Halford Drive Storm Outlet):*

  While this storm sewer replacement could be completed under a medium-term timeframe, the drainage ditch re-alignment and minor regrading to improve overland routing should be completed in the short-term.

- *9C.3 (New Storm Sewers along Oldcastle Road, Castlewood Court & O'Neil Drive):*

  These sewer improvements can generally be completed under a long-term timeframe. Nevertheless, there is an immediate need to improve drainage along the west side Oldcastle Road, from Castlewood Court to North Talbot Road - including the replacement of culverts that are in poor to very poor condition.

Medium-Term Improvements: $11.2 Million

We recommend that the Town endeavor to complete the following improvements within a 10-year timeframe, or in conjunction with planned sanitary sewer improvements for the affected roadways:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
W.2	Collins Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	$1,130,000
W.3	New Storm Sewer along Fasan Drive	Schedule B	Turkey Creek	Wolfe Drain	$1,340,000
W.5	New Storm Sewer along Blackacre Drive	Schedule A	Turkey Creek	Wolfe Drain	$1,870,000
W.6	Replace Storm Outlets to Wolfe Drain	Schedule B	Turkey Creek	Wolfe Drain	$1,080,000
6C.1	Replace Halford Drive Storm Outlet	Schedule B	Little River	6th Concession Drain	$60,000
7C.1	New Storm Sewers along O'Neil Dr. & Moyhanan St.	Schedule A	Little River	7th Concession Drain	$230,000
H.4	Enlarge & Re-route Hurley Drain to New Hurley Pond	Schedule B	Little River	Hurley Drain	$3,320,000
9C.2	New Washbrook-Downing Pond	Schedule B	Little River	9th Concession Drain	$2,200,000

Long-Term Improvements: $6.4 Million

We recommend that the Town endeavor to complete the following improvements within a 20-year timeframe, or in conjunction with planned sanitary sewer improvements for the affected roadways:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
7C.2	New Storm Sewer along Hennin Street	Schedule A	Little River	7th Concession Drain	$370,000
9C.3	New Storm Sewer along Oldcastle Road, Castlewood Court and O'Neil Drive	Schedule A	Little River	9th Concession Drain	$1,880,000
9C.4	Extension of Washbrook Drain Enclosure	Drainage Act	Little River	9th Concession Drain	$4,170,000

Development-Driven Works: $8.6 Million

The following projects are stormwater ponds which serve to address stormwater management requirements of future development:

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Preliminary Budget Cost Estimate
9C.5	Oldcastle Heights Pond	Schedule B	Little River	9th Concession Drain	$1,310,000
9C.6	Downing Acres Pond	Schedule B	Little River	9th Concession Drain	$1,630,000
9C.7	9th Concession Pond	Schedule B	Little River	9th Concession Drain	$5,660,000

5.3.2 Preliminary Cost Estimate

Preliminary cost estimates have been prepared to approximate the probable construction costs for budgeting purposes. At this planning stage, the expected level of accuracy would typically range from about -15% to +30%. The costs presented herein were prepared with the following considerations:

- The estimates were prepared based on 2021 dollars;
- No allowances were included for potential easement and land acquisition costs;
- No allowances were included for the testing, handling and disposal of excess soils - soil testing was not completed as part of the Master Plan due to the scale of the project and limited access to privately-owned properties;
- The estimates do not include the costs of application or permit fees;
- An overall allowance of 25% was included to account for engineering, geotechnical, archaeological and project administration costs;

- An overall allowance of 30% was included for contingency purposes; and,
- All cost estimates provided herein exclude HST.

5.4 DOWNSTREAM IMPACTS OF RECOMMENDED IMPROVEMENTS

Section 4.6 of this report discussed the capacity of the downstream receivers as well as modelled 100-year flows for the existing condition. This section summarizes the modelled 100-year flows for both existing and proposed (i.e., improved) conditions. The proposed condition accounts for all of the recommended improvements of this SMP - as well as full buildout of the designated future development blocks.

5.4.1 Wolfe Drain

When comparing the impact of each of the recommended options (see Figures H2.1 through H2.4), we note that Option 1a and Option 2 will both maintain flows along the Wolfe Drain below the existing 100-year peak flow rate of 7.7 m^3/s - whereas Option 1b will generally limit the flow to the allocated flow rate of 6.1 m^3/s[(1)] (as specified in the design documents for the Herb Gray Parkway). Options 3 & 4 would both exceed this existing flow condition and should only be considered as valid options if the ongoing *Turkey Creek Watershed Study* were to confirm that these additional flows could be released from the Oldcastle Hamlet area – and that all stakeholders (including the MTO) were in agreement with this increase in flow rate from Oldcastle.

Appendix J depicts hydraulic modelling results (i.e., plans, hydraulic grade line profiles and hydrographs) that demonstrate the benefit from each of the recommended drainage improvement options as compared to the existing condition.

The key area of concern is located along the low point of Highway 3, just east of Mun. No. 1100 (i.e., between model Junction J302 and J303) – where the new Collins Drain Pond has been proposed (see Figure J1 for a plan of the area). At this location, the predicted 100-year water level for the existing condition extends to the edge of pavement on Highway 3. As depicted in Figures J2 and J3, the recommended improvements associated with Option 1b would result in a 0.23 metre (m) reduction to the high-water level at this location. This option does not provide the largest reduction in water level, but it does generally limit the flow from the Oldcastle area to the allocated flow rate of 6.1 m^3/s[(1)] (as specified in the design documents for the Herb Gray Parkway).

A reduction in the high-water level at the Highway 3 low point of as much as 0.41m could be achieved with the implementation of either Option 1a or Option 2 – either of which would result in a peak flow of approximately 7.6 m^3/s, which less than the existing flow rate of 7.7 m^3/s (see Figure J4 for flow hydrographs).

[(1)] Technically, the model estimates a maximum peak flow of 6.63 m^3/s. However, as depicted in Figure J4 of Appendix J, the duration which the peak flow exceeds 6.1 m^3/s is relatively short and the excess volume is marginal in comparison to the total flow volume. Moreover, it should be acknowledged that the Wolfe Drain downstream of the study area (i.e., from Highway 401 to Howard Avenue) includes a relatively wide floodplain as well as a stormwater pond at the northeast corner of Howard Avenue and Highway 401. Thus, the marginal excess volume can reasonably be expected to have no adverse impact on the downstream receivers.

Also shown in Figure J4 are flow hydrographs for Options 3 and 4. Again, these two options would only be valid if the findings of the ongoing *Turkey Creek Watershed Study* determine that the downstream receivers can safely convey these peak flows. As shown in Figure J3, the high water levels associated with Options 3 and 4 are similar to that of Option 1b at the key area of concern (i.e., low point of Highway 3, adjacent to new Collins Drain Pond).

It should be noted that all of the options under consideration result in a net improvement (i.e., a decrease) to the hydraulic grade line, as compared to the existing condition.

5.4.2 6th Concession Drain

our review of the original design parameters for the 6th Concession Drain suggests that the allocated flow rate for this subwatershed is 4.4 m^3/s at the northern limit of Highway 401. Through this OSMP, we have modelled an existing flow rate of 3.2 m^3/s and a proposed flow rate of 3.3 m^3/s. The increase in flow is marginal and the proposed peak flow rate is notably less than the allocated flow. Thus, we conclude that the proposed improvements will not adversely impact the downstream receiver.

5.4.3 7th Street Drain

Considering both the existing and proposed peak flow rates estimated in the ULRMP at the southern limit of the Highway 401 corridor, the existing flow rate of 6.8 m^3/s is the lesser rate. The current OSMP modelled an existing and proposed peak flow rate of 2.9 m^3/s. Thus, there is no impact to the downstream receiver as the existing and proposed peak flows estimated by the OSMP are the same; and these flows are below the ULRMP flow estimates.

5.4.4 7th Concession Drain

Considering both the existing and proposed peak flow rates estimated in the ULRMP at the northern limit of the Highway 401 corridor, the existing flow rate of 8.1 m^3/s is the lesser rate. We have modelled an existing flow rate of 2.0 m^3/s and a proposed flow rate of 2.2 m^3/s as part of this OSMP. We note that our modelled flows represent a significant deviation from the flow predicted in the ULRMP, which is explained in section 4.6.9.

With regard to the proposed increase in flow (i.e., from 2.0 m^3/s to 2.2 m^3/s), we note that the 7th Concession Drain can sufficiently contain and convey the proposed increase up to the extents of our model analysis, which is the future SWM corridor along the proposed east-west arterial (approximately midway between County Road 42 and Highway 401 – see Figure A10).

5.4.5 8th Concession Drain

Considering both the existing and proposed peak flow rates on the 8th Concession Drain at the southern limit of the Highway 401 corridor (as estimated in the ULRMP), the proposed flow rate of 3.6 m^3/s is the lesser rate. We have modelled an existing flow rate of 0.7 m^3/s and a proposed flow rate of 1.0 m^3/s as part of this OSMP. We note again that our modelled flows represent a significant deviation from the ULRMP flow rate. This deviation is primarily attributed to the hydraulic routing limitations of the existing drainage system, which is accounted for in the OSMP model.

With regard to the proposed increase in flow (from 0.7 m^3/s to 1.0 m^3/s), we note that the 8th Concession Drain can sufficiently contain and convey the proposed increase up to the extents of our model analysis, which is the future SWM corridor along the proposed east-west arterial.

5.4.6 Hurley Relief Drain

An existing peak flow rate of 6.6 m^3/s has been estimated for the Hurley Relief Drain at the southern limit of the Highway 401 corridor in the ULRMP. We have modelled an existing flow rate of 2.7 m^3/s. Similar to the explanation given for the deviation on the 7th Concession Drain (section 5.4.4), this flow deviation can be attributed to: the actual imperviousness of 32% measured in the OSMP (as compared to an assumed imperviousness of 60% in the ULRMP); and, hydraulic routing limitations considered in the OSMP but not in the ULRMP. Under the proposed condition, the drain is to be re-routed to the 9th Concession Pond, which will outlet at a controlled rate into the 9th Concession Drain.

5.4.7 9th Concession Drain

Considering both the existing and proposed peak flow rates on the 9th Concession Drain at the southern limit of the Highway 401 corridor (as estimatedin the ULRMP), the proposed flow rate of 6.9 m^3/s is the lesser rate. As part of the current OSMP, we have modelled both the existing and proposed peak flow rates to be 5.4 m^3/s. Thus, not only will the 9th Concession Pond serve to mitigate the adverse drainage impacts from future development, but it will also provide flow attenuation for the re-routed Hurley Relief Drain - resulting in a positive impact (i.e., reduction in flow) to the downstream receivers. Based on the preliminary capacity assessments of the ongoing *Little River Floodplain Mapping* project, additional outflows from the 9th Concession Pond could be considered. At this time, however, the OSMP model estimates that the 9th Concession Drain is at its capacity limit south of Highway 401, and as such, it is prudent to assume that the downstream receiver may not be able to safely accommodate increased flow rates.

5.4.8 Comparison of ULRMP and OSMP Flows

We have compared the flows for each drain in the Little River watershed – as predicted through the ULRMP and the current OSMP, based on the 100-year 24-hour Chicago storm used in the ULRMP. These comparisons are summarized below in Table 2 for both the existing and the proposed condition. We have also summarized how these flows compare to the OSMP design storms (i.e., the 100-year 4-hour Chicago storm and 100-year 12-hour AES storm). It should be noted that all tabulated flows are compared at boundary between the Town of Tecumseh and the City of Windsor.

We wish to clarify that the overall summation of flows is provided in the table primarily to demonstrate the magnitude of the cumulative impact resulting from the deviations between the predicted ULRMP and OSMP flows. The summed flows do not capture the hydrologic routing and contributing flows downstream of the Tecumseh-Windsor boundary, nor do they include Tecumseh's flow contribution from the 6th Concession Drain sub-watershed.

Table 2 – 100-year Peak Flows (m^3/s) @ City Limits

AREA	ULRMP		OSMP							
	100y24h		Max.		100y24h		100y4h		100y12h	
	Ex.	Pr.	Ex.	Pr.	Ex.	Pr.	Ex.	Pr.	Ex.	Pr.
7th St.	6.8	7.7	3.0	3.0	3.0	3.0	2.9	2.9	1.2	1.2
7th Conc.	8.1	10.1	2.2	2.4	2.2	2.4	2.0	2.2	1.7	2.0
8th Conc.	3.8	3.6	0.7	1.1	0.7	1.1	0.7	1.0	0.6	0.9
Hurley	6.6	-	3.4	-	3.4	-	3.2	-	2.6	-
9th Conc.	9.6	6.9	5.4	5.4	4.3	4.8	4.1	4.3	5.4	5.4
OVERALL	34.9	28.3	14.7	11.9	13.6	11.3	12.9	10.4	11.5	9.5

5.4.9 Canard River Drains

To our knowledge, the capacity of these receivers from the current study area limits to a sufficient outlet (i.e., the Canard River) has not been assessed. By default, the capacity of these receivers is assumed to be limited to agricultural drainage rates as specified in the Standards. It is our understanding that no improvements or development are currently planned for this subwatershed.

5.5 FUTURE DEVELOPMENT

The future development blocks designated in Figure A3 have all been accounted for in the preliminary sizing of the stormwater ponds discussed in Section 5.2. These ponds are intended to address stormwater management quality and quantity requirements at a regional scale for the designated future development blocks. Preliminary pond design stage-storage-outflow relationships are summarized in Appendix K.

- Other large undeveloped areas within the study area will require individual stormwater management plans to address both quality and quantity control and limit runoff to agricultural discharge rates, as prescribed in the *Windsor/Essex Region Stormwater Management Standards Manual* (ERCA, December 2018). These undeveloped lands include:lands south of County Road 46, east of Walker Road and north of Moynahan Street; and,lands south of Highway 3.

All other vacant properties will generally fall under “infill development”, which is discussed in the following section.

5.6 INFILL DEVELOPMENT

The term ‘infill development’ may have a different meaning from a planning versus a stormwater management perspective. Within the context of stormwater management, infill development should consider any development within an area that was built-up before the need for stormwater management was recognized (or areas built to an older SWM standard). For these types of developments, the minimum objective is to ensure that the infill does not adversely impact the existing condition. Infill development should never make things worse, nor should it be required to improve or rectify an existing sub-standard condition - unless there is a practical opportunity and a willingness to do so on the part of the developer.

For the purposes of this OSMP, we recommend that a simplified approach be adopted to determine the stormwater management (SWM) requirements for new infill developments. This will help to expedite approvals and will translate to cost savings to both the Town and private developers. In addition, this approach would provide an equitable and easy-to-implement standard for all infill developments across the entire study area - irrespective of the hydrodynamics of the drainage system at any given point for any given storm. The recommended approach does consider varying degrees or levels of SWM, based on the nature and the size of the proposed development (e.g., full development of an undeveloped parcel versus a small addition to an existing development). A detailed discussion on the rationale for the recommended approach is provided in Appendix K.

In summary, the recommended SWM requirements for infill developments within the Oldcastle Hamlet area have been categorized into four distinct levels: Normal; Exempt; Basic; and Enhanced - as described below.

5.6.1 Infill SWM – Normal

This SWM level will generally apply as the default requirement for all infill development, with possible exceptions as described within this section (as well as in the following subsections for Exempt, Basic and Enhanced SWM requirements). To achieve this level, the following SWM criteria shall apply:

- Storage Volume Required (m^3/ha) = 3 x (Imp %) + 100; per hectare of overall property area.
- Allowable Release Rate (m^3/s/ha) = 0.054; per hectare of overall property area.

Because the foregoing SWM measures will generally apply to the entire property area of an existing development, they will tend to result in a gradual improvement over the existing condition, in which a number of pre-existing building sites have very limited storage (i.e., flow attenuation) on their property.

It should be noted that the existing conveyance system capacity assessments and proposed SMP improvements outlined in this report do not account for the future flow attenuation anticipated from these SWM measures for infill developments. Thus, the existing and future conveyance system capacity assessments outlined in this report represent the worst-case scenario - whereby the foregoing SWM measures are expected to cumulatively increase the level of service and resiliency of the system as infill development (combined with the recommended SWM measures) progresses.

Interim Conditions:

The OSMP has identified several specific areas where the existing drainage system is providing a substandard level-of-service. In these areas, a lower allowable release rate (and a corresponding higher storage volume requirement) is recommended to control flows in a manner that will not exacerbate the known deficiencies in the existing drainage system. This would apply to the following areas until the corresponding improvements (specified in brackets) are completed:

- The Wolfe Drain subwatershed – See Figure A5 (W.1);
- Halford Drive (6C.1);

- Demonte Drain (8C.1);
- Del Duca Drive (H.2); and,
- Ure Street (H.3).

For infill developments in the above-noted areas, we recommend that the following interim SWM criteria be applied until such time as the recommended improvements are implemented:

- Storage Volume Required (m^3/ha) = 3 x (Imp %) + 170; per hectare of overall property area.
- Allowable Release Rate (m^3/s/ha) = 0.038; per hectare of overall property area.

7th Street Drain Subwatershed:

The 7th Street Drain was designed based on a 5-year return period. For infill developments within this subwatershed, we recommend that the following interim SWM criteria be applied:

- Storage Volume Required (m^3/ha) = 5.8 x (Imp %) – 350; per hectare of overall property area.
- Allowable Release Rate (m^3/s/ha) = 0.097; per hectare of overall property area.

5.6.2 Infill SWM – Exempt

This SWM level will generally apply to minor infill development activities such as: the paving of existing gravel parking lots; and small parking lot expansions and/or building additions of less than 5% of the total property area. In these instances, no specific SWM requirements are recommended, although the implementation of SWM measures should be encouraged to the extent that is practical.

5.6.3 Infill SWM – Basic

This SWM level will generally apply to infill development activities on properties with: existing imperviousness in excess of 60%; and, where a 'Normal' level of SWM is not practical (i.e., new storage cannot be reasonably accommodated via surface storage in parking lots and/or grassed depressions). A 'Basic' level of SWM is intended to meet the minimum objective of ensuring that the proposed development does not adversely impact the existing condition. To achieve this level, the following storage volume criteria should be applied:

- Storage Volume Required (m^3) = 340 x New impervious area (ha).

5.6.4 Infill SWM – Enhanced

This SWM level will generally apply to infill developments where the consequences of storage exceedance (and subsequent spills onto adjacent lands) would pose an unacceptable risk. To be clear, our definition of 'unacceptable risk' means that the consequence of exceedance is likely to cause severe damage. It does not mean that the consequence of any negative or undesired outcome is unacceptable. Examples of this would include: the nuisance and access issues associated with surface ponding depths exceeding 0.3 metres; or minor flood damage from surface ponding encroachment onto buildings or vehicles. Such consequences are generally considered acceptable for extreme storms exceeding the 100-year floodproofing standard.

To achieve an 'Enhanced' level of SWM, an additional storage volume requirement due to Backwater (over and above the 'Normal' level requirements) is recommended:

7th Street Drain Subwatershed:

- Additional Storage Volume due to Backwater (m^3) = Q_{allow} (m^3/s) x 1,800 seconds

All Other Subwatersheds:

- Additional Storage Volume due to Backwater (m^3) = Q_{allow} (m^3/s) x 3,600 seconds

As an added measure, the 'Enhanced' level of SWM should also consider the potential to contain the additional storage volume from the Stress Test; to the extent that is practical (i.e., the additional storage can be reasonably accommodated via surface storage). The additional storage volume for Stress Test can be approximated using the following:

7th Street Drain Subwatershed:

- Additional Storage Volume for Stress Test (m^3/ha) = Per table below:

Impervious %	Storage Volume (m^3/ha)
50	10
60	40
70	60
80	70
90	50
100	30

All Other Subwatersheds:

- Additional Storage Volume for Stress Test (m^3/ha) = 200 – 1.8 x (Imp %); per hectare of overall property area.

5.7 FLOODPROOFING

As a typical standard, the lowest opening elevation on a building should be at least 0.3 metres (m) above the 100-year on-site storage elevation. While best efforts should always be made to achieve this standard, some flexibility is also necessary to accommodate pre-existing conditions that were constructed prior to the implementation of modern floodproofing standards.

With regard to floodproofing above the water levels anticipated through the modelling of the Town's drainage system, Appendix L provides estimated 100-year elevations for information purposes only. In reviewing these elevations, it must be acknowledged that:

1) These elevations are not Regulatory floodline elevations and are not intended to be applied as a floodproofing requirement – either as the denoted elevation or as a sum of the elevation plus a freeboard depth.

2) These elevations are conservatively derived as explained in Section 3 of this OSMP. Thus, it would not be unreasonable to consider these elevations without any freeboard as a sufficient floodproofing measure up to a 100-year return period.
3) In certain cases, these elevations exceed the existing finish grades approximated by the LiDAR topographic data. Actual flood risk and potential damages should be assessed for individual properties with consideration that lowest building openings may be above the LiDAR-derived finish grade elevations. These locations have been highlighted in the figures of Appendix L as critical areas. This SMP cannot practically eliminate all flood risk - and thus, the owners of the highlighted properties should consider mitigation measures on their respective properties to reduce any unacceptable risk as they see fit.

Notwithstanding the above, a preferred floodproofing elevation would not only provide a freeboard depth but would also ensure that the lowest building opening was above the highest surface ponding elevation that could occur before water spilled along an overland route. This type of assessment can be performed relatively easily with open-source LiDAR data. Wherever possible, a minimum 0.2m freeboard should be added to the spill elevation to account for flow depth - as well as the inherent errors in accuracy from both the LiDAR data and the constructed finish grades.

5.8 CLIMATE CHANGE RESILIENCY

Significant resiliency to handle extreme rainfall events will be provided by: the recommended stormwater system improvements and floodproofing guidance, which are based on conservative design standards; and, the recommended SWM measures for infill and future development. More specifically, we note that:

- the design 100-year 4-hour Chicago storm distribution used in our model assessments is a theoretical frequency distribution, not observed in nature, and gives the most intense storm possible for any given frequency and duration.
- our model approach ignores any on-site attenuation. As discussed in section 3.2 herein, we ignored any incidental storage capacity located on private properties (i.e., the surface flow corridor and ponding extents was limited to the Town's right-of-way for the purpose of our model analysis). As explained in section 5.6.1, recommended Infill SWM measures are expected to cumulatively increase the level of service and resiliency of the system as infill development (combined with the recommended SWM measures) progresses.
- a relatively low soil conductivity rate of 1 mm/hour was used as the design condition, while significantly higher rates – see section 3.2.1 for further discussion – could be expected to coincide with the more extreme high-intensity thunderstorms that typically occur in late summer or early fall within our region.
- storm relief sewers and overland flow routes are recommended to mitigate excessive surface ponding depths and associated flood risks.

In addition, a Stress Test simulation, as prescribed in the *Windsor/Essex Region Stormwater Management Standards Manual* (ERCA, December 2018), was undertaken to evaluate the resiliency of the stormwater system's storage capacity. Results confirm that all stormwater management pond sizing, as presented in Appendix K, includes sufficient capacity to contain the Stress Test event runoff within its banks.

5.9 ON-SITE STORAGE (SURFACE PONDING)

Where surface storage options on specific properties are limited to the parking lot areas, consideration should be given to relaxing the "Parking Lot Storage" requirement prescribed in the *Windsor/Essex Stormwater Management Standards Manual*, Section 3.3.2. This requirement is best suited for commercial areas where patrons are more likely to be burdened by frequent nuisance ponding resulting from surface storage during minor events. For a private industrial workplace, the effect of nuisance ponding would generally be limited to staff - and thus, the business owner should be afforded the discretion to weigh the impact of more frequent surface ponding against the added cost of underground storage. Nevertheless, the recommended WQS storage volumes are provided below for consideration:

WQS Storage Volume Required (m^3/ha) = 1.8 x (Imp %) – 130; per hectare of overall property area.

For Interim Conditions (as described in Section 5.6.1):

- WQS Storage Volume Required (m^3/ha) = 2.2 x (Imp %) – 135; per hectare of overall property area.

5.10 EASEMENTS & PROPERTY ACQUISITIONS

In order for the Town to implement any of the recommended conveyance improvements on privately-owned lands, an easement would be required. An easement is a legal right to use another's land for a specific limited purpose. In order to secure the easements required for the conveyance improvements, the Town would work with the individual property owners to determine fair compensation for use of the land for the intended purpose. An inventory of the proposed easements to be secured or established is provided in Appendix M.

Some relevant information regarding easements is provided below for information purposes:

- Property owners still own the land - the Town does not own the land the easement occupies.
- Permanent easements are typically 6 metres wide. Actual width required may be more or less depending on the size and type of stormwater infrastructure being proposed.
- A temporary easement may be required in addition to permanent easements. These temporary easements are known as working easements and are typically used strictly to provide additional access for heavy equipment during open-cut installation of sewers and for short-term maintenance access following construction.
- Easements are typically created along property lines, within the building setback for most lots.
- Depending on the intended use of the easement, the area may need to be kept clear of all obstructions, such as structures, parking lots and fences.
- An agreement between the property owner and the Town will detail the intended use and any use restrictions for the easement.

6.0 CONCLUSIONS

6.1 CLOSING REMARKS

Through the execution of this study, the Town of Tecumseh has been provided with an opportunity to take a comprehensive look at the existing drainage system in the Oldcastle Hamlet area and identify potential improvements that would complement and enhance the overall drainage system - with due consideration for the capacity of the downstream receiving bodies. As discussed herein, a strategic balance of conveyance and storage improvements has been recommended, which will significantly improve drainage capacity in the Oldcastle area.

Through the recommendations of this OSMP, the Town can provide clear and consistent guidance for addressing SWM measures in future developments - with the assurance that the new developments will not adversely impact downstream receiving bodies. In particular, the holistic approach outlined in the OSMP addresses many of the challenges commonly associated with SWM designs for the development of individual properties (i.e., infill developments).

6.2 RECOMMENDATIONS & IMPLEMENTATION

The following recommendations and requirements should be followed in order to faithfully implement the design intentions of the OSMP:

1. The recommended drainage improvement works should be undertaken based on the phasing plan outlined in Section 5.3 of this report.

2. The recommended drainage improvements include changes to a number of municipal drains, namely: the Wolfe Drain, the Collins Drain, the Washbrook Drain & the Hurley Relief Drain. These improvements will need to be implemented under the Drainage Act. Drainage boundary adjustments will also be required to implement the recommended improvements on Castlewood Court and the Oldcastle Heights development.

3. New infill developments in the Oldcastle Hamlet area should reference Section 5.6 of this report for guidance in the design of new SWM measures.

4. The Town of Tecumseh should work to secure or establish easements and property acquisitions as needed to implement the recommended stormwater conveyance and storage improvements. A detailed inventory of the affected properties is provided in Appendix M.

5. Detailed design of the recommended stormwater ponds should consider and account for the preliminary design stage-storage-outflow relationships that were used in the overall model assessment – as outlined in Appendix K. While it is not expected that these parameters be strictly followed, the design intent from these relationships should be maintained.

6. Geotechnical investigations are strongly recommended to help inform the detailed design and construction of individual drainage improvement projects recommended under the OSMP.

7. For the implementation of floodproofing measures, proponents should reference Section 5.7 of this report for guidance and recommendations. In certain cases, the modelled 100-year elevations

exceed finish grades approximated by the LiDAR topographic data. Actual flood risk and potential damages should be assessed by the individual property owners with consideration that lowest building openings may be above the LiDAR-derived finish grade elevations.

8. The conditional assessment of driveway access culverts provided in Appendix E has identified numerous culverts in need of immediate maintenance or replacement due to poor hydraulic capacity. These culverts should be cleaned and repaired (or replaced, where applicable) as soon as possible.

9. The Hurley Relief Branch Drain and its culvert crossing the abandoned CASO rail right-of-way are both prone to rapid sedimentation and should be inspected regularly (i.e., at least once per year) and cleaned as required to maintain flows until the proposed re-routing works can be implemented.

10. The Castlewood Court storm outlet that runs along the rear yards of several Trafalgar Court properties should be inspected and cleaned as needed to maintain flows until the proposed sewer re-routing can be implemented.

11. As part of the concurrent Class EA for this project, MTE Consultants Inc. (MTE) were retained to complete a *Natural Heritage Constraint Assessment* for the OSMP study area. A summary of their recommendations for next steps aimed at obtaining approvals for the new works described herein can be found in Section 7 of the Environmental Assessment Project File. In order to proceed with the improvements recommended under this OSMP, MTE has indicated that timing windows could be utilized to mitigate against adverse impacts to some of the species and habitats that may be affected. In any case, approvals from the Department of Fisheries and Oceans Canada (DFO), the Ontario Ministry of the Environment, Conservation and Parks (MECP), and the Essex Region Conservation Authority (ERCA) will be required.

12. As part of the concurrent Class EA for this project, a *Stage 1 Archaeological Background Assessment* of the OSMP study area was undertaken by AMICK Consultants Limited. A summary of AMICK's recommendations for next steps can be found in Section 6 of the Environmental Assessment Project File.

13. As part of the concurrent Class EA for this project, AECOM was retained to complete a desktop *Cultural Heritage Screening Review* for the purpose of identifying any recognized and/or potential cultural heritage resources within the OSMP study area. A copy of AECOM's report can be found in Section 6 of the Environmental Assessment Project File. The recommended drainage improvements as proposed in the OSMP do not result in impacts to any built heritage or cultural heritage landscapes.

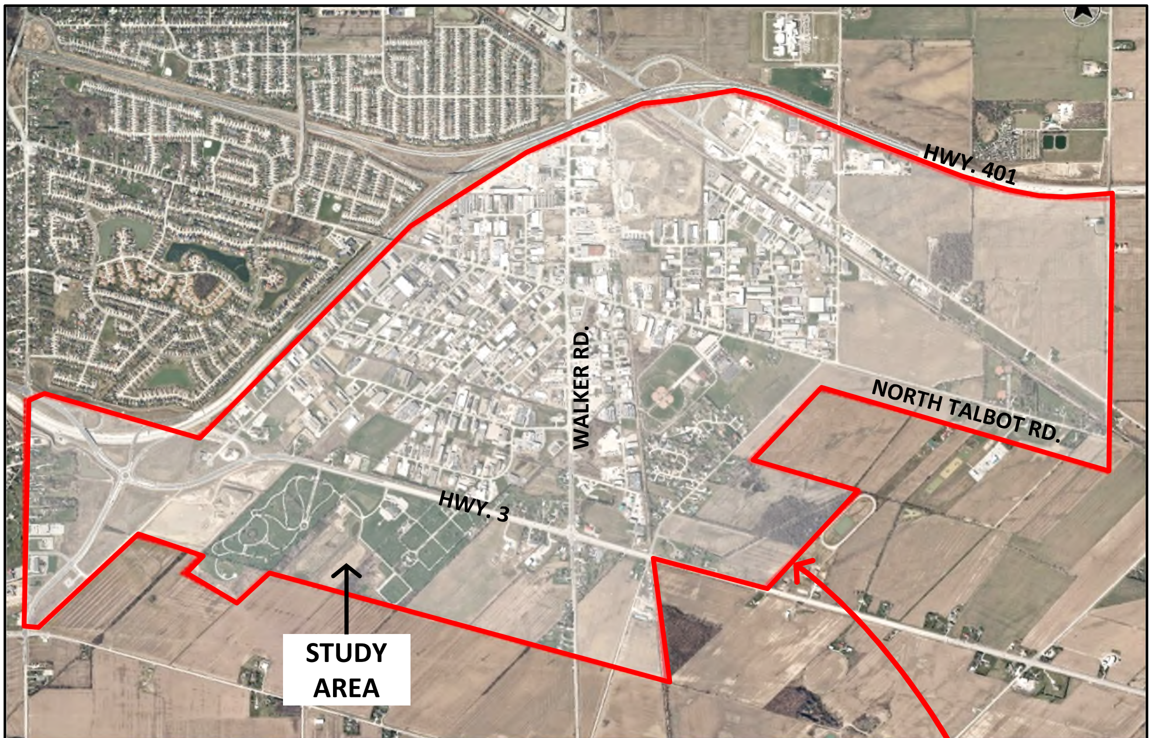
14. The small area of *Burford Loam – Shallow Phase* located within the OSMP study area generally coincides with a defined *Significant Groundwater Recharge Area (SGRA)*. Any new development within this area should conform to policies identified in the technical studies for the *Essex Region Source Protection Plan* (ERCA, 2015). We recommend consultation with the Essex Region Conservation Authority for guidance in this regard.

15. The Town of Tecumseh should inform the City of Windsor of predicted flows from the OSMP as they relate to the ongoing *Sandwich South (Little River watershed) Floodplain Mapping* project. Section 5.4 of this report discusses the differences between the Upper Little River Master Plan (ULRMP) flows and the modelled flows from this Oldcastle Stormwater Master Plan (OSMP). Based on the capacity assessments from the *Little River Floodplain Mapping* project, additional outflows from the 9th Concession Pond could be considered.

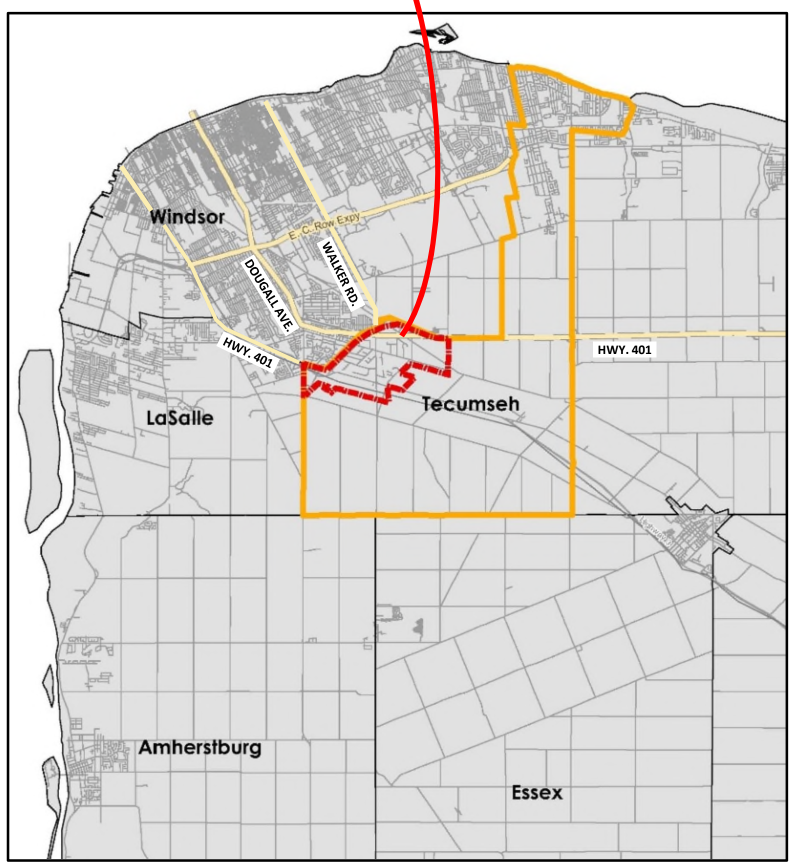
16. Although the SWM ponds recommended herein are all located outside of the 4-kilometre radius measured from the Windsor Airport (i.e., their wildlife control zone), the Windsor Airport should be notified and consulted during detailed design.

APPENDIX A

STUDY AREA FIGURES

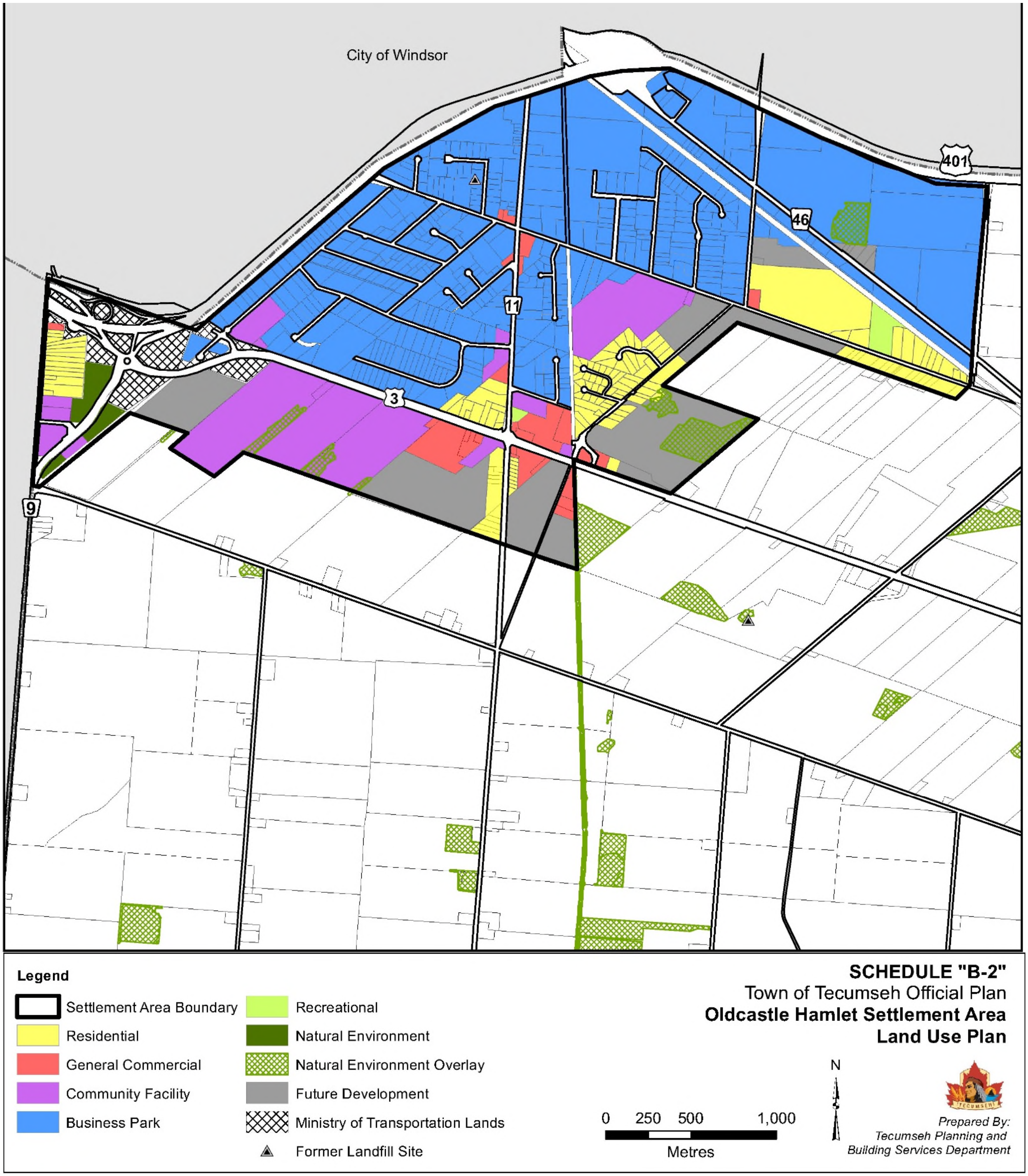


Oldcastle Business Park, Tecumseh



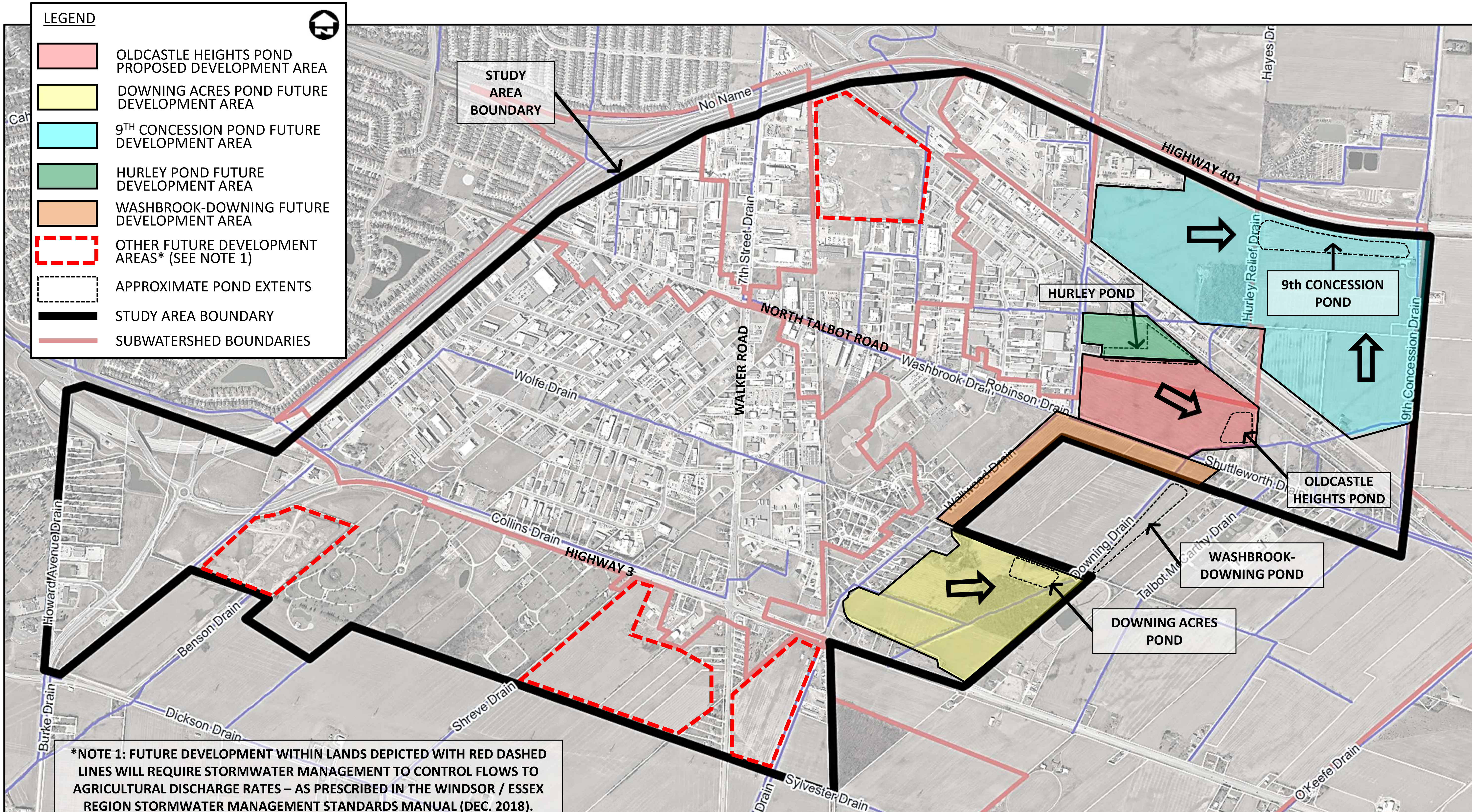
Landmark Engineers Inc.

Title: STUDY AREA LOCATION MAP	Date: OCT. 2020	Scale: NTS	FIGURE A1
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



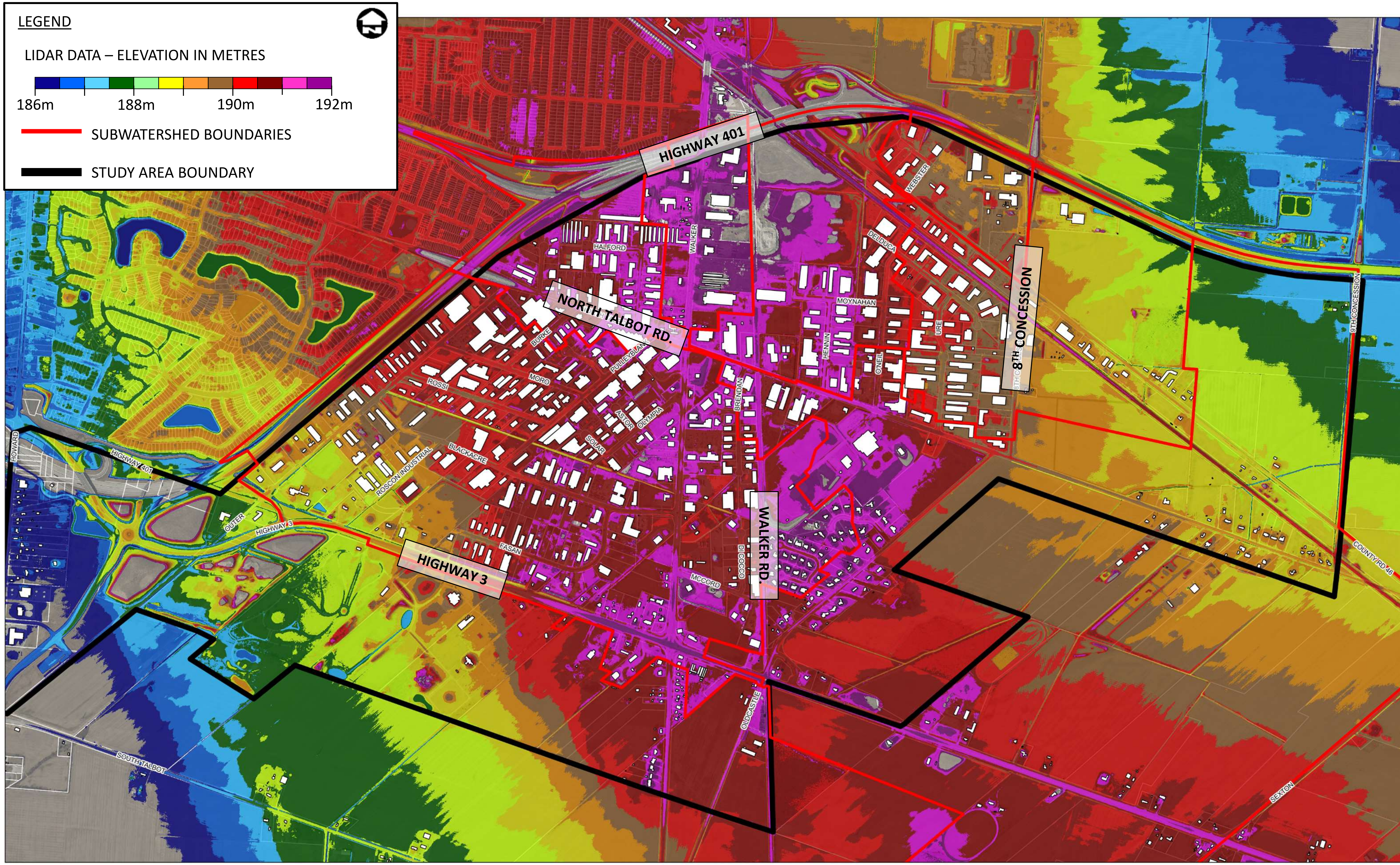
Landmark Engineers Inc.

Title: LAND USE PLAN	Date: SEPT. 2020	FIGURE
	Scale: NTS	A2
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



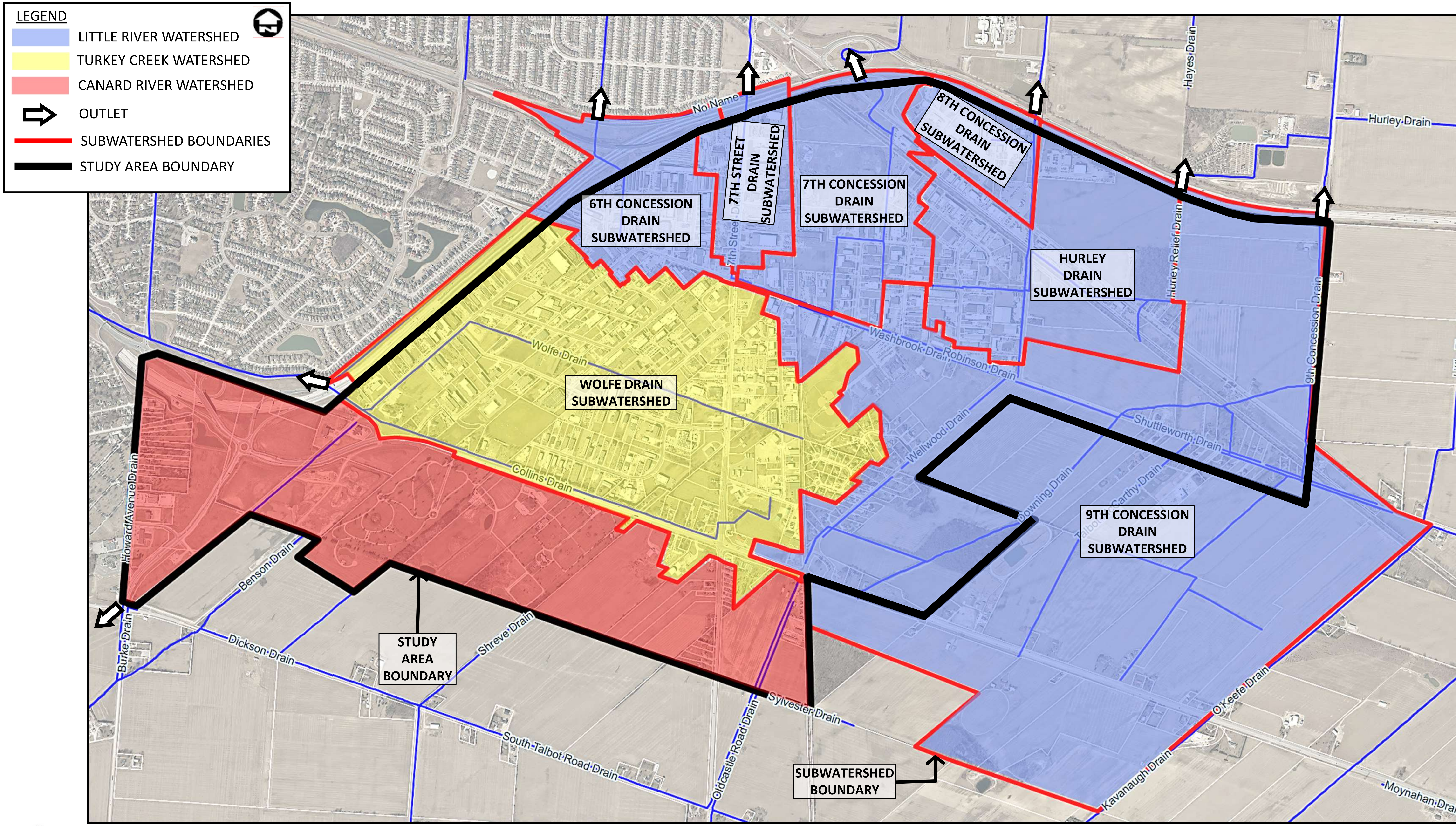
Landmark Engineers Inc.

Title: FUTURE DEVELOPMENT BLOCKS	Date: JAN. 2022	FIGURE A3
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



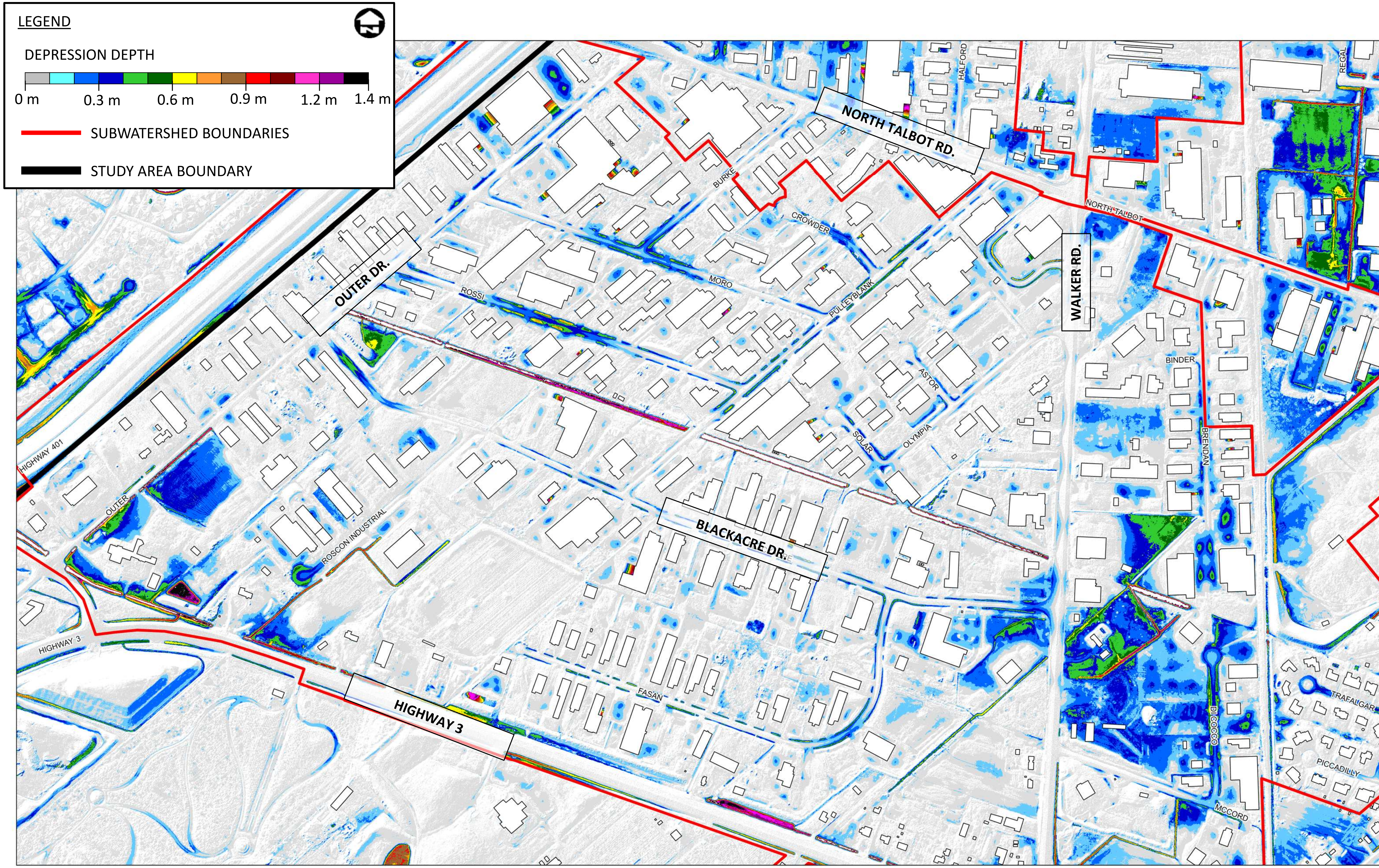
Landmark Engineers Inc.

Title: TOPOGRAPHIC MAP	Date: OCT. 2020	Scale: NTS	FIGURE A4
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



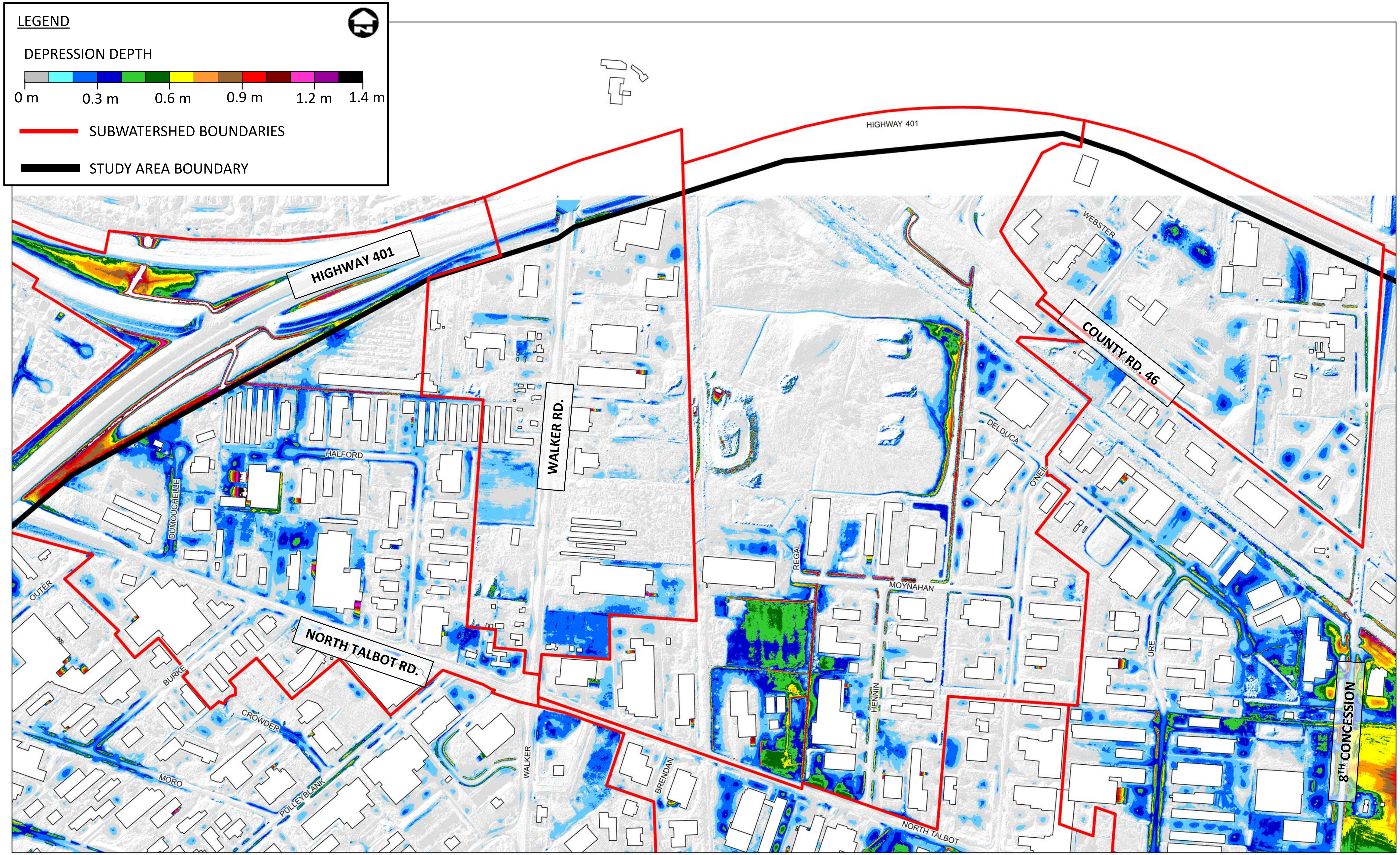
Landmark Engineers Inc.

Title: WATERSHED & SUBWATERSHED BOUNDARY MAP	Date: OCT. 2020	Scale: NTS	FIGURE A5
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



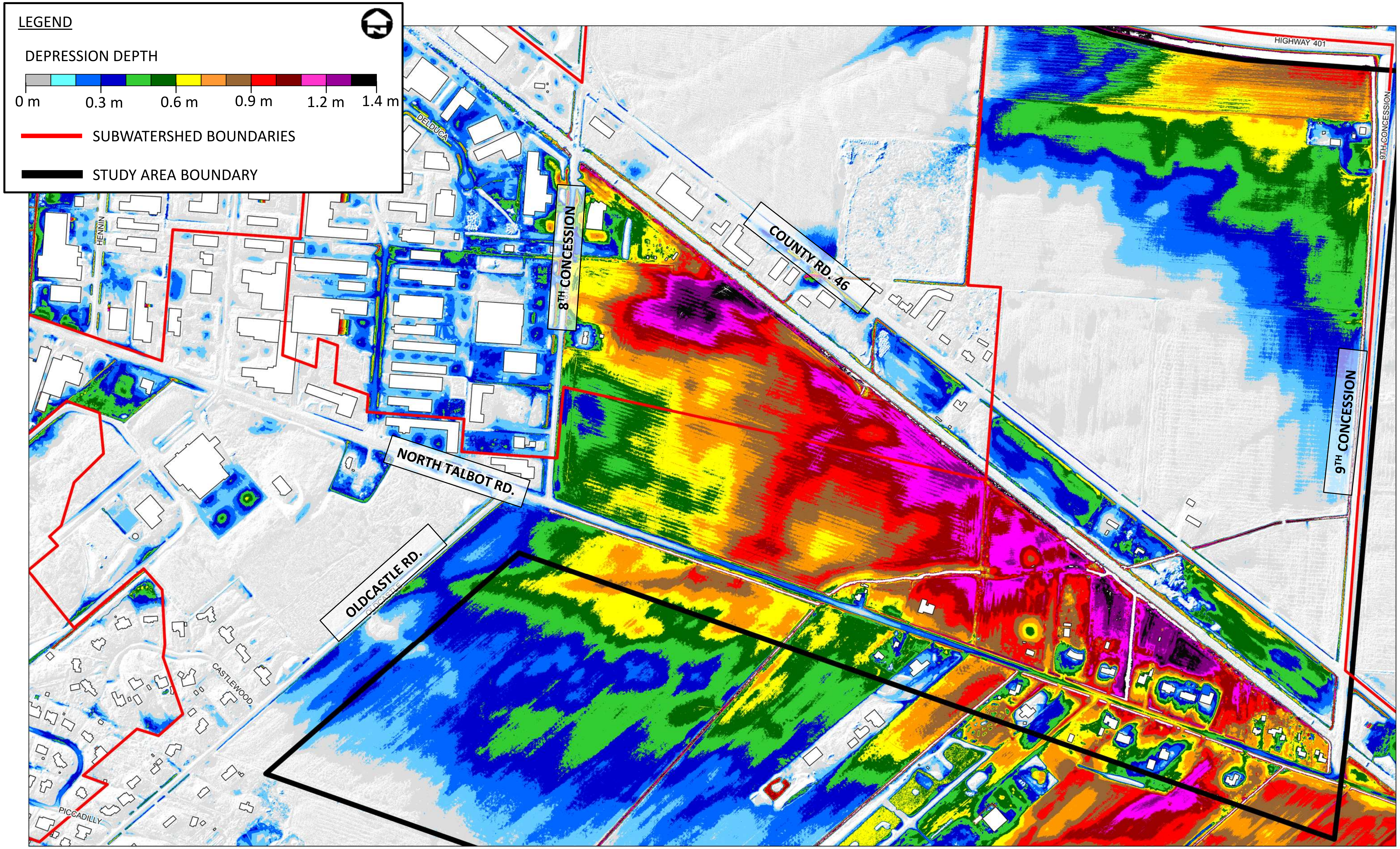
Landmark Engineers Inc.

Title	DEPRESSION MAP: WOLFE DRAIN AREA
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	OCT. 2020
Scale	NTS
Project No.	19-010
FIGURE	A6



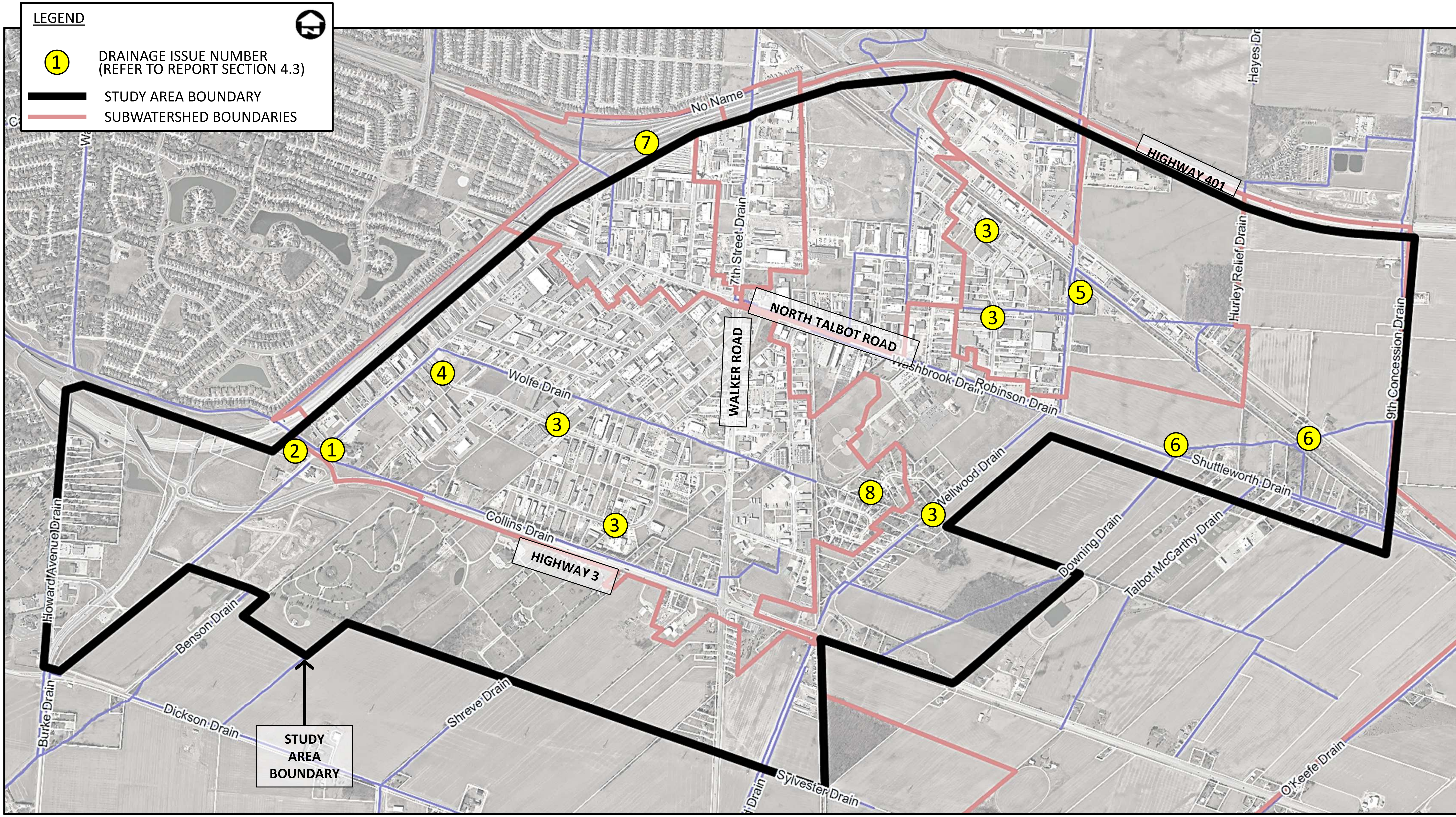
Landmark Engineers Inc.

Title: DEPRESSION MAP: 6TH CONC., 7TH STREET, 7TH CONC. & 8TH CONC	Date: OCT. 2020	FIGURE A7
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



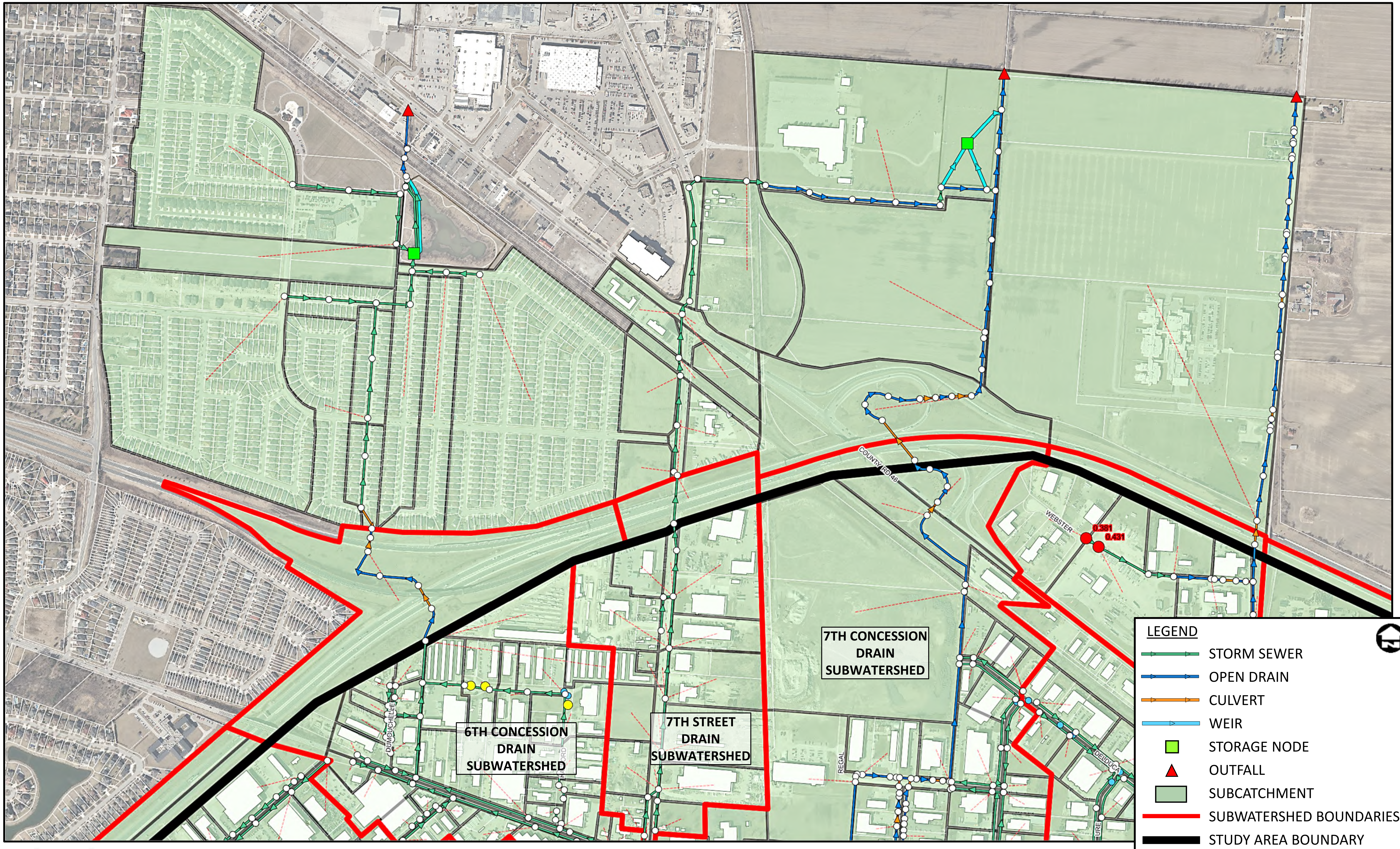
Landmark Engineers Inc.

Title	DEPRESSION MAP: HURLEY AND 9TH CONCESSION DRAIN AREAS	Date OCT. 2020	FIGURE
		Scale NTS	A8
Project	OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



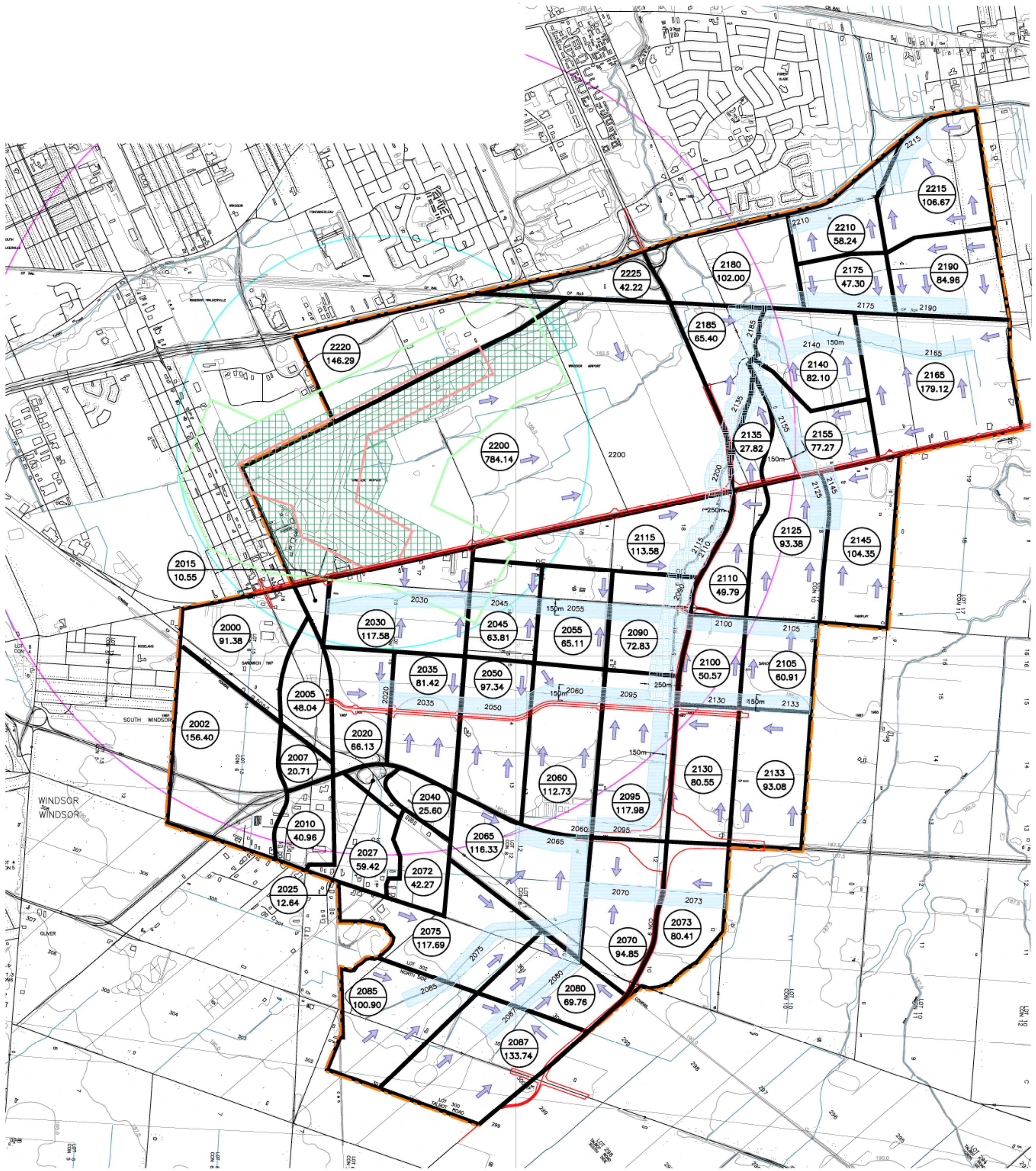
Landmark Engineers Inc.

Title: OBSERVED DRAINAGE ISSUES	Date: SEPT. 2021		FIGURE A9
	Scale: NTS		
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



Landmark Engineers Inc.

Title: EXTERNAL AREAS DOWNSTREAM OF STUDY AREA	Date: OCT. 2020	Scale: NTS	FIGURE A10
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



Stantec

300 Hagey Blvd. Suite 100
Waterloo, ON, N2L 0A4
519.579.4410

Legend

STUDY AREA
STORM DRAINAGE BOUNDARY
2165 — CATCHMENT I.D.
172.92 — AREA (HECTARES)
2 KM RADIUS FROM AIRFIELD CENTRE (WILDLIFE CONTROL ZONE)
4 KM RADIUS FROM AIRFIELD CENTRE (WILDLIFE CONTROL ZONE)
ZONE OF NO TOLERENCE
ZONE OF NO CONFIDENCE
STORM WATER MANAGEMENT CORRIDOR (150m WIDE)
STORM WATER MANAGEMENT CORRIDOR (250m WIDE)
DIRECTION OF FLOW
GENERAL AVIATION

Revision	By	Appd.	YY.MM.DD

File Name: 160311265_C–SD.dwg	KS	JI	JI	12.02.02
	Dwn.	Chkd.	Dsgn.	YY.MM.DD

Permit-Seal

Client/Project

ESSEX REGION CONSERVATION AUTHORITY

UPPER LITTLE RIVER
ENVIROMENTAL ASSESSMENT
Windsor, ON

Title

PROPOSED CATCHMENT AREAS

Project No.	Scale
1603-11265	1:20,000 (0, 200, 600, 1000m)

Drawing No.	Sheet	Revision
3	1 of 1	0

APPENDIX
B

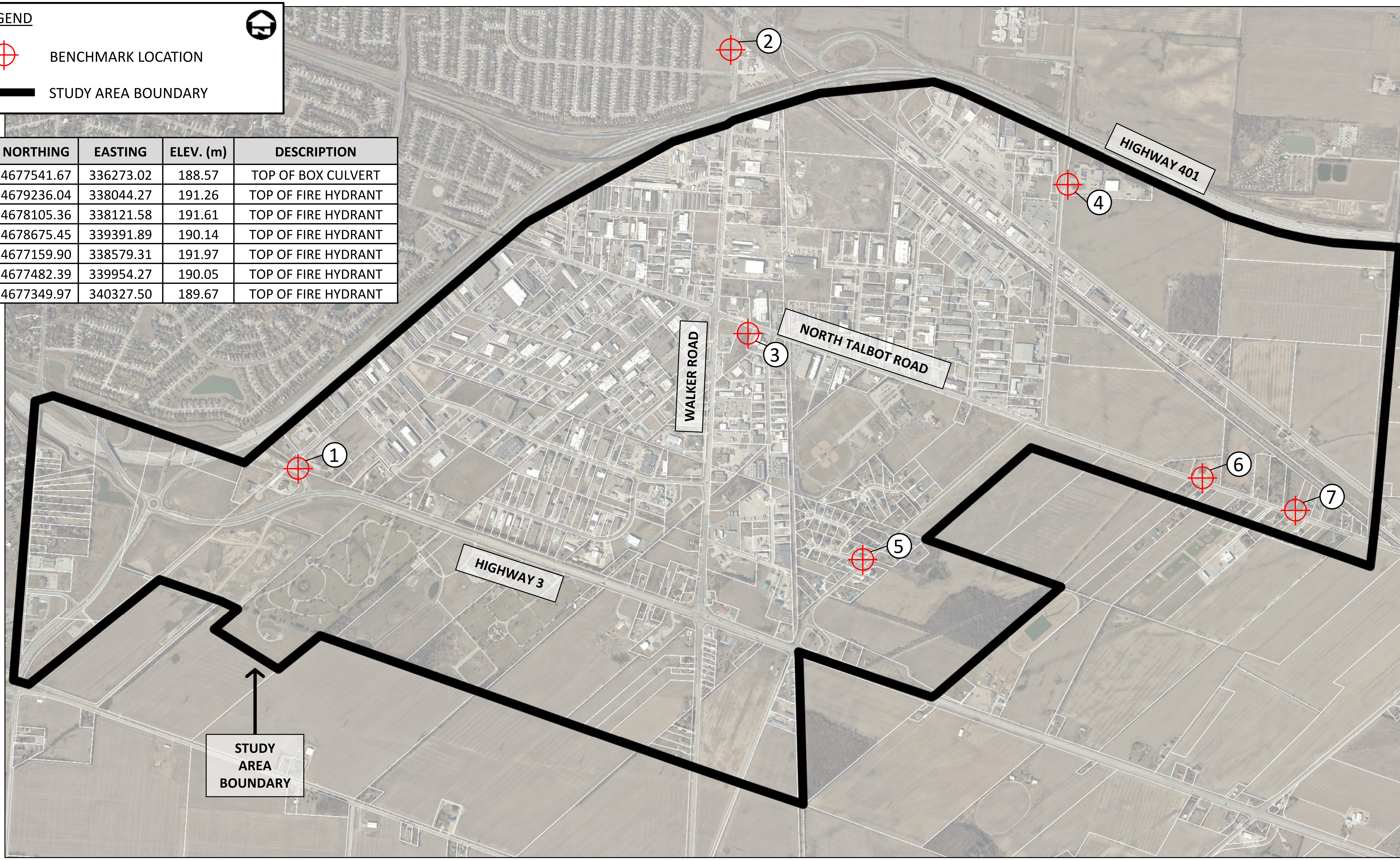
MUNICIPAL DRAIN BENCHMARKS

LEGEND

BENCHMARK LOCATION

STUDY AREA BOUNDARY

BM NO.	NORTHING	EASTING	ELEV. (m)	DESCRIPTION
1	4677541.67	336273.02	188.57	TOP OF BOX CULVERT
2	4679236.04	338044.27	191.26	TOP OF FIRE HYDRANT
3	4678105.36	338121.58	191.61	TOP OF FIRE HYDRANT
4	4678675.45	339391.89	190.14	TOP OF FIRE HYDRANT
5	4677159.90	338579.31	191.97	TOP OF FIRE HYDRANT
6	4677482.39	339954.27	190.05	TOP OF FIRE HYDRANT
7	4677349.97	340327.50	189.67	TOP OF FIRE HYDRANT



Landmark Engineers Inc.

Note: Benchmark elevations herein are based on survey performed by Landmark Engineers using Sokkia GCX3 - a dual-frequency Global Navigation Satellite System (GNSS) receiver that provides Real-Time Kinematic (RTK) centimeter-level performance. **These elevations are approximate, with a typical accuracy of +/- 5 cm.**

Title	BENCHMARKS
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	APR. 2022
Scale	NTS
Project No.	19-010

FIGURE B1

APPENDIX C

MODEL CALIBRATION & INPUTS

1.0 MODEL CALIBRATION

1.1 OBSERVED DATA

Flow monitoring data was collected by AMG Environmental between August 2018 and August 2019. A total of five (5) flow monitoring locations were selected to measure both water levels and velocity. Flow was derived from the velocity readings based on the hydraulic cross-section. Figure C1 herein shows the monitoring locations as well as the contributing catchment areas for each location.

1.2 RAINFALL

The model calibration efforts benefitted from a suite of useful rainfall events captured during the one-year flow monitoring period. A total of six (6) rainfall events were selected for calibration, which varied by season, magnitude and intensity. The events can be generally described by the following types:

- Directly Connected Impervious Area (DCIA): Relatively short duration and intense storm with dry antecedent conditions. This is an ideal storm to determine directly connected impervious areas (DCIA).
- Rainfall Losses & Pervious Runoff (INFL): Intense storm with high volume and/or wet antecedent moisture conditions will induce runoff from lawns, fields, and other pervious areas that would not otherwise produce runoff in a typical storm. These storms are ideal to determine soil infiltration capacity, hydraulic conductivity, and groundwater influence.
- Hydrologic routing (HYDR): Series of slow-moving weak storm events spread over multiple days with little recovery time between storms. After determination and validation of DCIA, these storms are ideal to determine overland flow parameters such as slope, roughness and flow path lengths. Slow-moving storms typically have little variation in peak intensity or volume.

Table 1 below provides a summary of the calibration events, where RG01 represents the rainfall amount measured by the project rain gauge installed by AMG Environmental during the afore-mentioned one-year monitoring period. This gauge was located at Tecumseh Fire Station No.2.

Table 1 – Rainfall Events Used for Calibration

EVENT	FROM		TO		TYPE	DUR. (hrs)	RG01 mm
1	20-Sep-2018	6:00	20-Sep-2018	12:00	DCIA	6	45.0
2	24-Sep-2018	15:00	25-Sep-2018	15:00	HYDR	24	22.1
	25-Sep-2018	19:00	25-Sep-2018	22:00	INFL	3	38.6
3	6-Oct-2018	0:00	6-Oct-2018	20:00	INFL	20	40.6
4	31-Oct-2018	3:00	31-Oct-2018	9:00	HYDR	6	20.1
	1-Nov-2018	3:00	2-Nov-2018	6:00	HYDR	27	40.7
5	18-Apr-2019	15:00	19-Apr-2019	9:00	HYDR	18	16.5
	19-Apr-2019	22:00	21-Apr-2019	0:00	HYDR	24	24.4
6	25-Apr-2019	18:00	26-Apr-2019	6:00	HYDR	12	29.7

Events 1 to 3 were compared to Windsor Airport IDF data to assess their relative magnitude, refer to the rainfall analysis slide herein for IDF curve comparisons. Event 2 was determined to have a short-duration intensity equal to a 10-year storm. Event 1 exceeded a 2-year storm for a 6-hour duration. All other events were less than a 2-year return period.

Beyond the monitoring period, the study captured two additional events from the Town of Tecumseh rain gauge at Fire Station No.2 that served to validate the model. Event 7 was a low intensity, high-volume event that occurred between January 10 to 12, 2020, with fully saturated soil conditions. Event 8 was a multi-cell summer storm with several short-duration high-intensity rainfalls that occurred on August 28, 2020 and produced a very high rainfall volume. As depicted on the IDF Curve slide herein, this storm produced short-duration peak rainfall intensities between 5-year to 10-year return period and a 24-hour rainfall volume slightly exceeding a 100-year return period.

1.3 CALIBRATION PARAMETERS

Hydrologic model inputs followed the Windsor/Essex Region Stormwater Management Standards Manual (December 2018), with exception being deviations to the soil (infiltration) parameters. The calibration process was largely driven by adjustments to these parameters, with minor adjustments to parameters such as flow length, slope and subarea routing. The soil parameters were tailored to suit antecedent moisture conditions for each specific calibration event. Table 2 below provides a summary of the parameters used for each event.

Table 2 – Calibration Parameters

EVENT	TYPE	DATE	SOIL PARAMETERS				Groundwater Deep Seepage
			Soil D		Soil A		
			k (mm/hr)	IMD	k (mm/hr)	IMD	(mm/hr)
1	DCIA	20-Sep-2018	5	0.21	13	0.32	0.5
2	INFL	24-Sep-2018	5	0.21	13	0.32	0.5
3	INFL	6-Oct-2018	0.2	0.1	3	0.1	0.1
4	HYDR	31-Oct-2018	0.1	0.1	1	0.1	0.1
5	HYDR	18-Apr-2019	0.1	0.1	1	0.1	0.1
6	HYDR	25-Apr-2019	0.3	0.1	3	0.1	0.1
7	HYDR	11-Jan-2020	0	0	0	0	0
8	INFL	28-Aug-2020	5	0.21	13.0	0.32	0.5

As mentioned in the report, we found that adjusting Green-Ampt conductivity rates (k) to a relatively high value of 5 mm/hr provided a good fit under the foregoing conditions. And while this is 10 times the rate of that of a conservative Standard design value of 0.5 mm/hr for clay soils, it is very reasonable to expect that very dry clay will experience shrinking and exhibit fissures that significantly increase infiltration rates. Conversely, swelling clays under wet or saturated condition would reasonably be expected to have very low infiltration rates, such as the 0.1 mm/hr values used to calibrate mid-fall and mid-spring events. Initial Moisture Deficit (IMD) values were varied from dry conditions to normal conditions, as per the Standards.

The flow monitoring slides herein depict a comparison of the head (m), flow (m^3/s) and velocity (m/s) for both the observed (dotted black line) and simulated (green or blue line) conditions. A synopsis of the comparison for each location is provided on the slides.

2.0 MODEL INPUTS

2.1 HYDROLOGIC INPUTS

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 for the agricultural lands within the study area.

2.1.1 RUNOFF Routine

The parameters listed in Table 3 below were applied to all subcatchments, excluding those representing agricultural lands (discussed in the next section 2.1.2).

Table 3 – Design Parameters for RUNOFF Routine

STORM	SOIL PARAMETERS			
	Soil D		Soil A	
	k	IMD	k	IMD
Chicago 4-hour	1	0.21	9.5	0.33
Stress Test	3	0.21	9.5	0.33
AES 12-hour	0.5	0.1	9.5	0.33

For the purpose of evaluating the existing storm system and recommending improvements, we believe it is reasonable to consider the foregoing relaxed parameters in lieu of those prescribed in the Standards manual. It should be acknowledged that these infiltration rates remain within the low end of the actual range that can be expected from shrinking clays under dry conditions. Furthermore, the Chicago and Stress Test storms represent high-intensity thunderstorms that tend to occur in the summer months when soil conditions are dryer. Note that the lower-intensity and more evenly distributed AES storm has considered the lower values of the Standards given that this regional type storm is more likely to occur under normal antecedent conditions. Moreover, we confirm that the conservative parameters in the Standards manual were also used for modelling of the future development blocks and corresponding preliminary design of the proposed stormwater ponds.

2.1.2 GROUNDWATER Routine

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. This model approach resonates with real-world conditions as a large part of the 9th Concession Drain area consists of very flat agricultural lands with highly impervious clay soils.

As part of the Leamington Stormwater Master Drainage Study for Reid Drain, Silver Creek and Big Creek (Stantec, May 2019), a comprehensive model calibration was performed on the Ruscom River watershed up to the Environment Canada hydrometric gauge (Ruscom Station). This effort provided validation for the GROUNDWATER routine model input parameters. This SMP modelling has adopted the same parameters, which are summarized as follows:

Lateral Flow

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 area 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.

Soil Parameters

The following soil (clay) 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) = 0.27 (0.38 for 100-year 12-hour AES)
- Saturated Conductivity = 3 mm/hr
- Conductivity Slope = 30
- Tension Slope = 10
- Deep Groundwater Flow or Seepage (GWF) = 0.5mm/hr

2.2 HYDRAULICS INPUTS

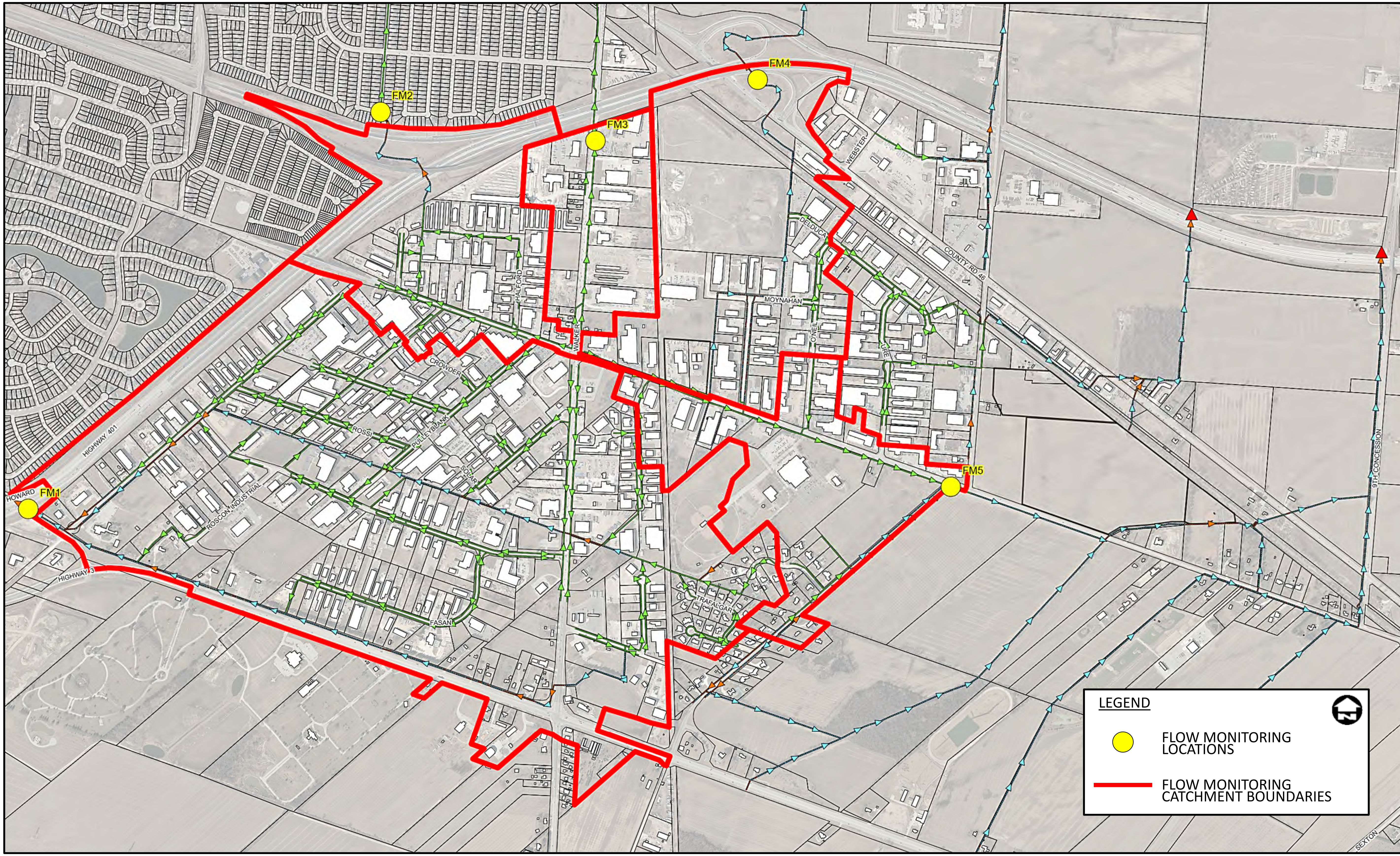
The hydraulic model inputs were based on a combination of Town's Geographic Information System (GIS) information, as-built drawings, municipal drain reports and field survey. For open channels, the assumed manning's roughness was varied for different conditions.

For the calibration modelling, an applicable roughness was assigned based on the current condition of the drain. Values used ranged from 0.035 to 0.08.

For the existing conditions modelling, open channels were modelled assuming a roughness of 0.045, representing light brush on the banks, and presumably the worst-case condition before the drain is maintained.

For the proposed condition modelling, open channels were modelled assuming a roughness of 0.035 (representing a channel with maintained vegetation).

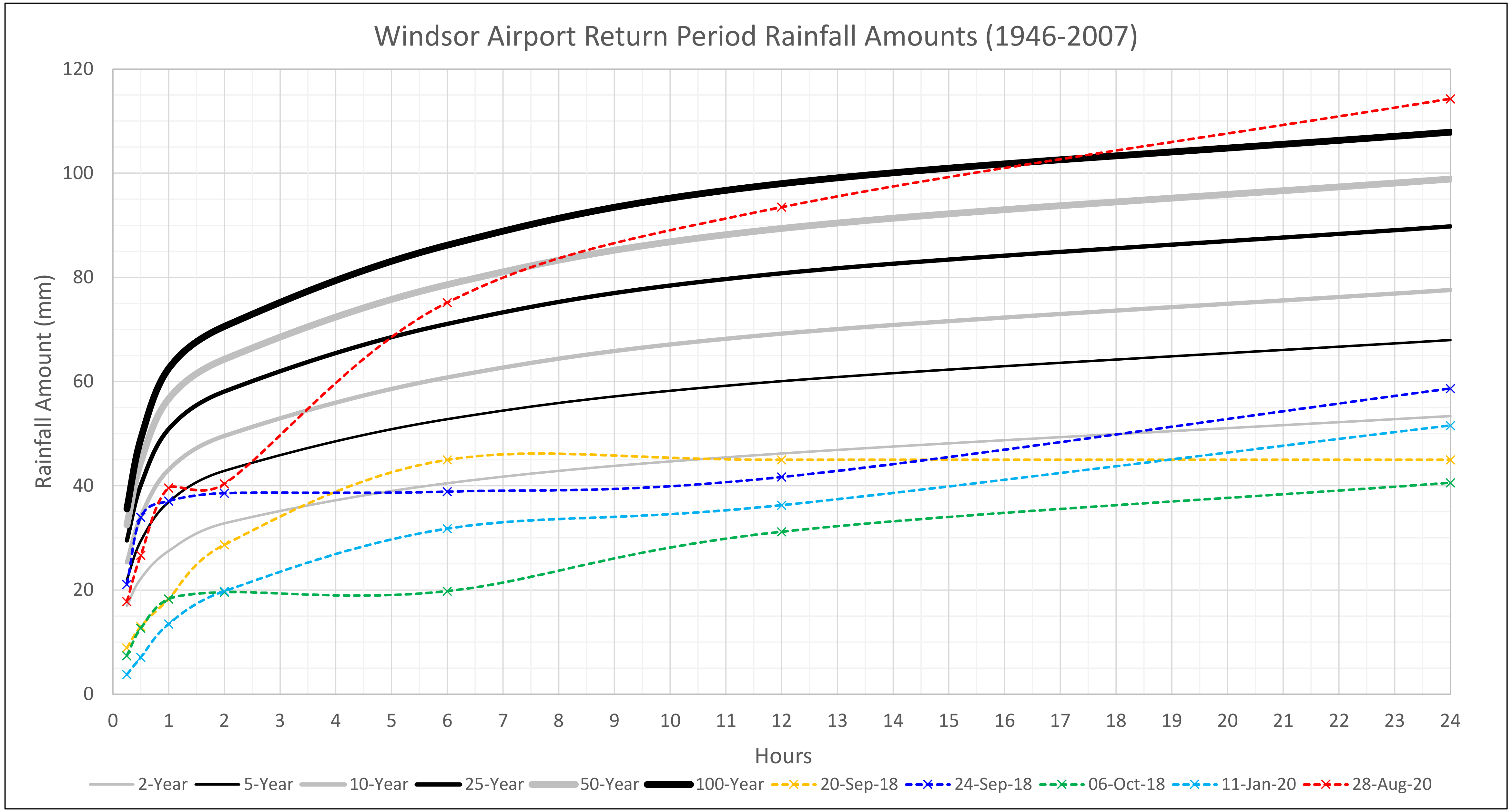
For modelling of the 100-year 12-hour AES storm, open channels were modelled assuming a roughness of 0.030, representing a channel with little vegetation. This scenario considers the potential for an AES type storm occurring in early spring/late fall conditions where the drain is less vegetated.



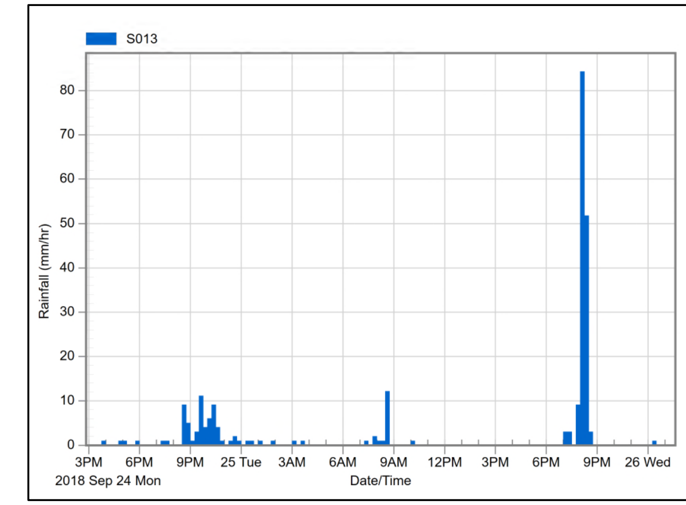
Landmark Engineers Inc.

Title: FLOW MONITORING PLAN	Date: OCT. 2020	Scale: NTS	FIGURE C1
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

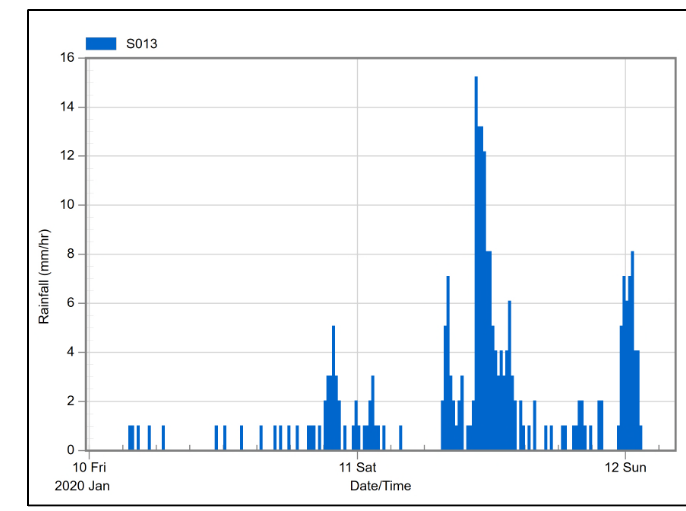
WINDSOR A & SIGNIFICANT EVENTS



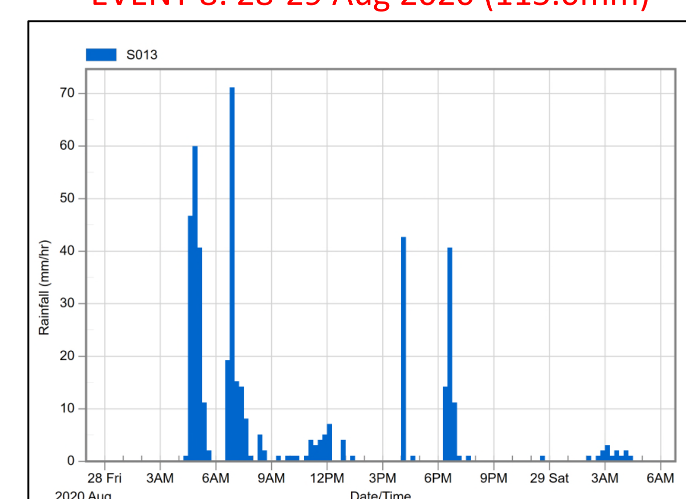
EVENT 2: 24-25 Sept 2018 (61.0mm)



EVENT 7: 10-12 Jan 2020 (63.0mm)

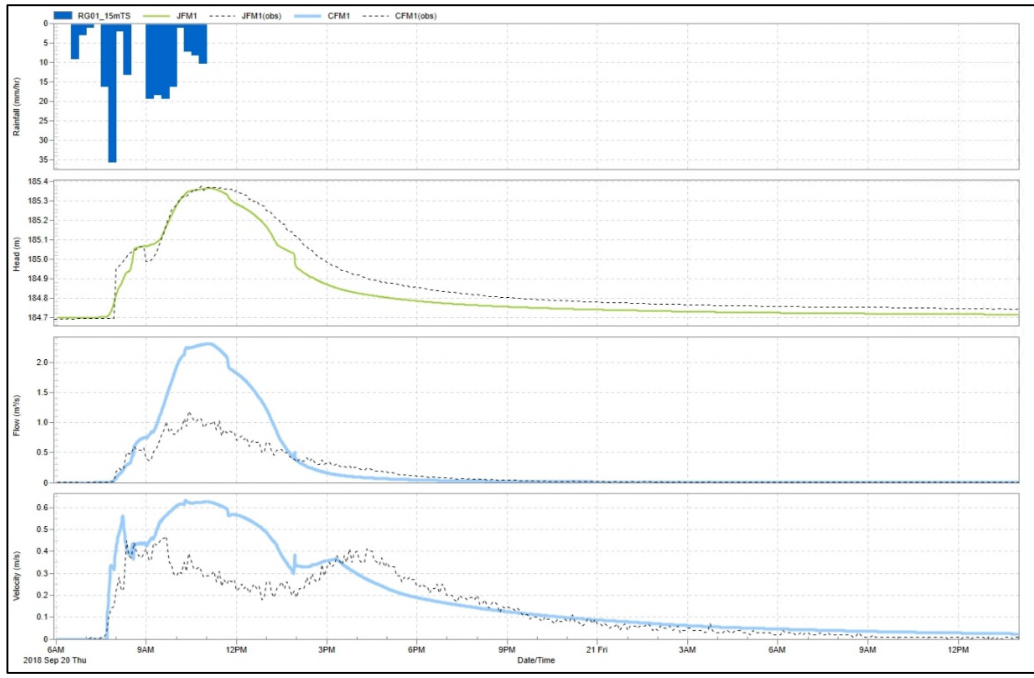


EVENT 8: 28-29 Aug 2020 (115.0mm)

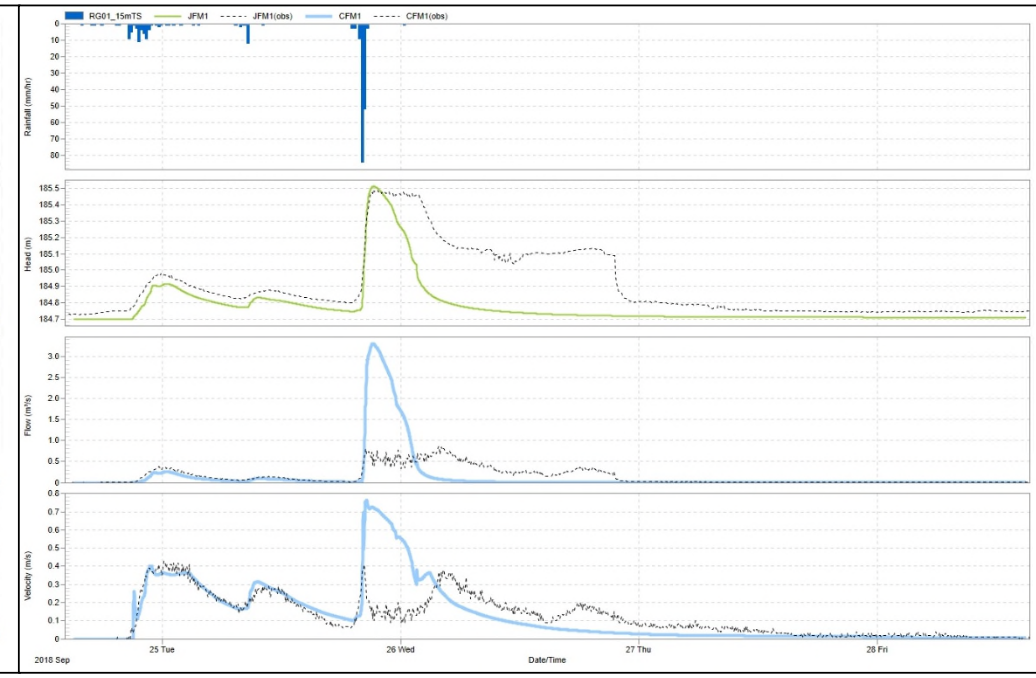


FM1 – WOLFE DRAIN

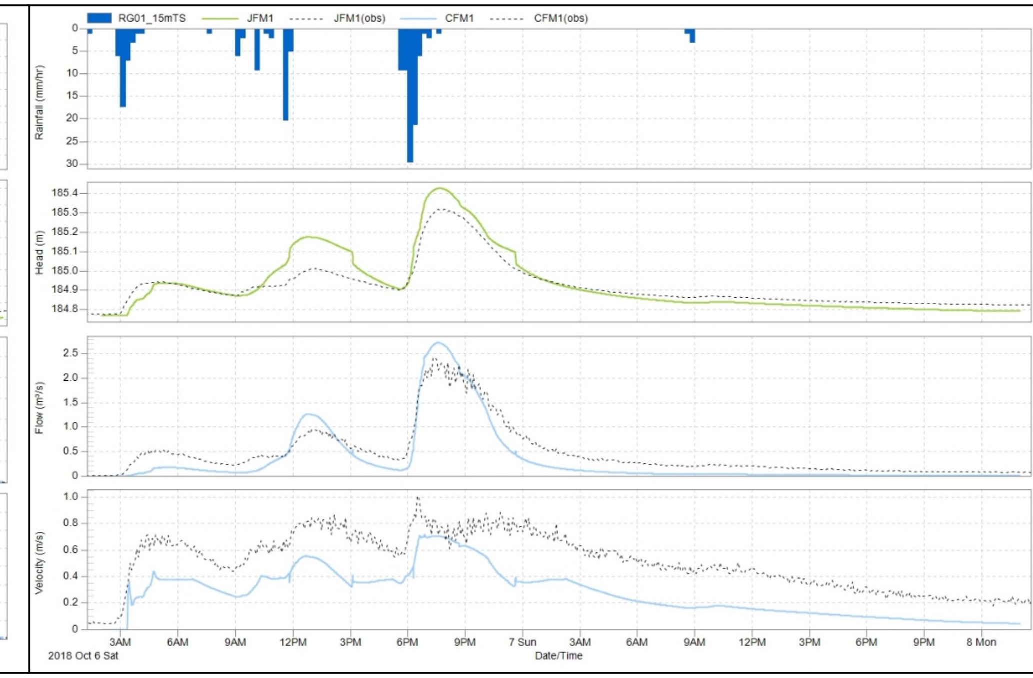
EVENT 1: 20 Sept 2018 (45.0mm)



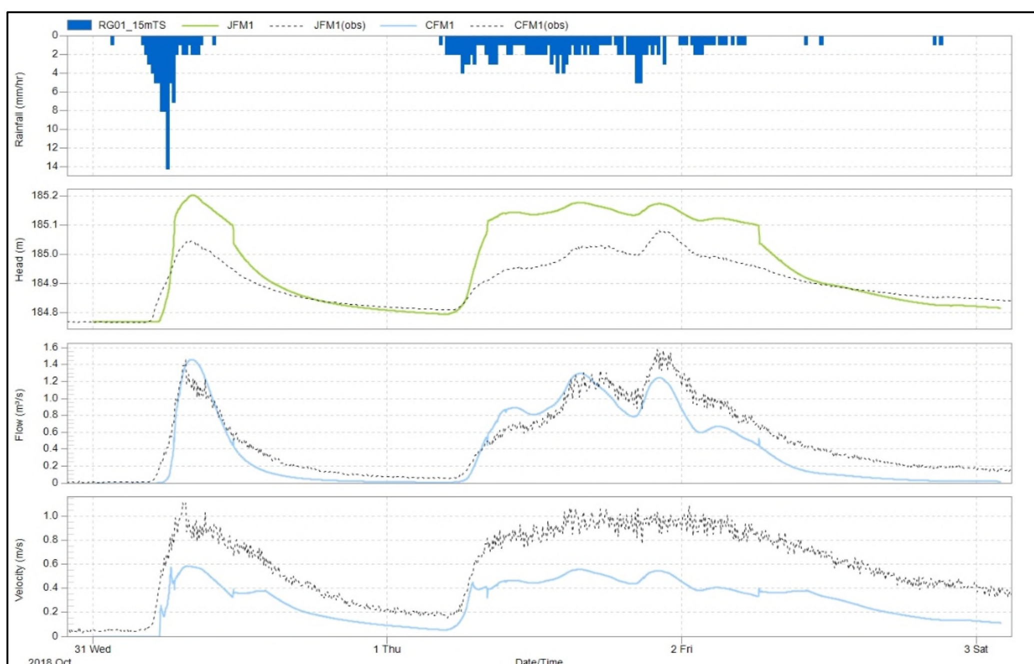
EVENT 2: 24-25 Sept 2018 (61.0mm)



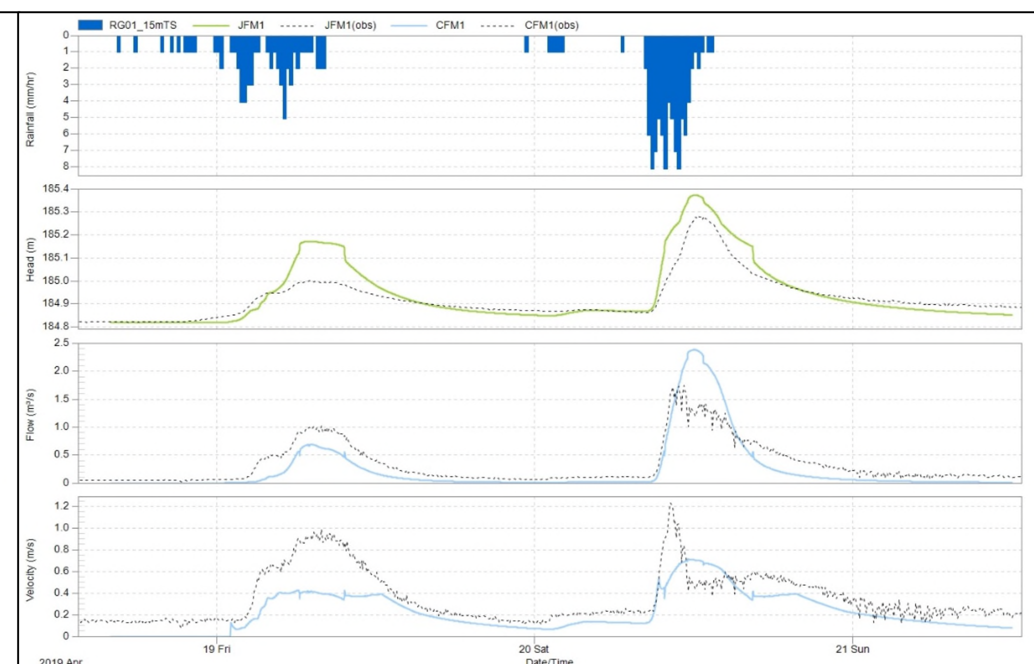
EVENT 3: 6 Oct 2018 (41.4mm)



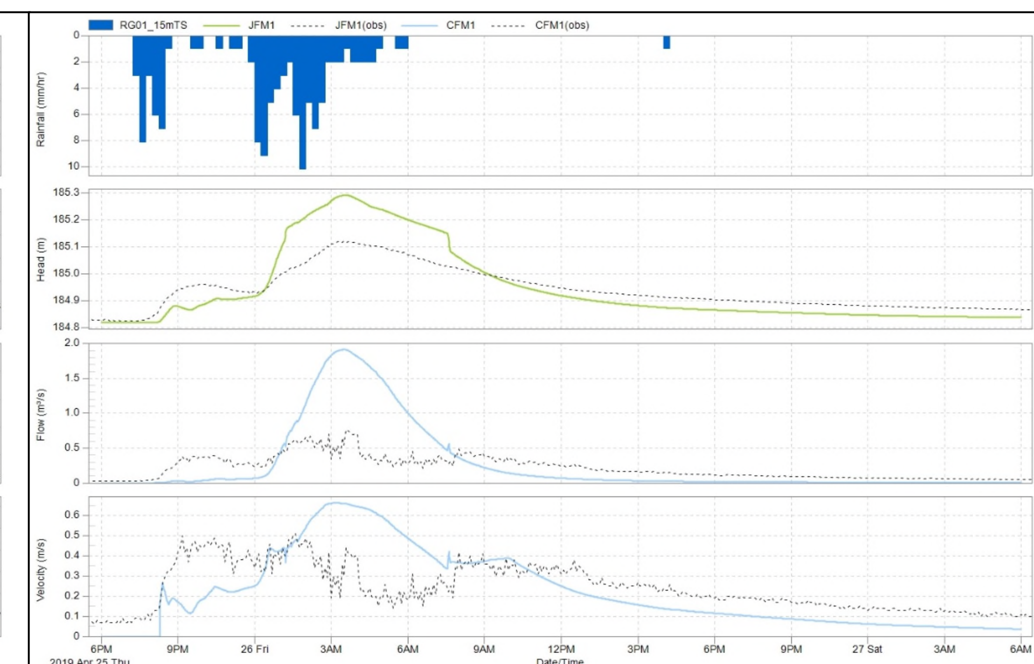
EVENT 4: 31 Oct - 2 Nov 2018 (61.8mm)



EVENT 5: 18-20 Apr 2019 (40.9mm)



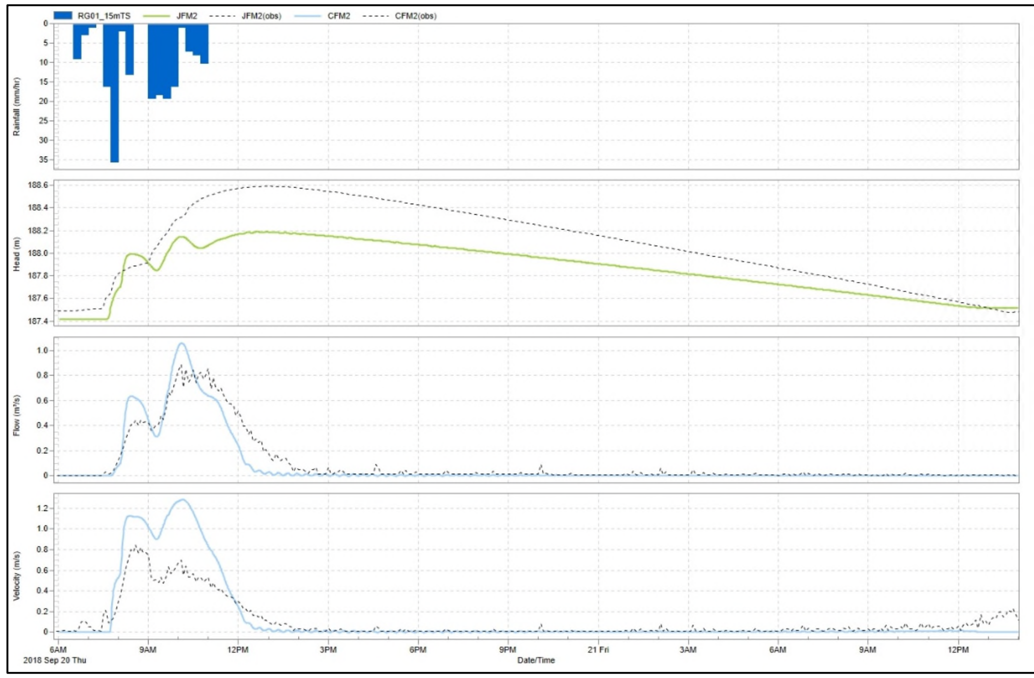
EVENT 6: 25-26 Apr 2019 (30.0mm)



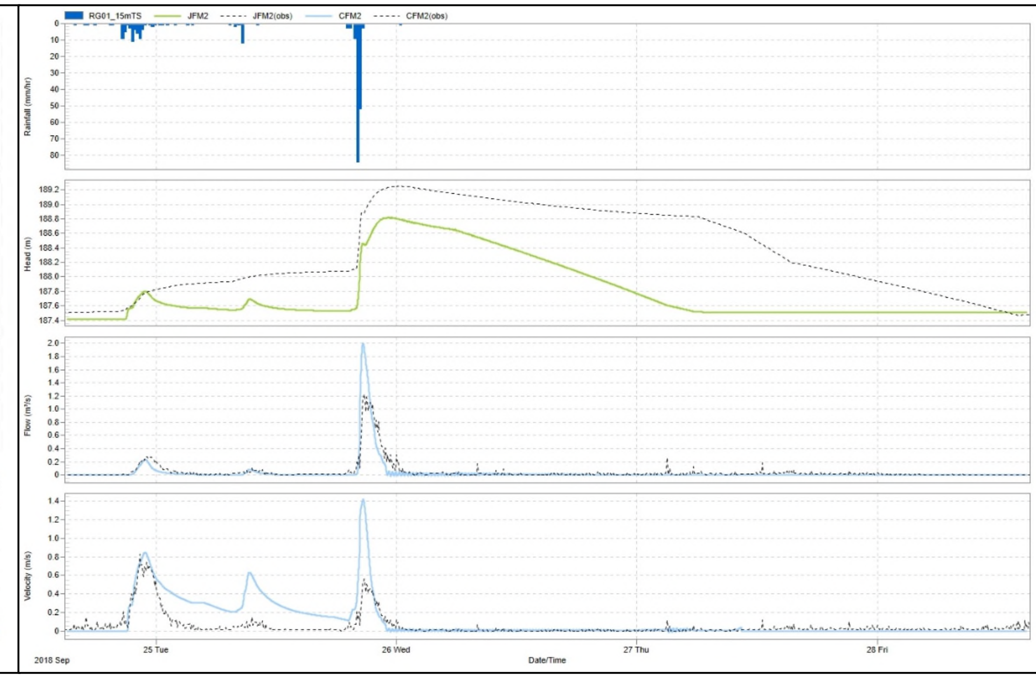
Landmark Engineers Inc.

FM2 – 6^{TH} CONC. DRAIN

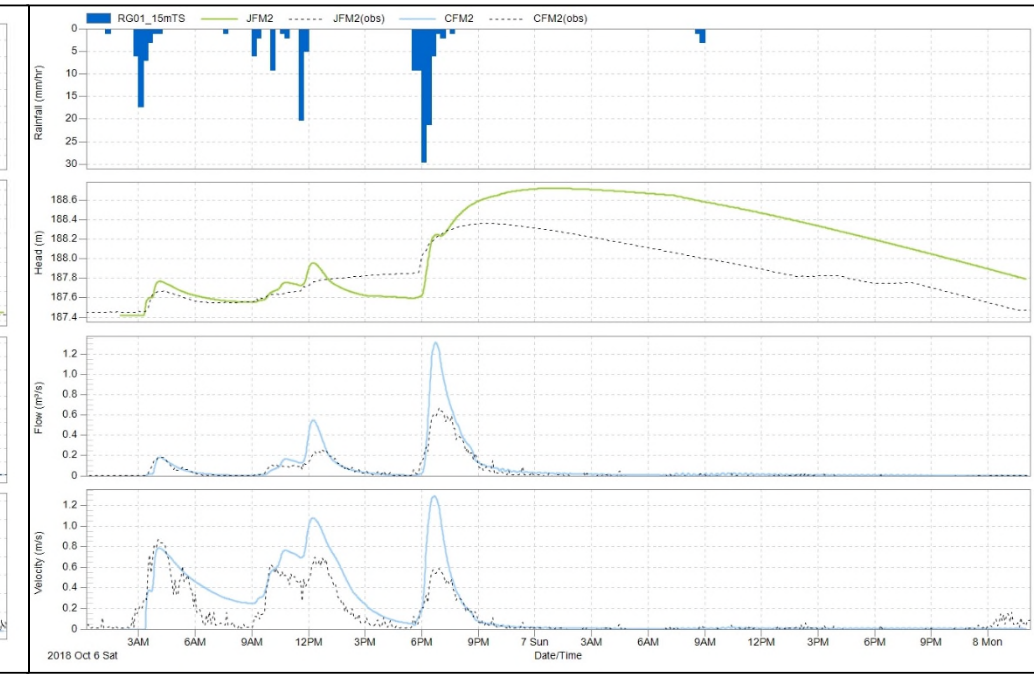
EVENT 1: 20 Sept 2018 (45.0mm)



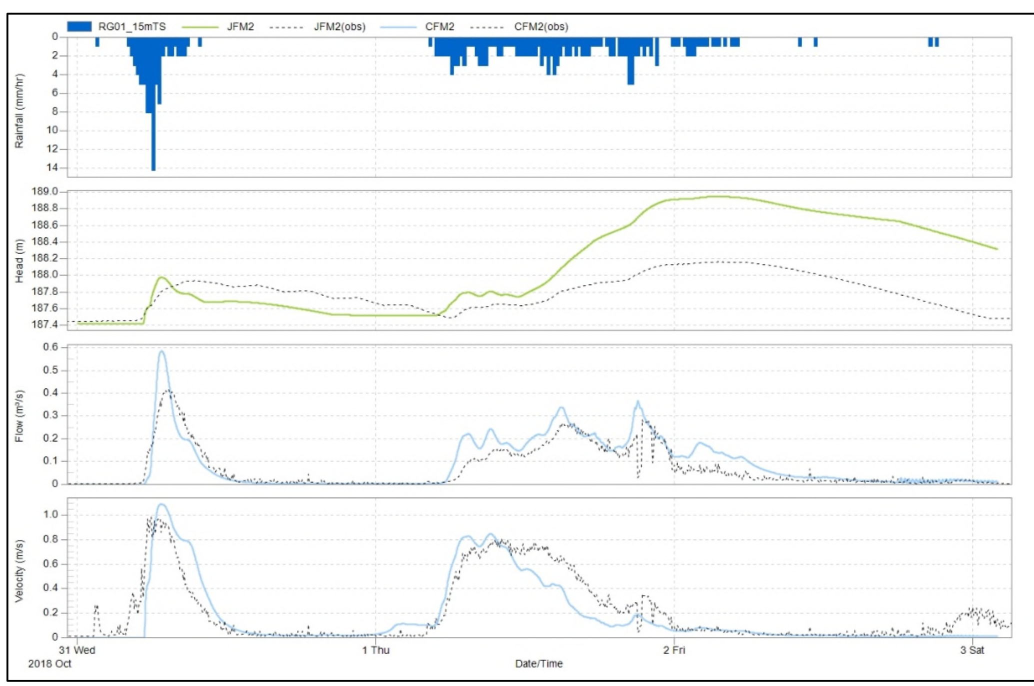
EVENT 2: 24-25 Sept 2018 (61.0mm)



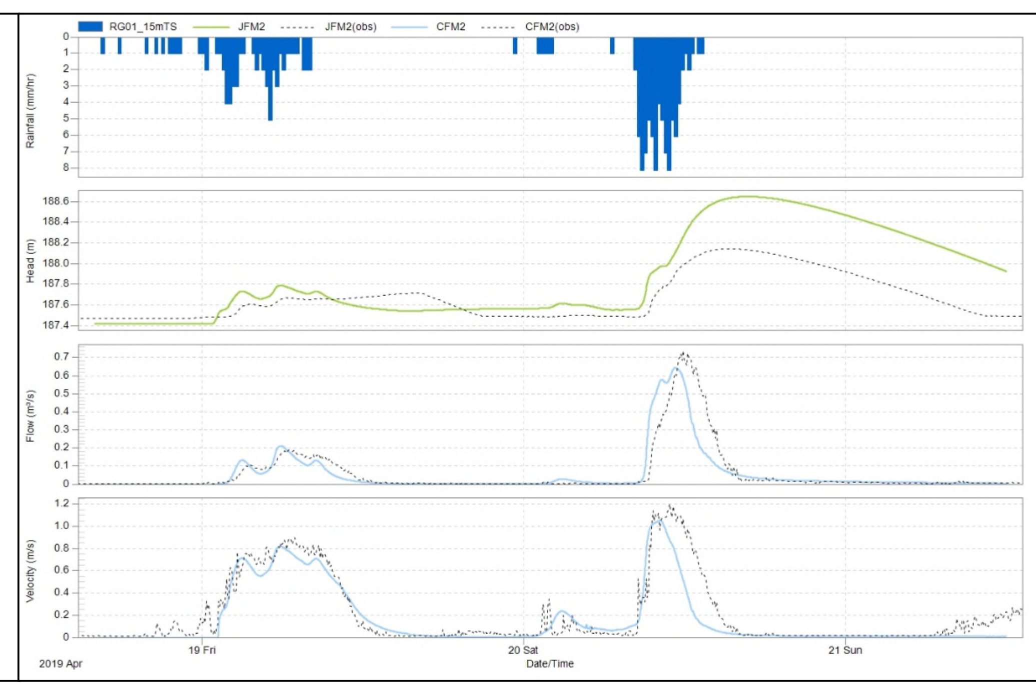
EVENT 3: 6 Oct 2018 (41.4mm)



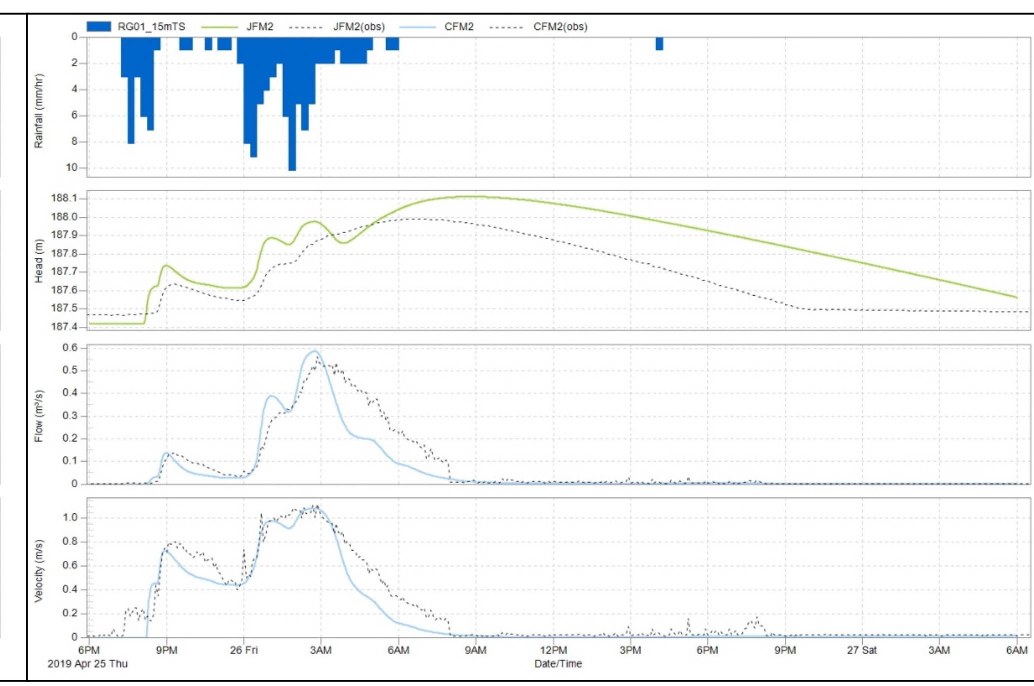
EVENT 4: 31 Oct - 2 Nov 2018 (61.8mm)



EVENT 5: 18-20 Apr 2019 (40.9mm)



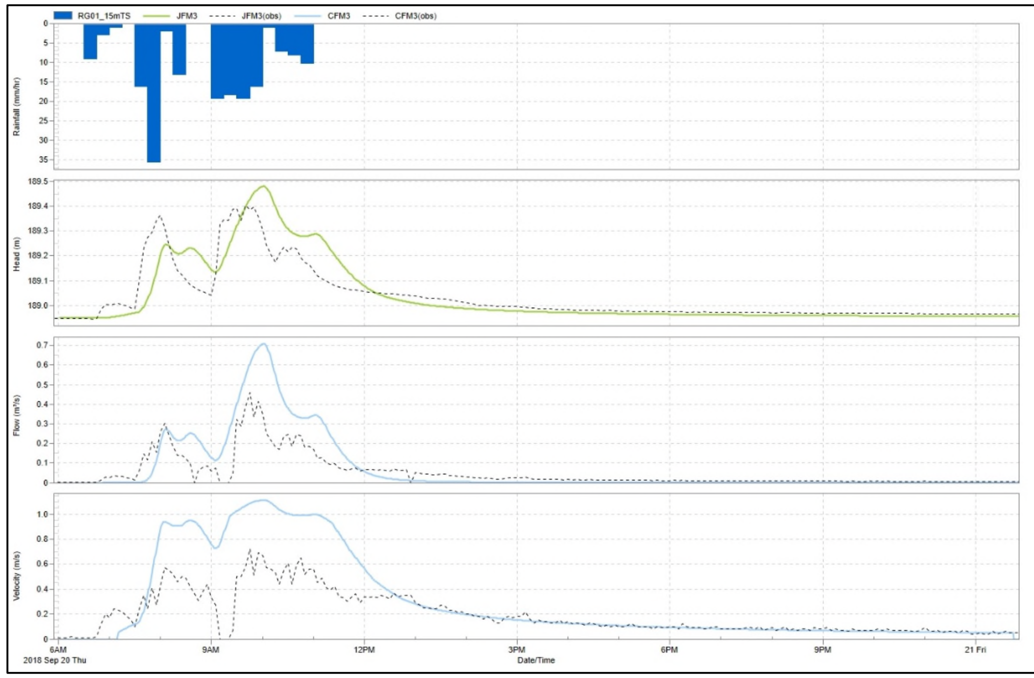
EVENT 6: 25-26 Apr 2019 (30.0mm)



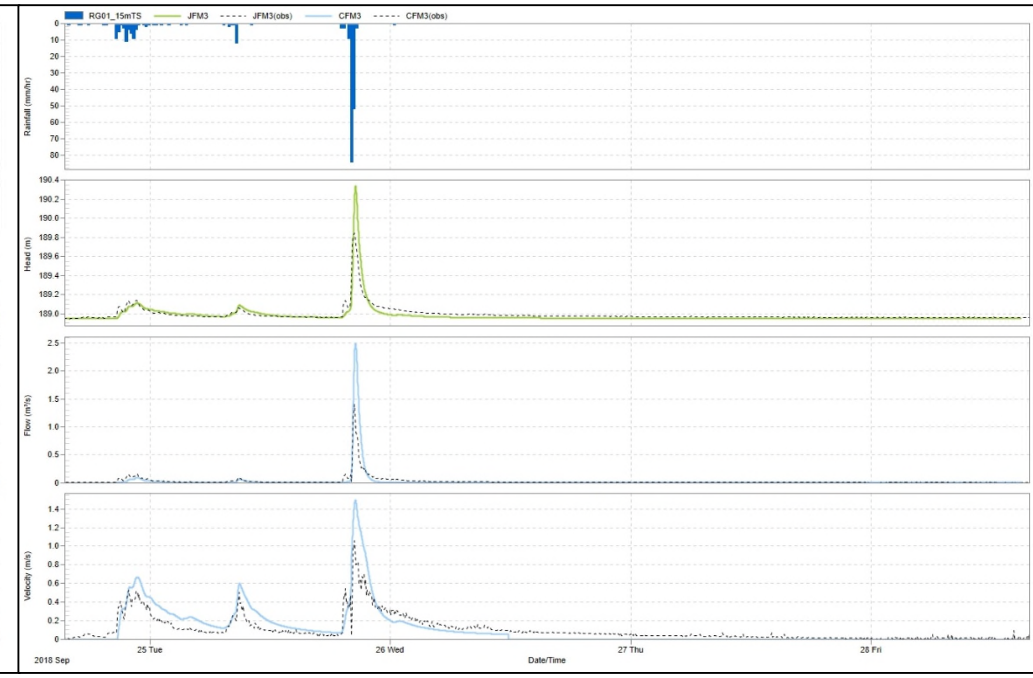
Landmark Engineers Inc.

FM3 – 7TH STREET DRAIN

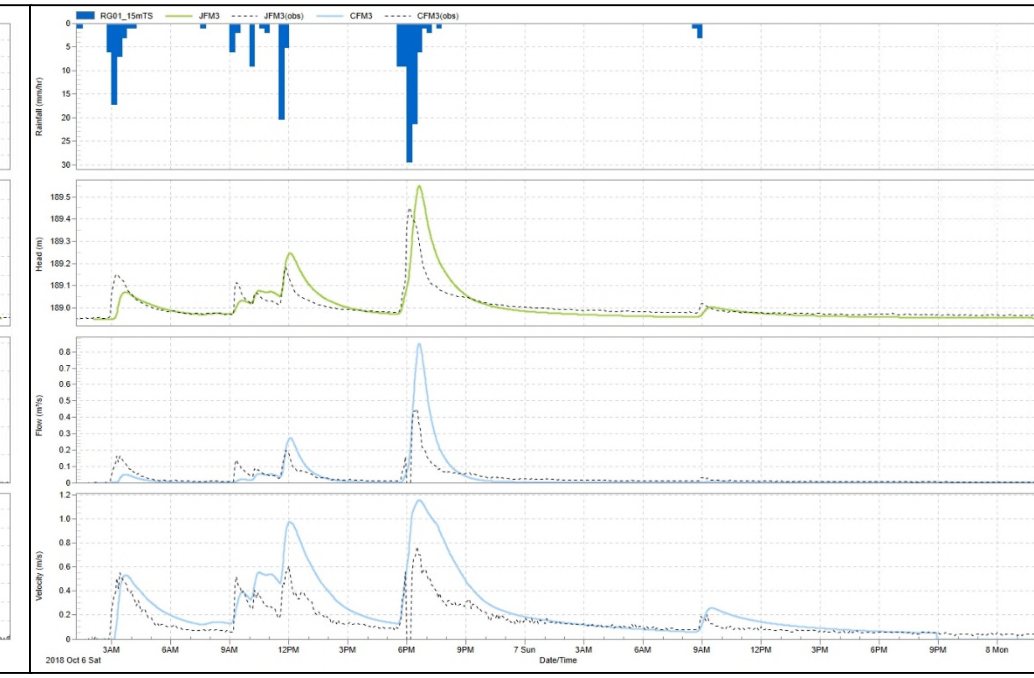
EVENT 1: 20 Sept 2018 (45.0mm)



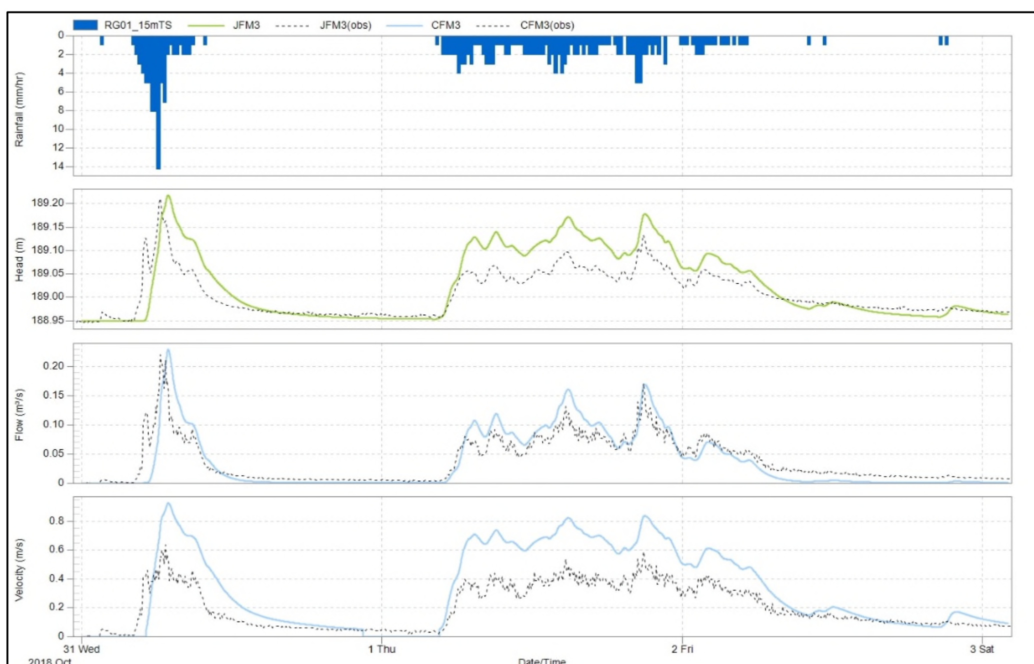
EVENT 2: 24-25 Sept 2018 (61.0mm)



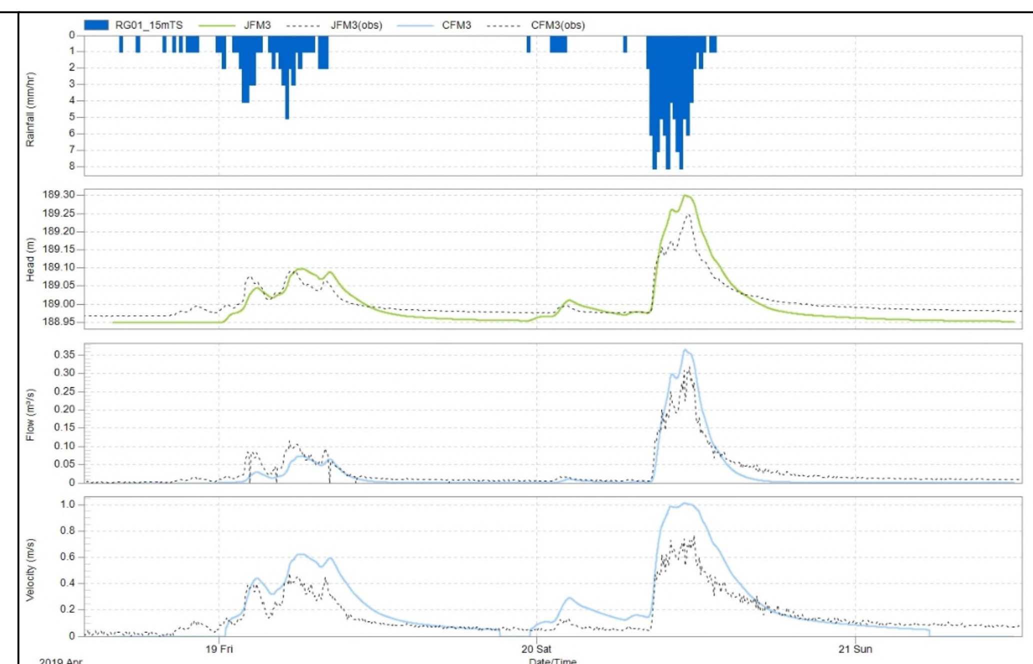
EVENT 3: 6 Oct 2018 (41.4mm)



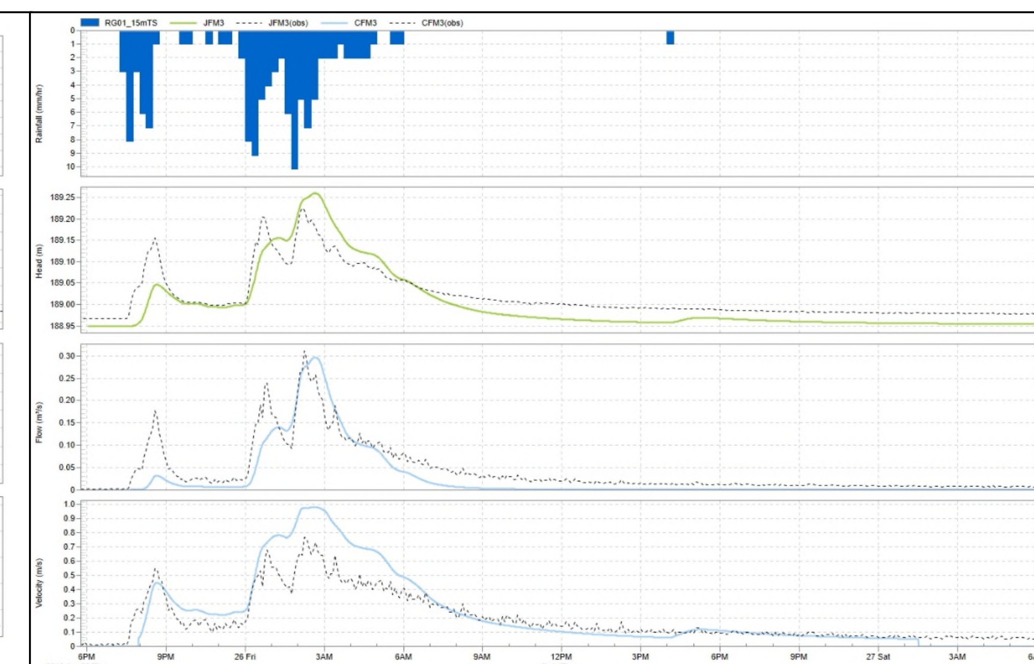
EVENT 4: 31 Oct - 2 Nov 2018 (61.8mm)



EVENT 5: 18-20 Apr 2019 (40.9mm)

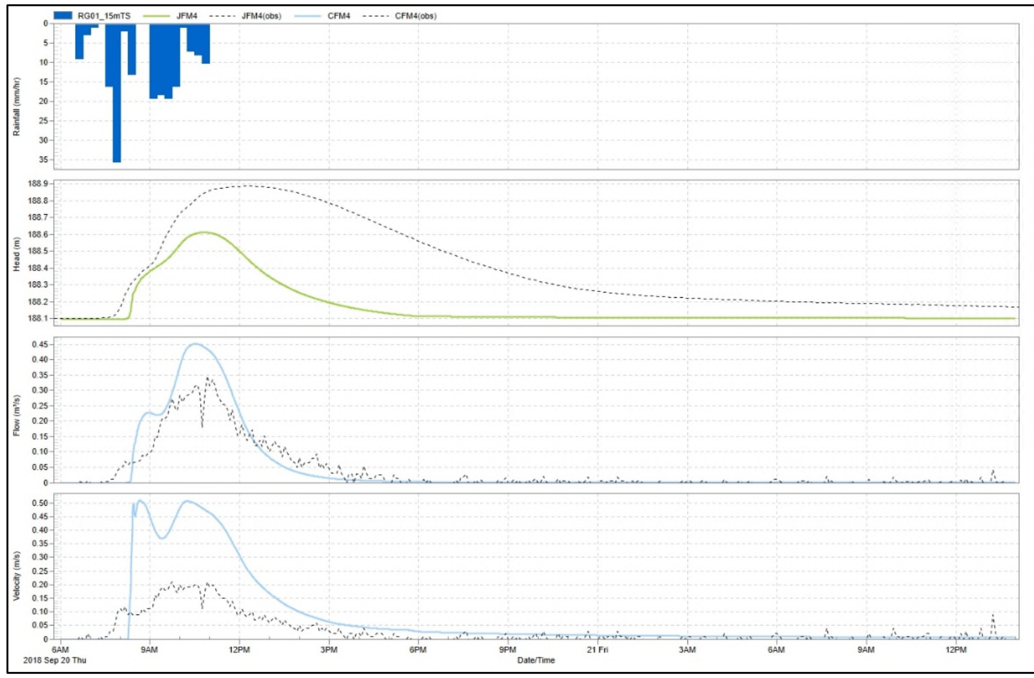


EVENT 6: 25-26 Apr 2019 (30.0mm)

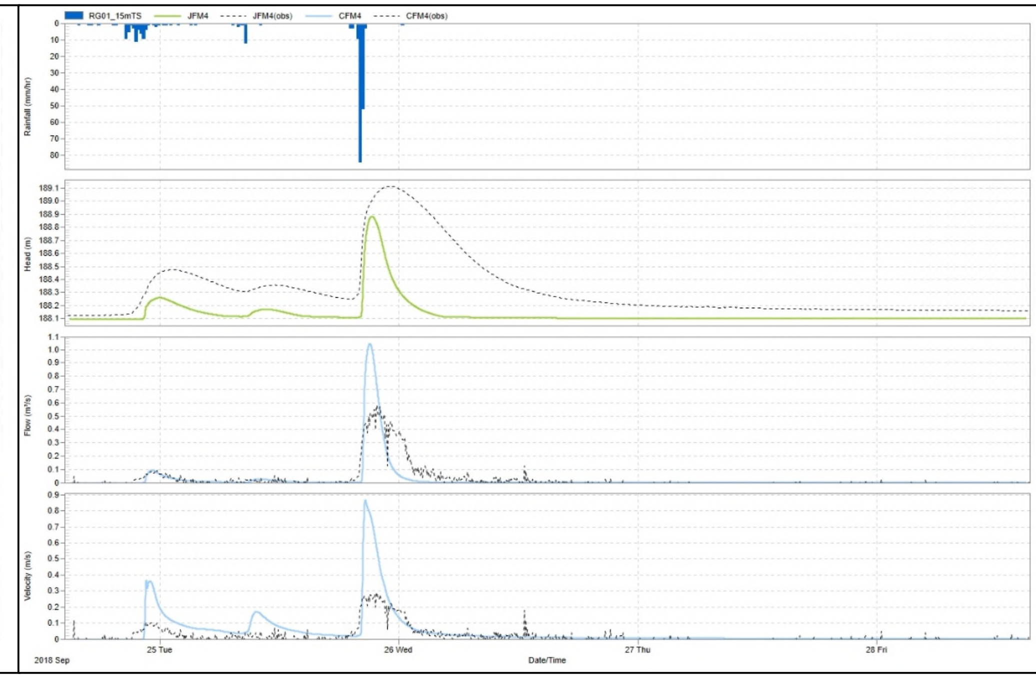


FM4 – 7TH CONC. DRAIN

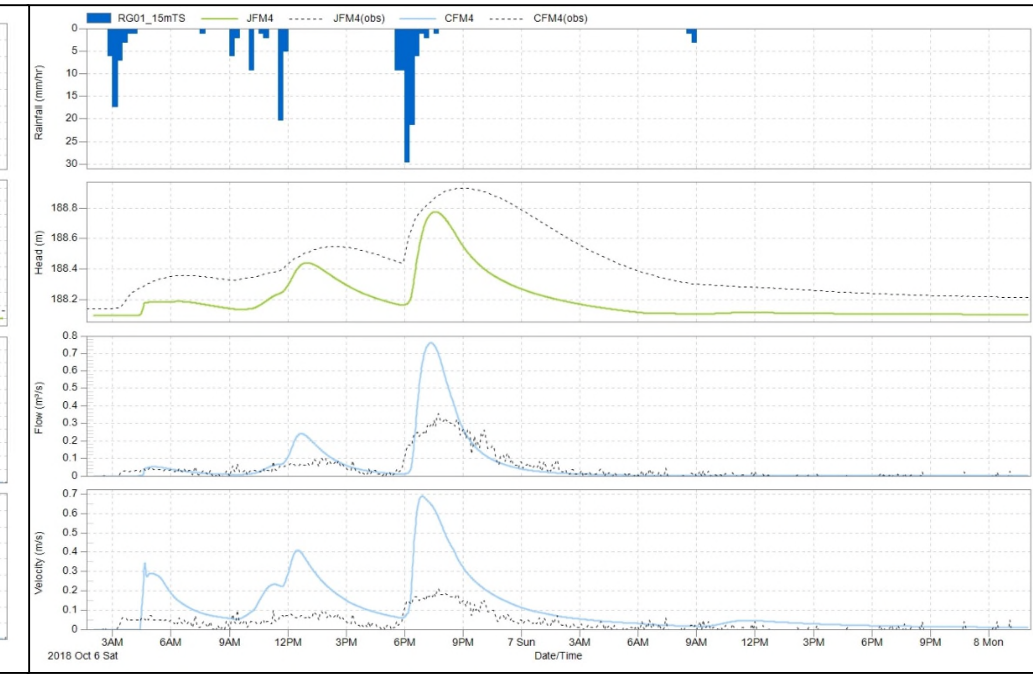
EVENT 1: 20 Sept 2018 (45.0mm)



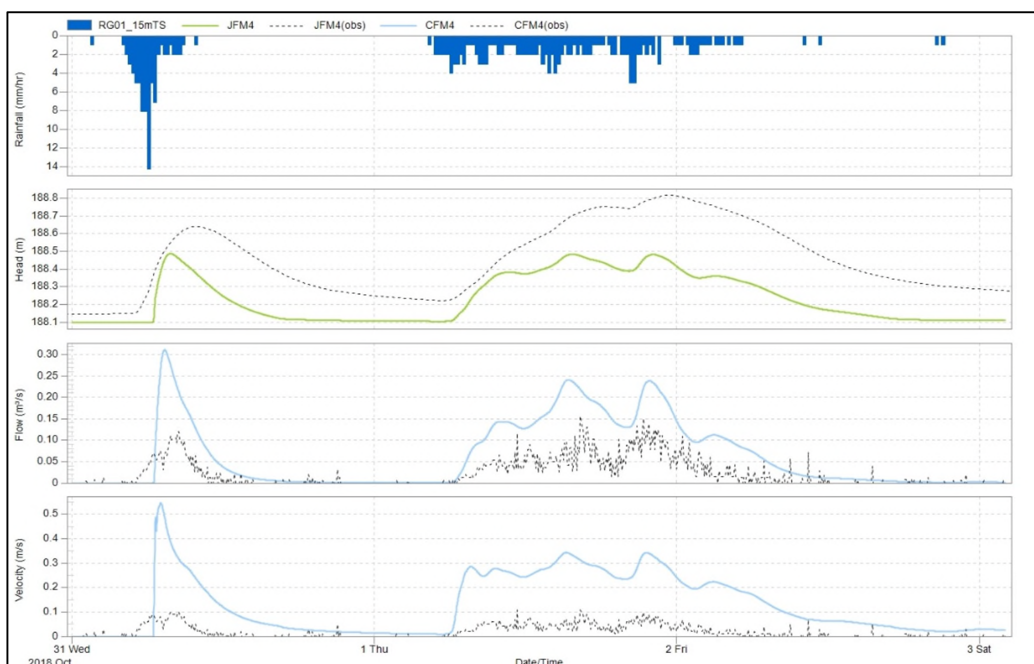
EVENT 2: 24-25 Sept 2018 (61.0mm)



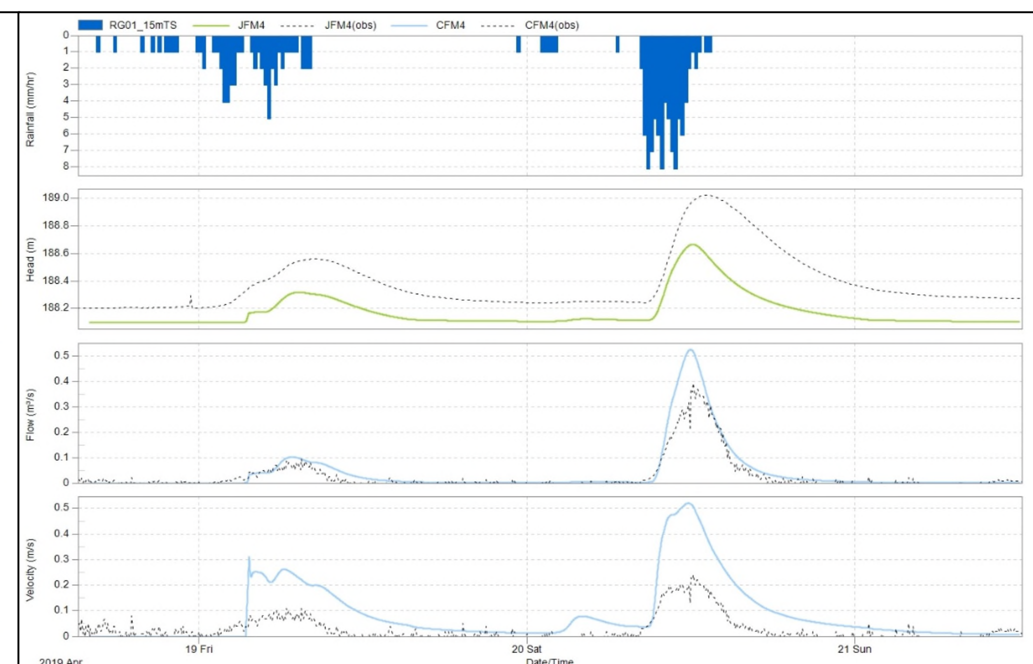
EVENT 3: 6 Oct 2018 (41.4mm)



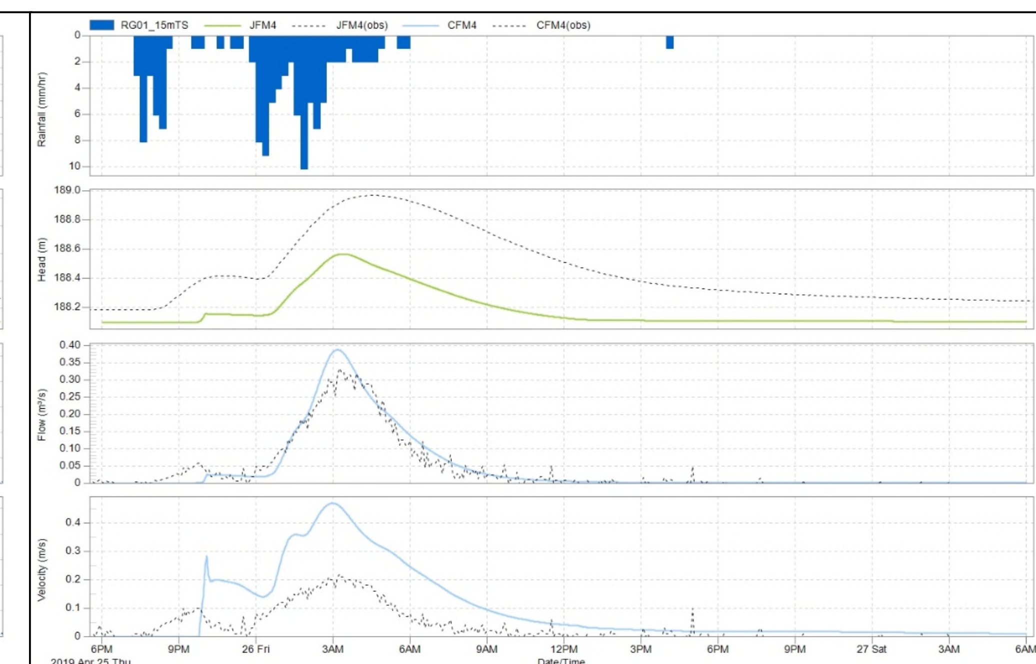
EVENT 4: 31 Oct - 2 Nov 2018 (61.8mm)



EVENT 5: 18-20 Apr 2019 (40.9mm)

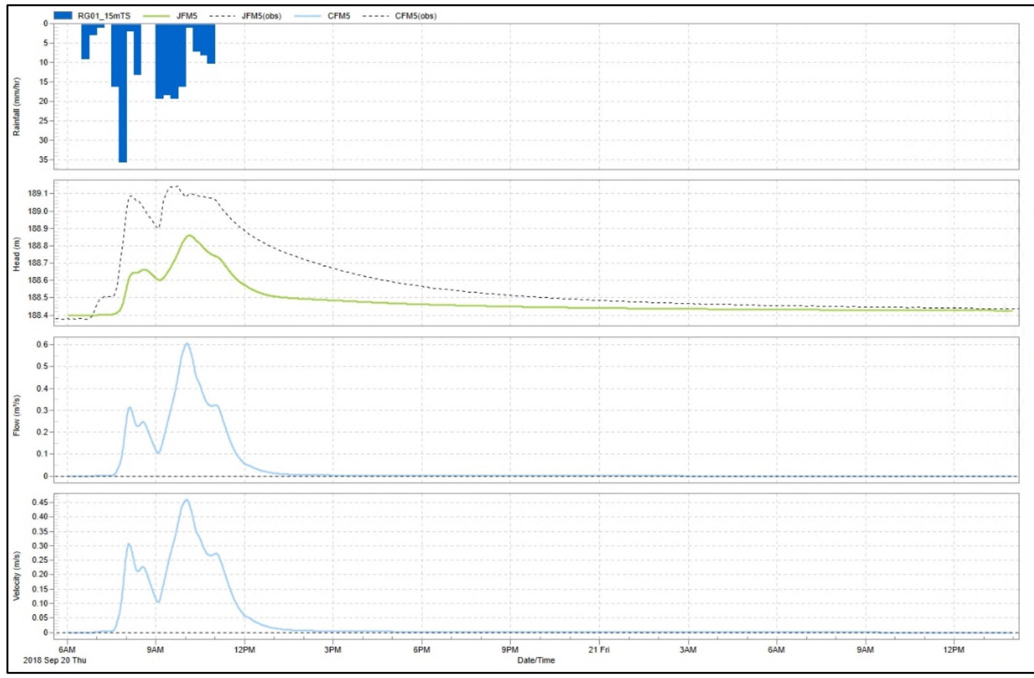


EVENT 6: 25-26 Apr 2019 (30.0mm)

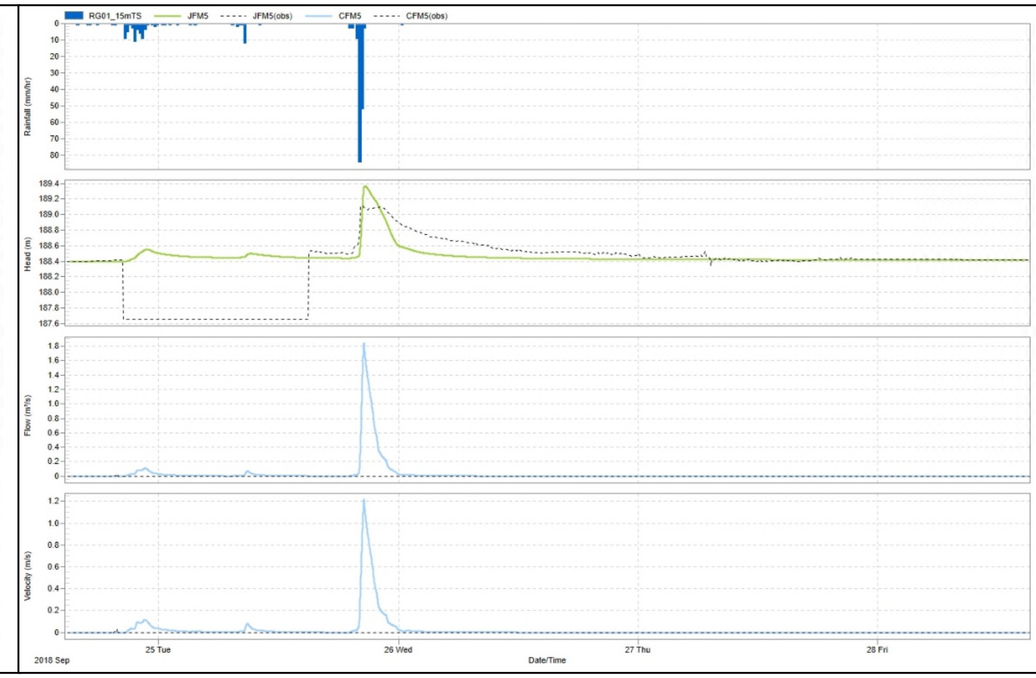


FM5 – WASHBROOK DRAIN

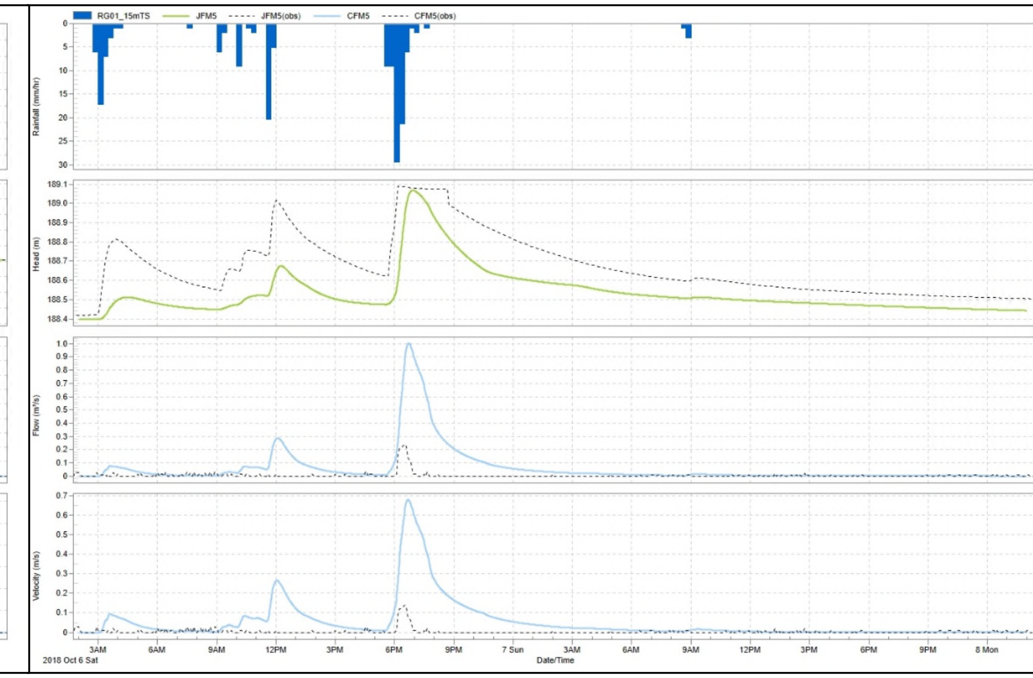
EVENT 1: 20 Sept 2018 (45.0mm)



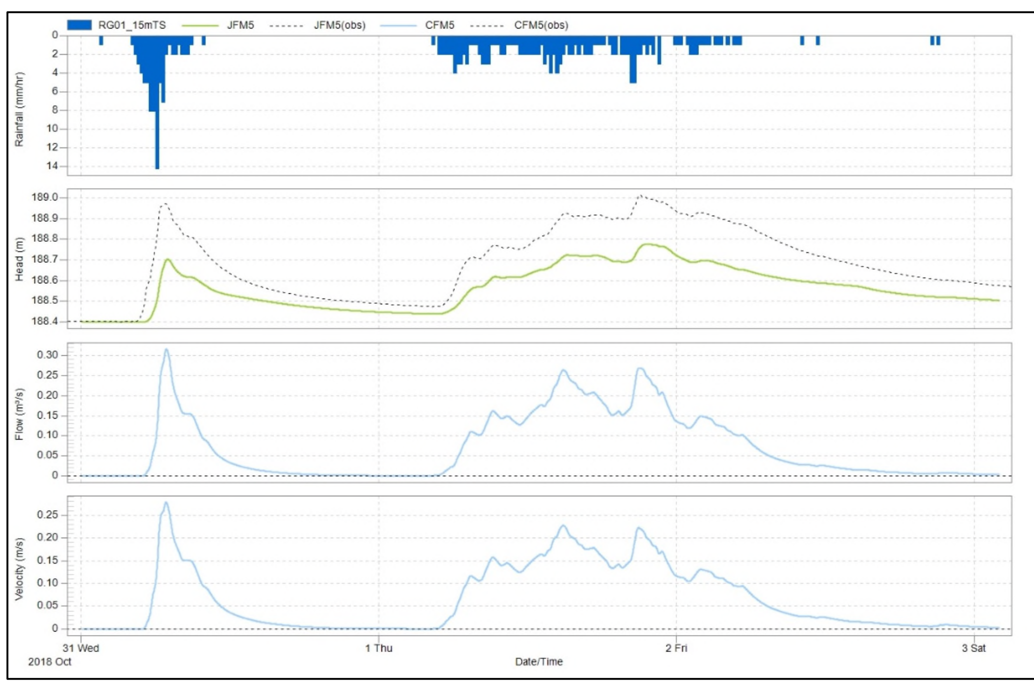
EVENT 2: 24-25 Sept 2018 (61.0mm)



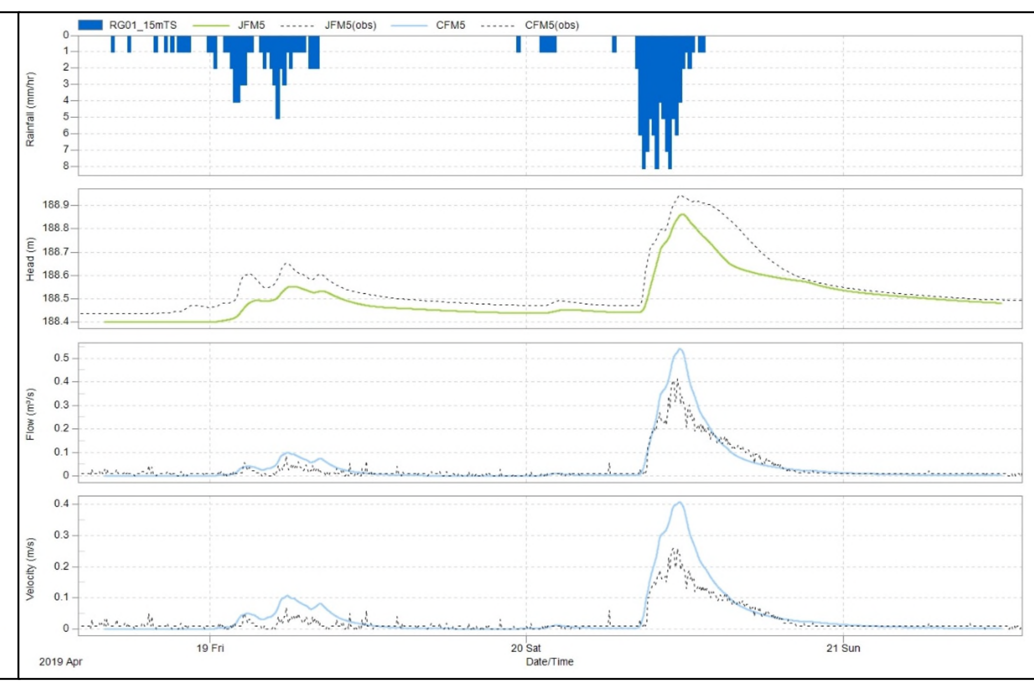
EVENT 3: 6 Oct 2018 (41.4mm)



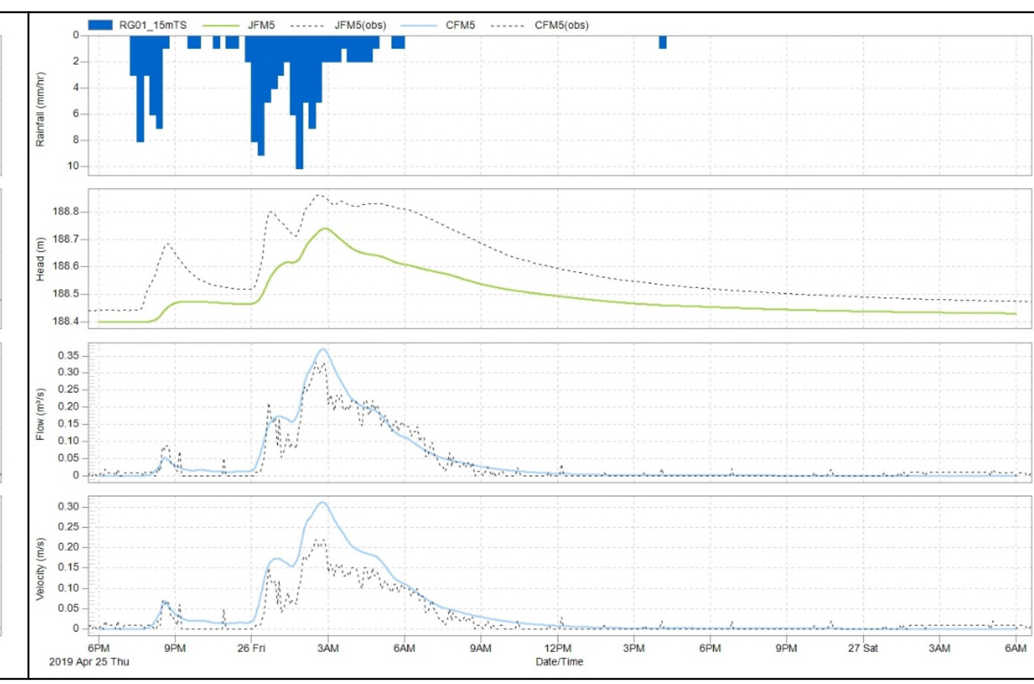
EVENT 4: 31 Oct - 2 Nov 2018 (61.8mm)



EVENT 5: 18-20 Apr 2019 (40.9mm)



EVENT 6: 25-26 Apr 2019 (30.0mm)



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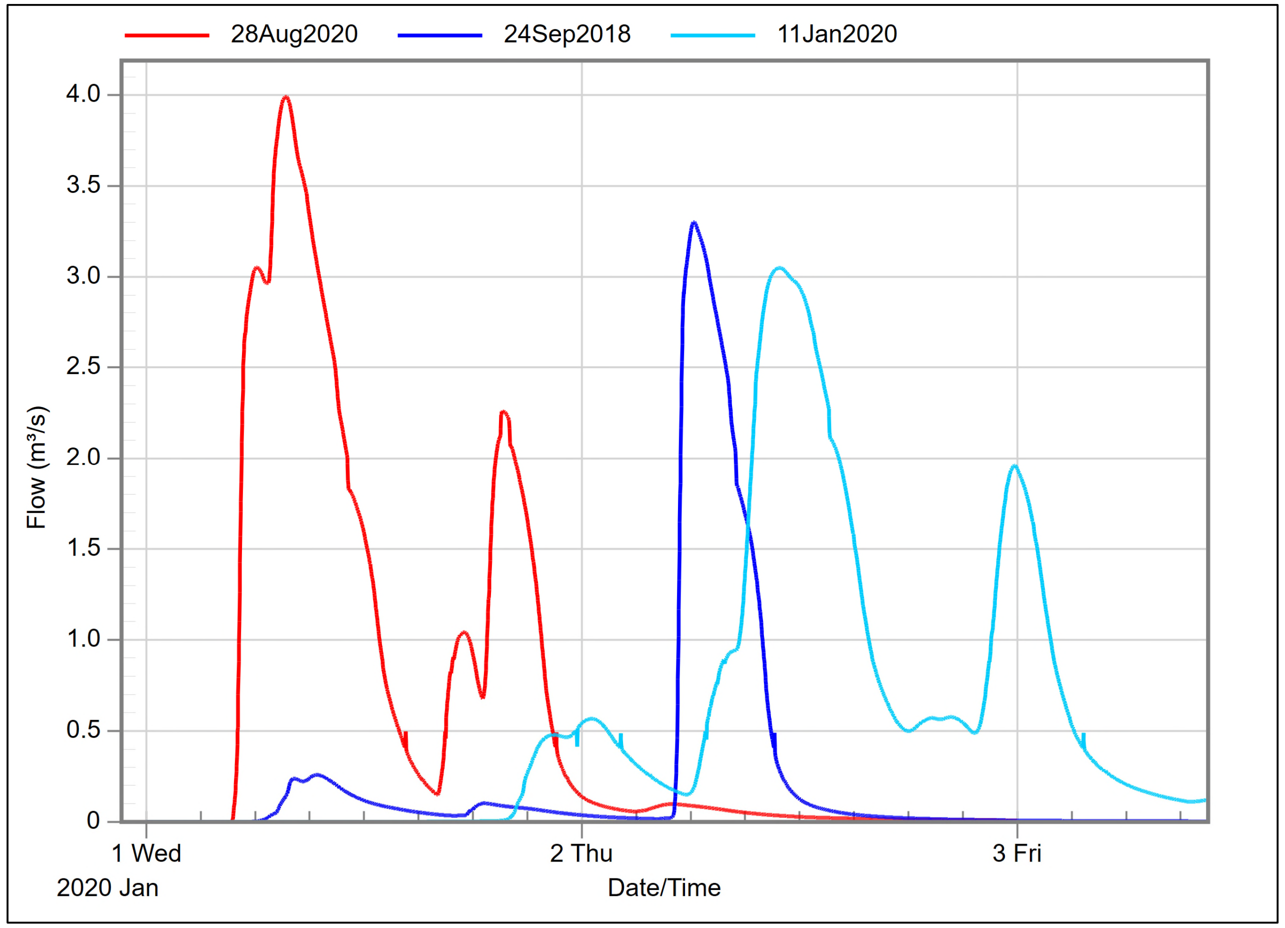
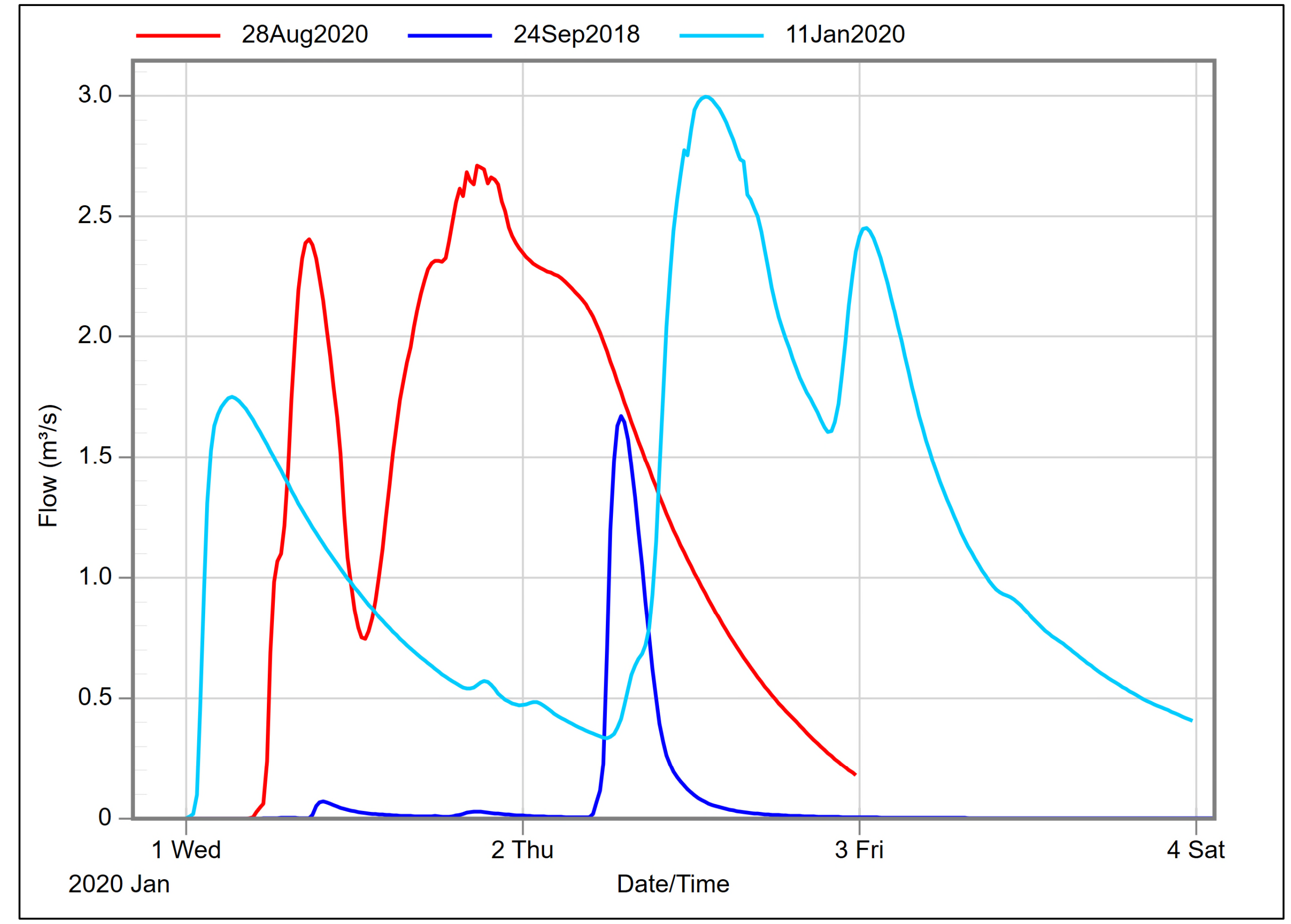
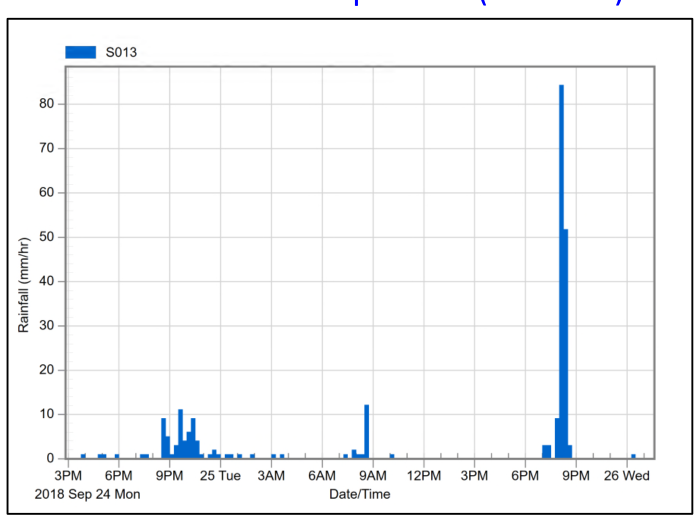
WOLFE DRAIN FLOW @ HWY 401 CROSSING



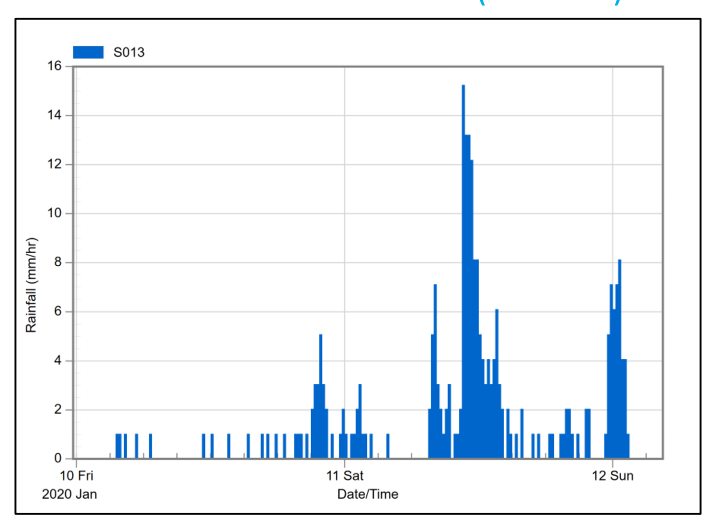
9TH CONC. DRAIN FLOW @ HWY 401 CROSSING



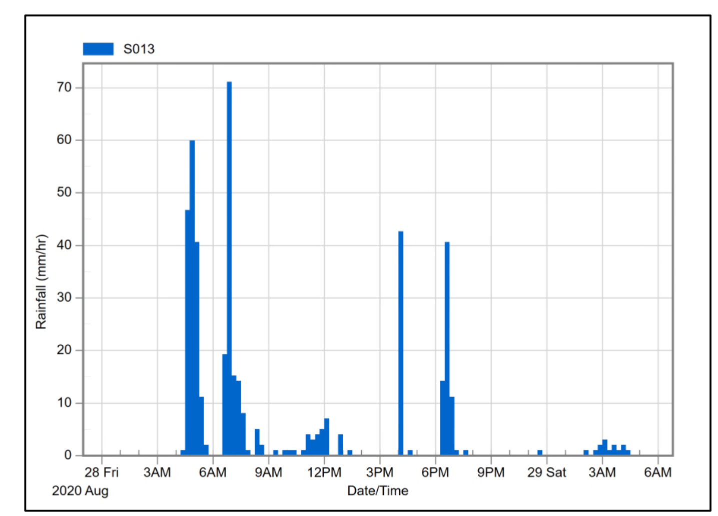
EVENT 2: 24-25 Sept 2018 (61.0mm)



EVENT 7: 10-12 Jan 2020 (63.0mm)



EVENT 8: 28-29 Aug 2020 (115.0mm)



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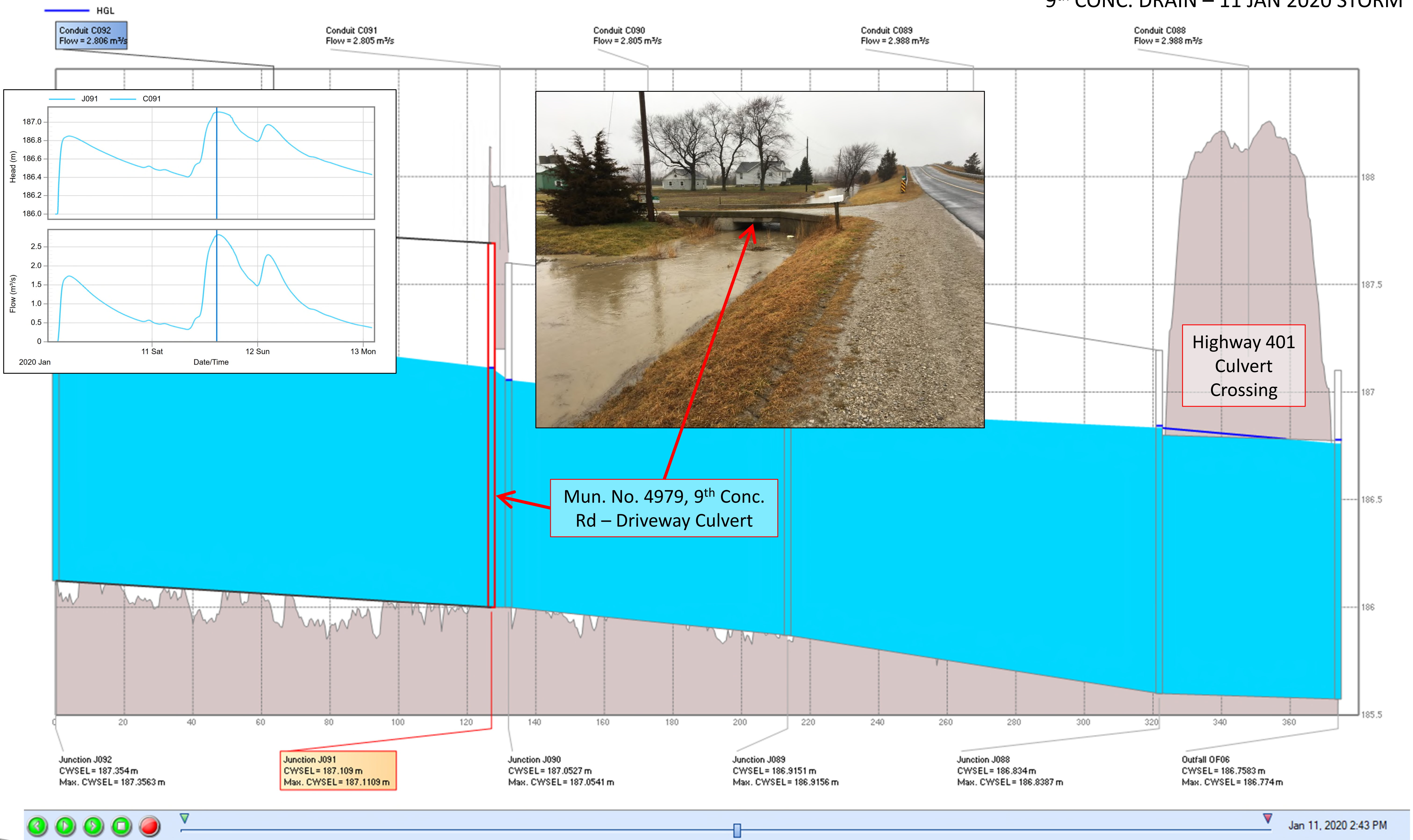
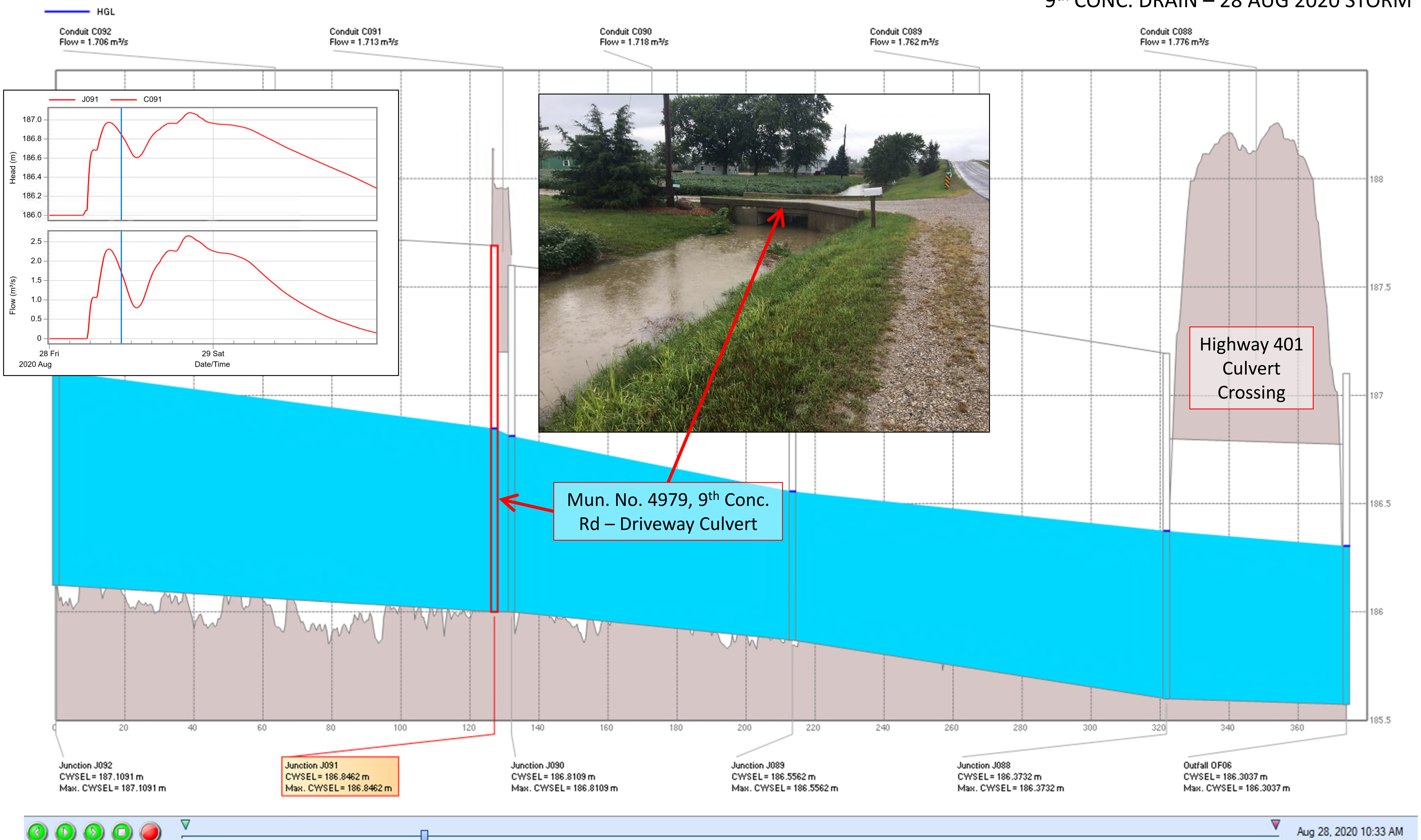
9th CONC. DRAIN – 11 JAN 2020 STORM

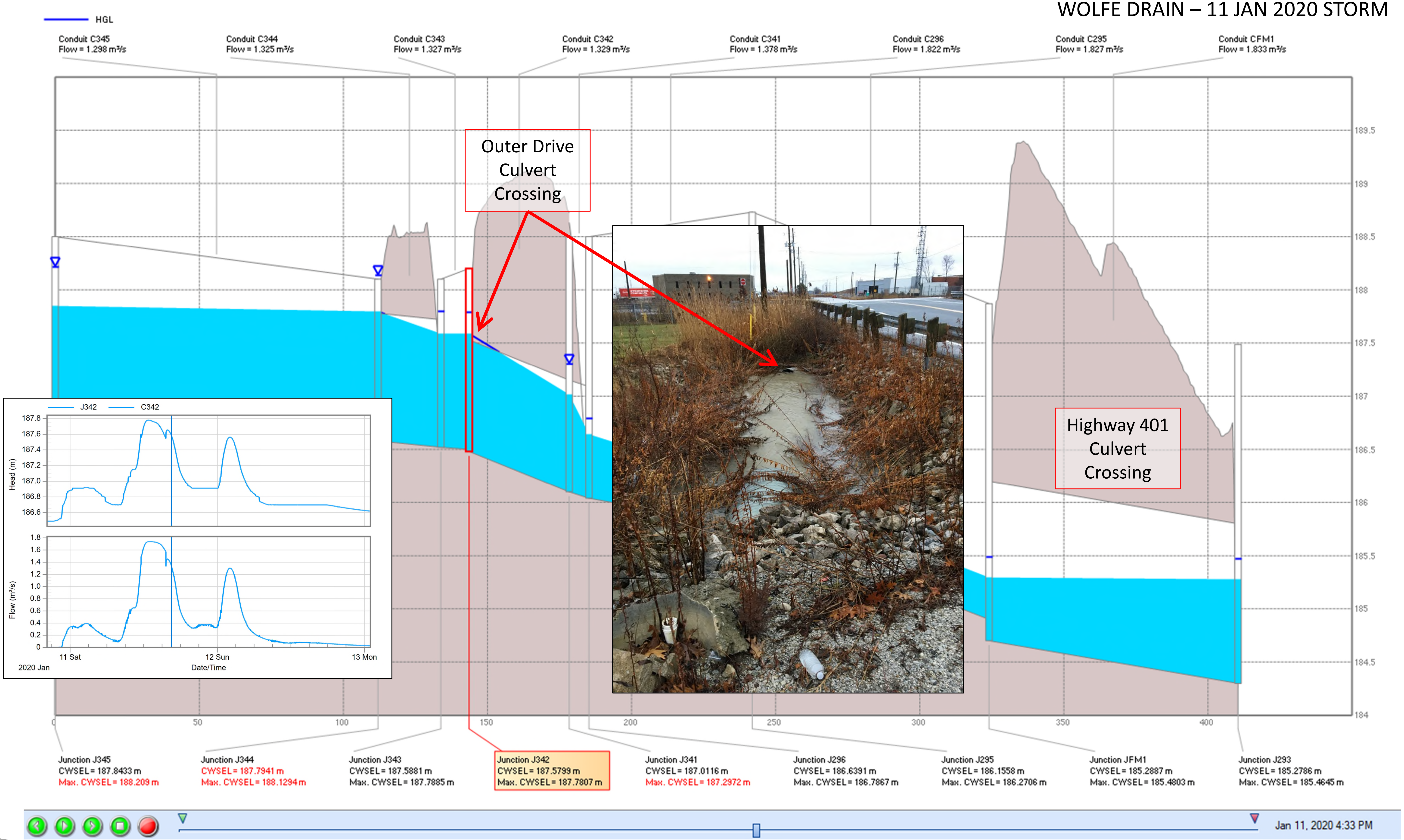


9th CONC. DRAIN – 28 AUG 2020 STORM



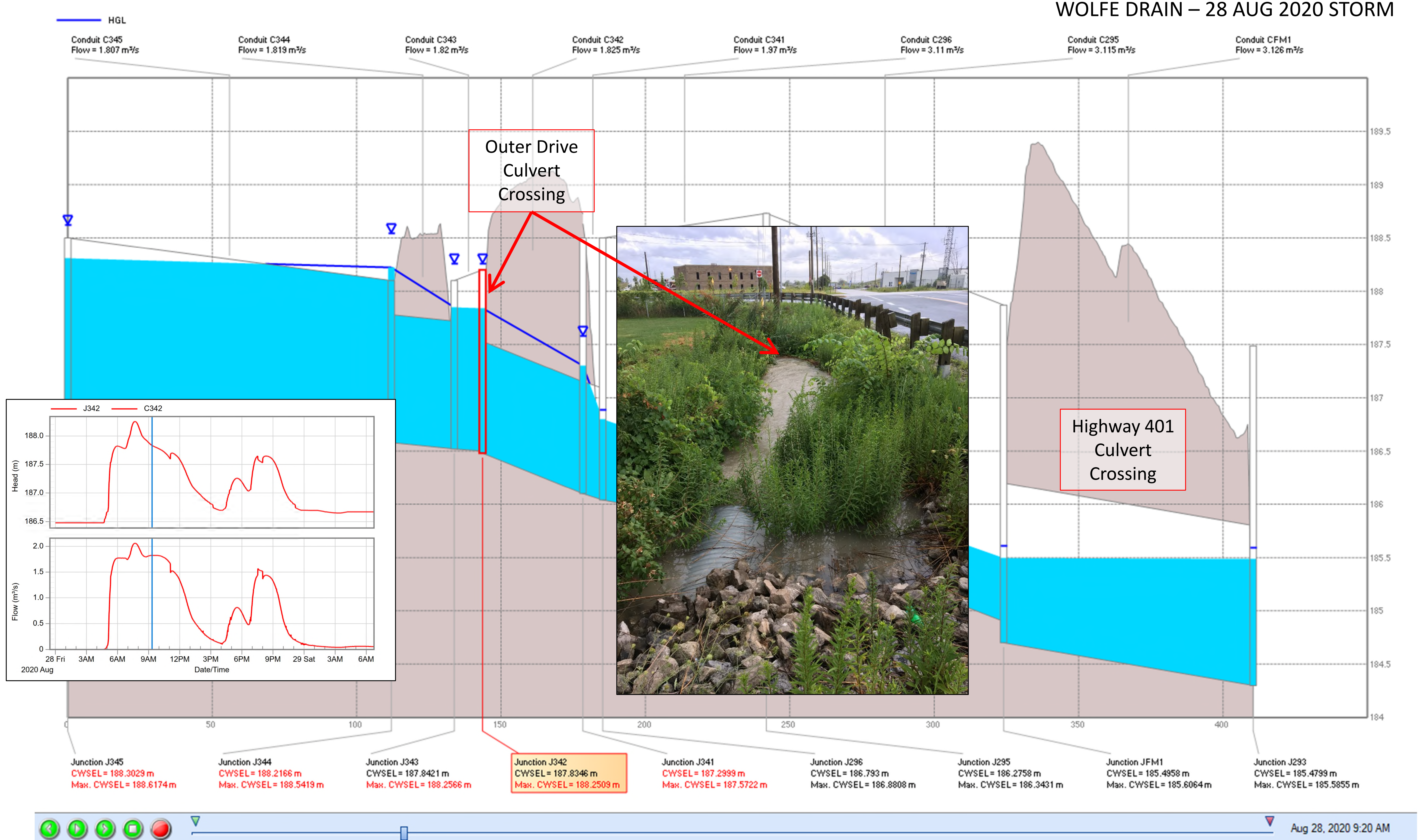
Landmark Engineers Inc.

WOLFE DRAIN – 11 JAN 2020 STORM



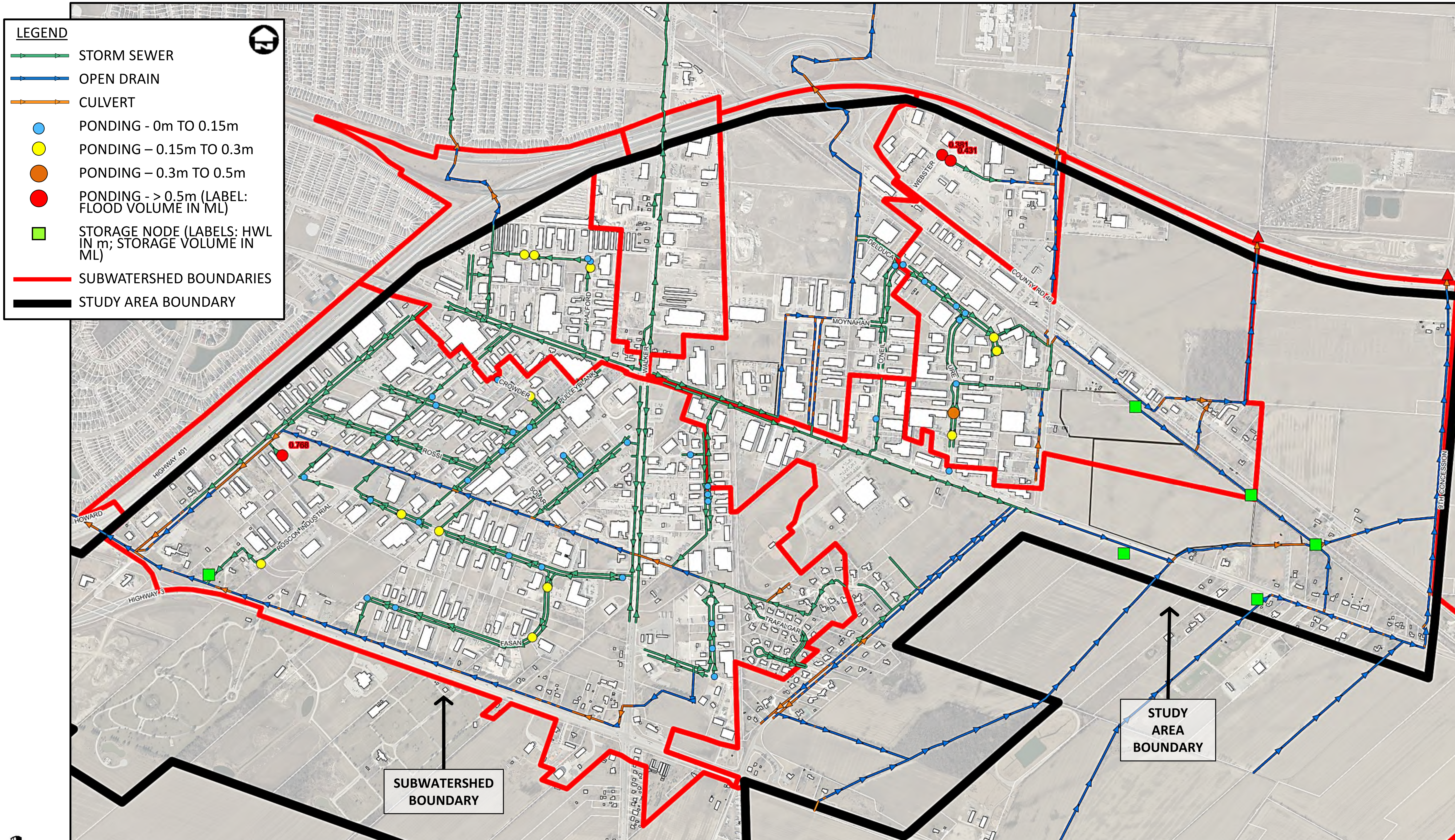
MODEL VALIDATION

WOLFE DRAIN – 28 AUG 2020 STORM



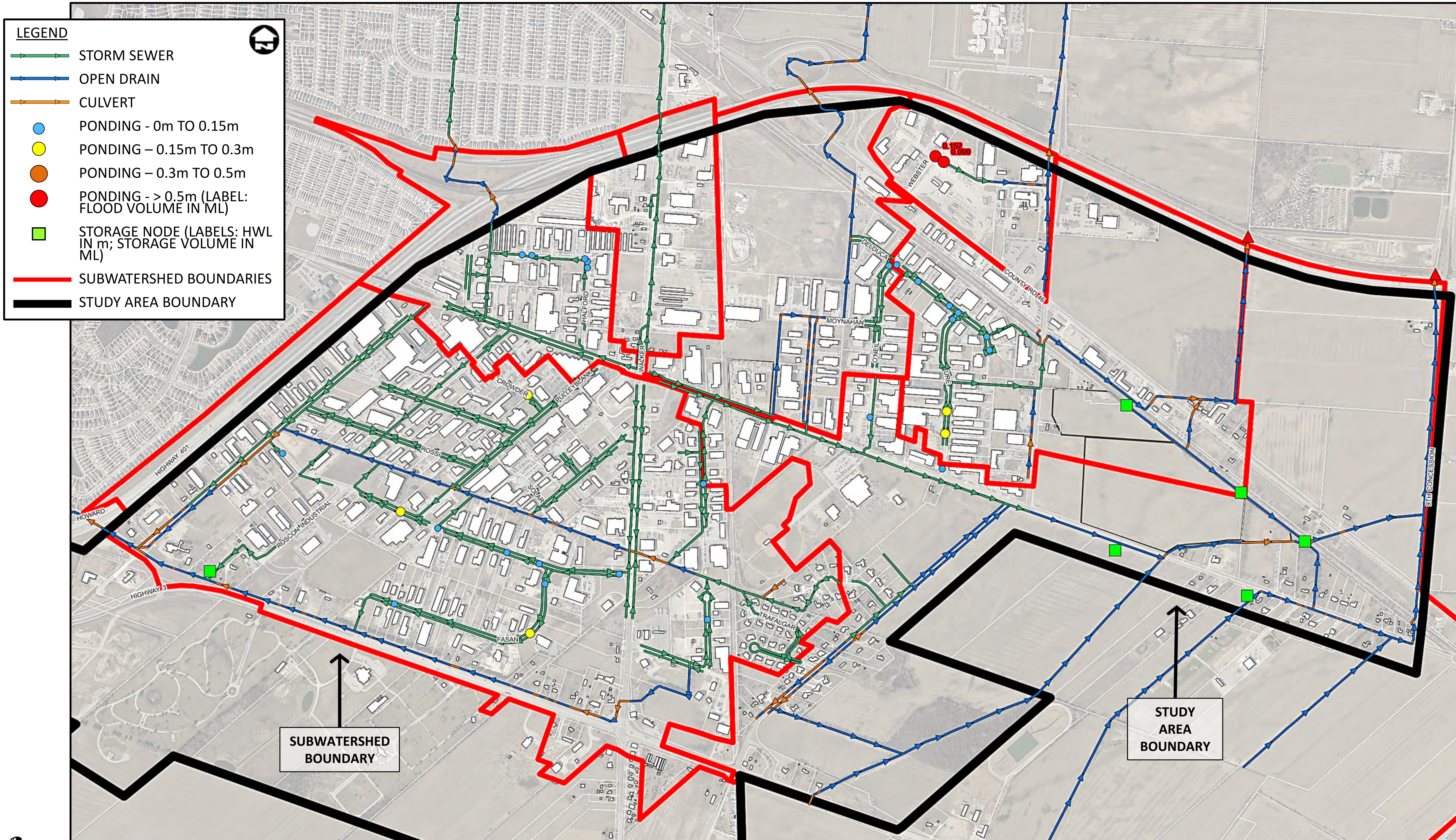
APPENDIX D

MINOR STORM SYSTEM MODEL RESULTS



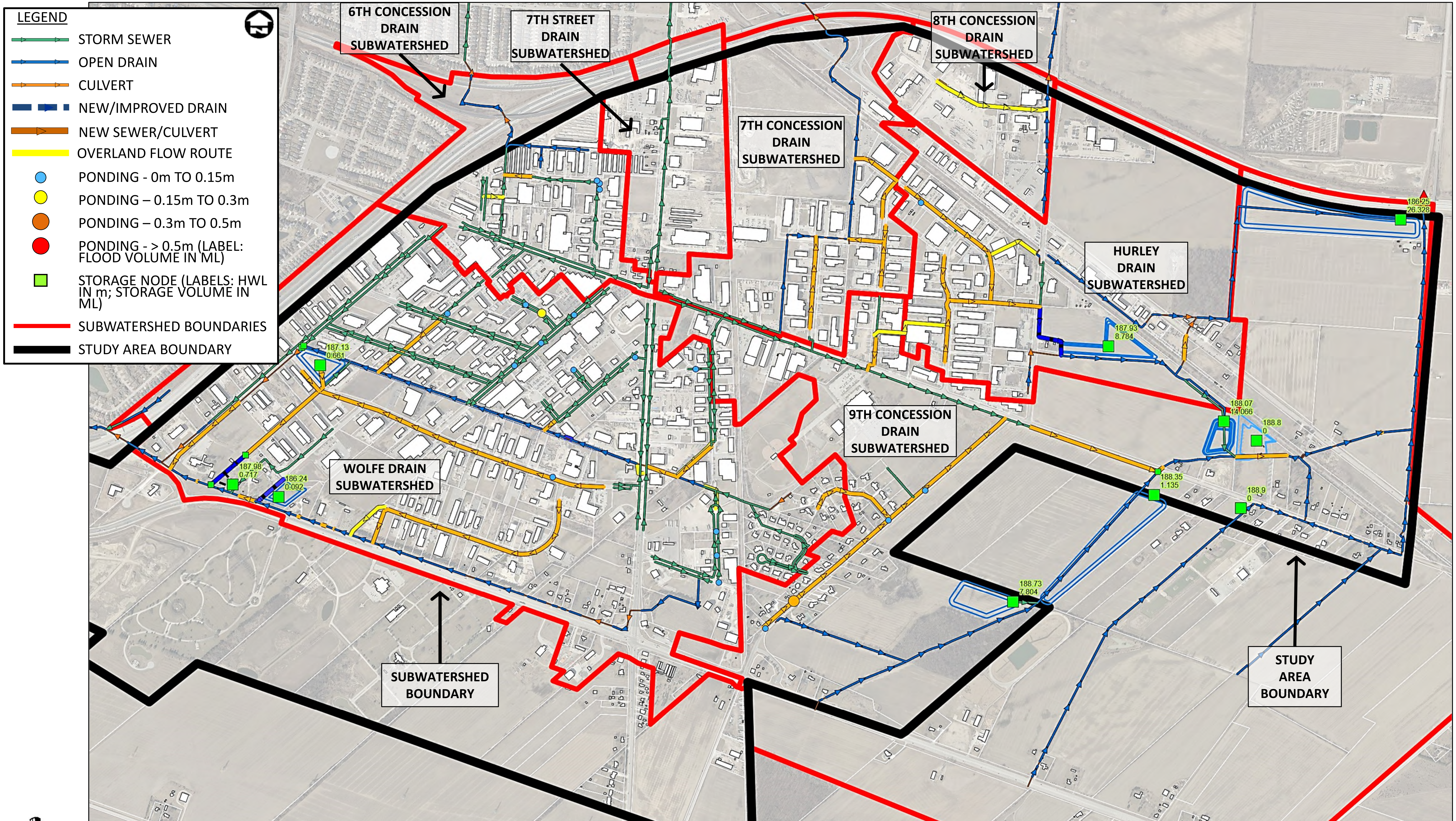
Landmark
Engineers Inc.

Title: EXISTING CONDITIONS: 2-YEAR 4-HOUR STORM	Date: OCT. 2020	Scale: NTS	FIGURE D1
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



Landmark
Engineers Inc.

Title EXISTING CONDITIONS: WATER QUALITY STORM	Date OCT. 2020		FIGURE D2
	Scale NTS		
Project OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



Landmark Engineers Inc.

Title: PROPOSED CONDITIONS: 2-YEAR 4-HOUR STORM	Date: SEPT. 2021	Scale: NTS	FIGURE D3
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

APPENDIX E

CULVERT ASSESSMENTS

LEGEND

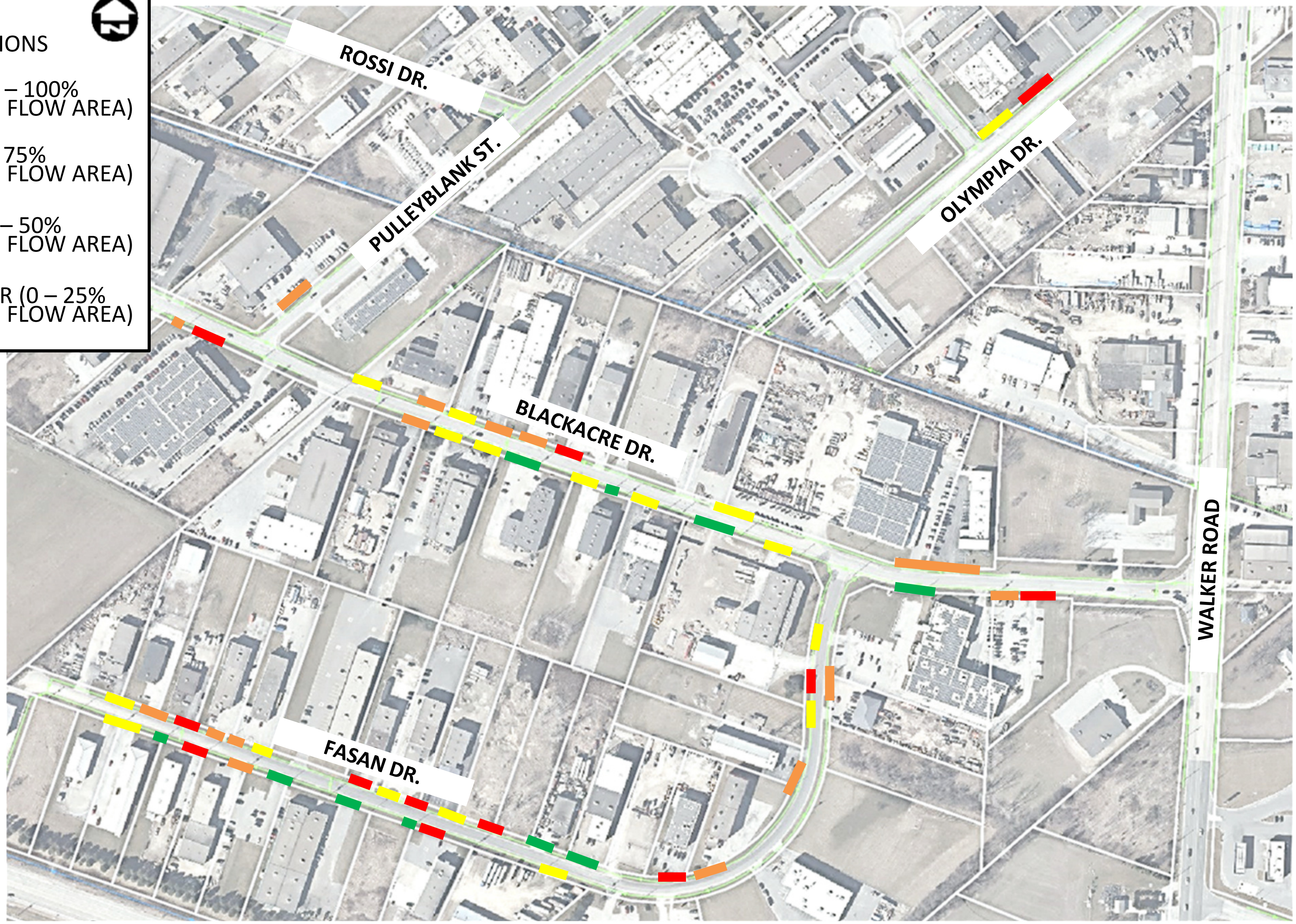
CULVERT CONDITIONS

GOOD (76 – 100% EFFECTIVE FLOW AREA)

FAIR (51 – 75% EFFECTIVE FLOW AREA)

POOR (26 – 50% EFFECTIVE FLOW AREA)

VERY POOR (0 – 25% EFFECTIVE FLOW AREA)



Landmark Engineers Inc.

Title: CULVERT CONDITIONS – WOLFE DRAIN AREA 1		Date: OCT. 2020	FIGURE E1
		Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN		Project No. 19-010	

LEGEND

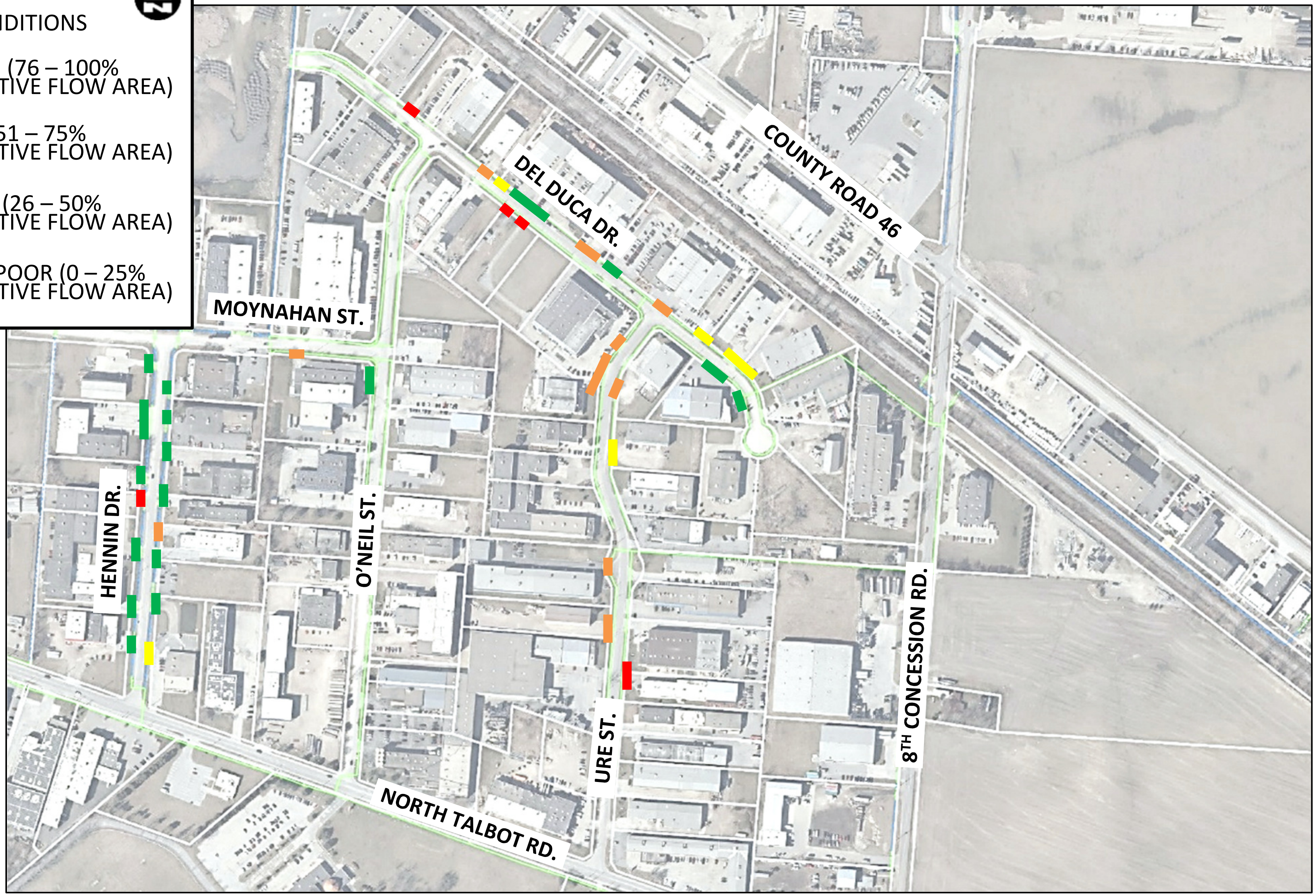
CULVERT CONDITIONS

GOOD (76 – 100% EFFECTIVE FLOW AREA)

FAIR (51 – 75% EFFECTIVE FLOW AREA)

POOR (26 – 50% EFFECTIVE FLOW AREA)

VERY POOR (0 – 25% EFFECTIVE FLOW AREA)



Landmark Engineers Inc.

Title: CULVERT CONDITIONS – 7TH CONCESSION AND HURLEY DRAIN AREAS	Date: OCT. 2020		FIGURE E2
	Scale: NTS		
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

LEGEND

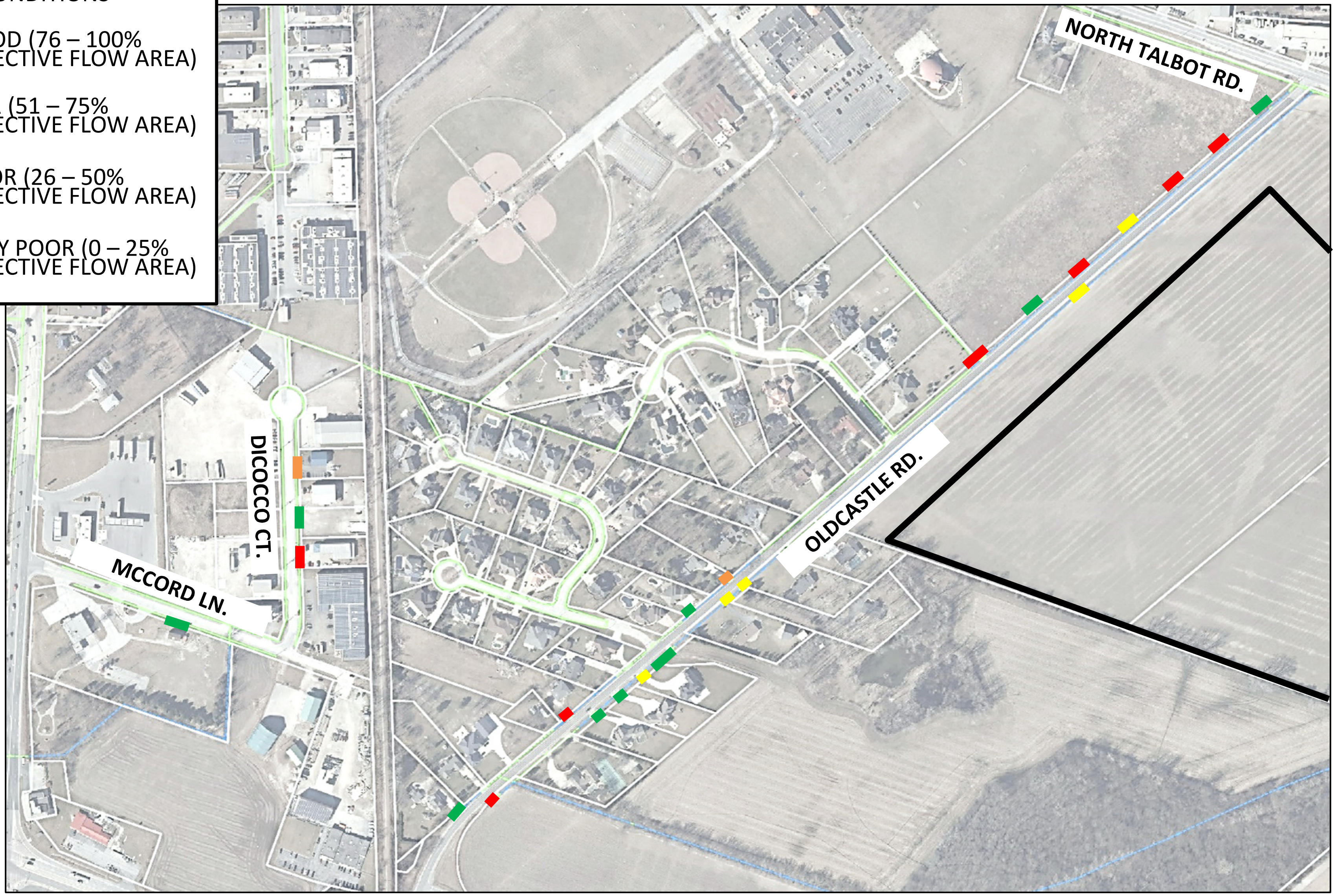
CULVERT CONDITIONS

GOOD (76 – 100% EFFECTIVE FLOW AREA)

FAIR (51 – 75% EFFECTIVE FLOW AREA)

POOR (26 – 50% EFFECTIVE FLOW AREA)

VERY POOR (0 – 25% EFFECTIVE FLOW AREA)



Landmark Engineers Inc.

Title: CULVERT CONDITIONS – OLDCASTLE ROAD AREA	Date: OCT. 2020	Scale: NTS	FIGURE E3
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

DATE	PT	NORTHING (Y-Coord.)	EASTING (X-Coord.)	DIA. (mm)	OPEN DEPTH (mm)	% OPEN AREA	MATERIAL	IMAGE NAME	CONDITION
11/25/2019	112	4678228	338564	450	450	100	CSP	112_Top of pipe_1.jpg	CLEAR
11/25/2019	113	4678240	338565	450	450	100	CSP	113_Top of pipe_1.jpg	CLEAR
11/25/2019	120	4678351	338414	300	300	100	PE	120_Top of pipe_1.jpg	CLEAR
11/25/2019	121	4678372	338433	450	450	100	PE	121_Top of pipe_1.jpg	CLEAR
11/25/2019	129	4678176	338544	450	450	100	CSP	129_Top of pipe_1.jpg	CLEAR
11/25/2019	133	4678071	338535	450	450	100	CSP	133_Top of pipe_1.jpg	CLEAR
11/25/2019	134	4678052	338534	450	450	100	CSP	134_Top of pipe_1.jpg	CLEAR
11/25/2019	149	4678480	338917	150	150	100	CSP	149_Top of pipe_1.jpg	CLEAR
11/25/2019	153	4678426	339009	300	300	100	CSP	153_Top of pipe_1.jpg	CLEAR
11/25/2019	155	4678414	339025	300	300	100	CSP	155_Top of pipe_1.jpg	CLEAR
11/25/2019	163	4678310	339157	450	450	100	CSP		CLEAR
11/25/2019	165	4678303	339144	450	450	100	CSP	165_Top of pipe_1.jpg	120mm DEEP DENT
11/25/2019	166	4678321	339121	450	450	100	CSP	166_Top of pipe_1.jpg	CLEAR
11/25/2019	167	4678328	339112	450	450	100	CSP	167_Top of pipe_1.jpg	CLEAR
11/25/2019	176	4678225	339017	300	300	100	CSP	20191125_155846.jpg	GRASS
11/25/2019	177	4678136	339023	675	675	100	CSP	20191125_160405.jpg	GOOD
11/25/2019	185	4676899	338325	525	525	100	CONC	20191125_163440.jpg	CLEAR
11/25/2019	186	4676977	338368	450	450	100	CONC	20191125_163913.jpg; 20191125_165334.jpg	CLEAR
11/25/2019	187	4676987	338379	450	450	100	CONC	20191125_164016.jpg	CLEAR
11/25/2019	191	4677076	338484	300	300	100	CSP	20191125_164618.jpg; 20191125_164626.jpg	BLOCKED BY ROCK
11/26/2019	200	4677357	338804	450	450	100	CSP	200_Top of pipe_1.jpg	GOOD
11/26/2019	203	4677487	338959	300	300	100	PE	203_Top of pipe_1.jpg	WATER
11/26/2019	209	4677611	339101	300	300	100	PE	209_Top of pipe_1.jpg	SUBMERGED
11/26/2019	269	4677172	338093	200	200	100	PE	269_Top of pipe_1.jpg	CLEAR
11/26/2019	270	4677168	338104	200	200	100	PE	270_Top of pipe_1.jpg	CLEAR
11/26/2019	282	4677294	337332	375	375	100	PE	282_Top of pipe_1.jpg	GOOD
11/26/2019	283	4677295	337329	375	375	100	PE		GOOD
11/26/2019	291	4677363	337135	375	375	100	PE	291_Top of pipe_1.jpg	GOOD
11/26/2019	292	4677363	337132	375	375	100	PE		GOOD
11/26/2019	322	4677268	337445	300	300	100	PE	20191126_125148.jpg	GOOD
11/26/2019	323	4677265	337454	300	300	100	PE	20191126_125250.jpg	CLEAR
11/26/2019	324	4677261	337465	300	300	100	PE	20191126_125317.jpg	CLEAR
11/26/2019	340	4677477	337721	300	300	100	CSP	20191126_141146.jpg	GOOD
11/26/2019	341	4677477	337717	300	300	100	CSP	20191126_141217.jpg	GOOD
11/26/2019	349	4677557	337472	375	375	100	PE	20191126_142006.jpg	GOOD
11/26/2019	204	4677489	338961	300	290	99	PE	204_Top of pipe_1.jpg	PHRAG
11/25/2019	104	4678089	338553	450	430	98	CSP	104_Top of pipe_1.jpg	CLEAR
11/25/2019	105	4678102	338554	450	430	98	CSP	105_Top of pipe_1.jpg	CLEAR
11/25/2019	189	4677064	338470	450	430	98	CSP	20191125_164607.jpg	GOOD
11/26/2019	228	4677096	338530	450	430	98	PE	228_Top of pipe_1.jpg	GOOD
11/26/2019	286	4677329	337232	375	350	97	PE	286_Top of pipe_1.jpg	GOOD
11/26/2019	213	4677693	339196	450	420	97	PE	213_Top of pipe_1.jpg	GOOD
11/26/2019	274	4677386	337646	300	280	97	HDPE	274_Top of pipe_1.jpg	GOOD
11/25/2019	188	4677001	338396	525	480	96	CSP	20191125_164230.jpg	GOOD

DATE	PT	NORTHING (Y-Coord.)	EASTING (X-Coord.)	DIA. (mm)	OPEN DEPTH (mm)	% OPEN AREA	MATERIAL	IMAGE NAME	CONDITION
11/25/2019	106	4678126	338555	450	410	96	CSP	106_Top of pipe_1.jpg	CLEAR
11/25/2019	107	4678138	338556	450	410	96	CSP	107_Top of pipe_1.jpg	CLEAR
11/26/2019	229	4677084	338516	450	410	96	PE	229_Top of pipe_1.jpg	GOOD
11/26/2019	231	4677066	338495	450	410	96	CSP	231_Top of pipe_1.jpg	GOOD
11/26/2019	358	4677604	337336	375	340	95	CSP	20191126_142612.jpg	GOOD
11/26/2019	379	4677541	337556	300	270	95	CSP	20191126_145723.jpg	GOOD
11/26/2019	385	4677690	336398	675	600	94	CSP	20191126_153354.jpg	GOOD
11/26/2019	386	4677692	336400	675	600	94	CSP	20191126_153401.jpg	GOOD
11/25/2019	102	4678073	338551	450	400	94	HDP	102_Top of pipe_1.jpg	CLEAR
11/25/2019	103	4678088	338552	450	400	94	HDP	103_Top of pipe_1.jpg	CLEAR
11/25/2019	119	4678342	338553	450	400	94	CSP	119_Top of pipe_1.jpg; 119_Top of pipe_2.jpg	RUSTED
11/25/2019	125	4678250	338549	450	400	94	CSP	125_Top of pipe_1.jpg	CLEAR
11/26/2019	207	4677570	339054	450	400	94	PE	207_Top of pipe_1.jpg	WATER
11/26/2019	223	4677149	338592	450	400	94	CSP	223_Top of pipe_1.jpg	GOOD
11/26/2019	227	4677103	338538	450	400	94	PE	227_Top of pipe_1.jpg	GOOD
11/26/2019	293	4677370	337113	450	400	94	CSP	293_Top of pipe_1.jpg	GOOD
11/25/2019	127	4678201	338545	525	460	93	CSP	127_Top of pipe_1.jpg	PHRAG
11/25/2019	101	4678037	338548	400	350	93	CSP	101_Top of pipe_1.jpg	CLEAR
11/25/2019	108	4678147	338557	450	390	92	CSP	108_Top of pipe_1.jpg	SLIGHTLY CHIPPED
11/25/2019	132	4678084	338537	450	390	92	CSP	132_Top of pipe_1.jpg	CLEAR
11/25/2019	136	4678300	338778	150	130	92	CSP	136_Top of pipe_1.jpg	CLEAR
11/25/2019	137	4678310	338778	150	130	92	CSP	137_Top of pipe_1.jpg	CLEAR
11/25/2019	178	4678124	339017	450	390	92	CSP	20191125_160649.jpg	GOOD
11/26/2019	354	4677585	337393	450	390	92	CSP	20191126_142320.jpg	GOOD
11/26/2019	348	4677556	337475	375	320	91	PE	20191126_141938.jpg	GOOD
11/25/2019	116	4678289	338569	450	380	90	CSP	116_Top of pipe_1.jpg	SOME DEBRIS
11/25/2019	117	4678301	338570	450	380	90	CSP	117_Top of pipe_1.jpg	PHRAG
11/25/2019	124	4678283	338552	450	380	90	CSP	124_Top of pipe_1.jpg	PHRAG
11/25/2019	131	4678128	338540	450	380	90	CSP	131_Top of pipe_1.jpg	120mm DEEP DENT
11/26/2019	232	4677013	338432	450	380	90	CSP	232_Top of pipe_1.jpg	PHRAG
11/26/2019	236	4676893	338341	450	380	90	CONC	236_Top of pipe_1.jpg	
11/25/2019	126	4678214	338546	525	440	89	CSP	126_Top of pipe_1.jpg	CLEAR
11/25/2019	123	4678317	338554	600	500	89	CSP	123_Top of pipe_1.jpg	PHRAG
11/26/2019	264	4677333	338209	300	250	89	CSP	264_Top of pipe_1.jpg	GOOD
11/26/2019	352	4677576	337417	300	250	89	CSP	20191126_142208.jpg	GOOD
11/26/2019	353	4677579	337409	300	250	89	CSP	20191126_142243.jpg	GOOD
11/26/2019	287	4677333	337220	410	340	89	CSP	287_Top of pipe_1.jpg	GOOD
11/25/2019	114	4678255	338566	450	370	88	CSP	114_Top of pipe_1.jpg	CLEAR
11/25/2019	130	4678140	338541	450	370	88	CSP	130_Top of pipe_1.jpg	SLIGHTLY CRUSHED
11/26/2019	284	4677311	337283	450	370	88	CSP	284_Top of pipe_1.jpg	GOOD
11/25/2019	122	4678326	338555	600	490	87	CSP	122_Top of pipe_1.jpg	PHRAG
11/25/2019	111	4678192	338561	450	360	86	CSP	111_Top of pipe_1.jpg	CLEAR
11/25/2019	135	4678037	338533	450	360	86	CSP	135_Top of pipe_1.jpg	70mm DEEP DENT
11/25/2019	156	4678390	339055	450	360	86	CSP	156_Top of pipe_1.jpg	GOOD
11/26/2019	193	4677174	338600	450	360	86	CSP	193_Top of pipe_1.jpg	GOOD

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11/26/2019	195	4677185	338612	375	300	86	CSP	195_Top of pipe_1.jpg	GOOD
11/26/2019	271	4677443	337652	300	240	86	HDPE	271_Top of pipe_1.jpg	GOOD
11/26/2019	314	4677314	337312	375	300	86	CSP	20191126_124335.jpg	GOOD
11/26/2019	319	4677284	337398	375	300	86	CSP	20191126_124933.jpg	UPTURNED
11/26/2019	338	4677475	337773	250	200	86	HDPE	20191126_141018.jpg	GOOD
11/26/2019	344	4677522	337572	300	240	86	HDPE	20191126_141643.jpg	GOOD
11/25/2019	110	4678179	338559	450	350	83	CSP	110_Top of pipe_1.jpg	
11/25/2019	115	4678267	338567	450	350	83	CSP	115_Top of pipe_1.jpg	CLEAR
11/25/2019	164	4678290	339154	450	350	83	CSP	164_Top of pipe_1.jpg	100mm DEEP DENT
11/26/2019	196	4677214	338646	450	350	83	CSP	196_Top of pipe_1.jpg	GOOD
11/26/2019	230	4677076	338507	450	350	83	PE	230_Top of pipe_1.jpg	GOOD
11/26/2019	194	4677180	338606	375	290	83	CSP	194_Top of pipe_1.jpg	GOOD
11/26/2019	318	4677288	337387	375	290	83	CSP	20191126_124803.jpg	GOOD
11/25/2019	151	4678470	338952	300	230	82	CSP	151_Top of pipe_1.jpg	GOOD
11/25/2019	154	4678421	339016	300	230	82	CSP	154_Top of pipe_1.jpg	GOOD
11/26/2019	266	4677243	338211	300	230	82	CSP	266_Top of pipe_1.jpg	20mm DEEP DENT
11/26/2019	273	4677394	337647	300	230	82	CSP	273_Top of pipe_1.jpg	GOOD
11/26/2019	345	4677529	337553	300	230	82	HDPE	20191126_141722.jpg	GOOD
11/26/2019	278	4677259	337434	450	340	81	PE	278_Top of pipe_1.jpg	GOOD
11/26/2019	356	4677597	337358	450	340	81	CSP	20191126_142456.jpg	GOOD
11/26/2019	369	4677612	337352	450	340	81	CSP	20191126_144730.jpg	GOOD
11/25/2019	145	4678501	338913	400	300	80	CSP	145_Top of pipe_1.jpg	GOOD
11/25/2019	160	4678353	339104	600	450	80	CSP	160_Top of pipe_1.jpg	CLEAR
11/25/2019	146	4678495	338920	300	220	79	CSP	146_Top of pipe_1.jpg	GOOD
11/25/2019	157	4678379	339047	450	330	79	CSP	157_Top of pipe_1.jpg	GOOD
11/26/2019	199	4677240	338684	450	330	79	CSP	199_Top of pipe_1.jpg	GOOD
11/26/2019	201	4677438	338903	450	330	79	CSP	201_Top of pipe_1.jpg	UNDERWATER
11/26/2019	214	4677695	339198	450	330	79	PE	214_Top of pipe_1.jpg	GOOD
11/26/2019	224	4677143	338585	450	330	79	CSP	224_Top of pipe_1.jpg	PHRAG
11/26/2019	267	4677231	338212	300	220	79	CSP	267_Top of pipe_1.jpg	CLEAR
11/26/2019	285	4677315	337271	450	330	79	CSP	285_Top of pipe_1.jpg	GOOD
11/26/2019	302	4677372	337145	300	220	79	CSP	20191126_123304.jpg	GOOD
11/26/2019	347	4677550	337493	300	220	79	CSP	20191126_141907.jpg	GOOD
11/26/2019	366	4677635	337284	450	330	79	CSP	20191126_144445.jpg	GOOD
11/26/2019	383	4677487	337783	300	220	79	PE		GOOD
11/26/2019	205	4677528	339007	450	320	76	PE	205_Top of pipe_1.jpg	WATER
11/26/2019	288	4677340	337198	450	320	76	CSP	288_Top of pipe_1.jpg	GOOD
11/25/2019	144	4678508	338903	400	280	75	CSP	144_Top of pipe_1.jpg	110mm DEEP DENT
11/26/2019	312	4677318	337301	375	260	74	CSP	20191126_124235.jpg	GOOD
11/25/2019	118	4678339	338576	450	310	73	CSP	118_Top of pipe_1.jpg	RUSTED
11/26/2019	216	4677509	339007	450	310	73	CSP	216_Top of pipe_1.jpg	GOOD
11/26/2019	357	4677600	337350	450	310	73	CSP	20191126_142534.jpg	GOOD
11/25/2019	180	4678060	339020	450	300	71	CSP	20191125_160945.jpg	GOOD
11/26/2019	208	4677572	339057	450	300	71	PE	208_Top of pipe_1.jpg	WATER
11/26/2019	211	4677652	339148	450	300	71	PE	211_Top of pipe_1.jpg	WATER
11/26/2019	226	4677117	338554	450	300	71	CSP	226_Top of pipe_1.jpg	GOOD

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11/26/2019	233	4677011	338428	450	300	71	CSP		90mm DEEP DENT
11/26/2019	279	4677260	337431	450	300	71	PE	279_Top of pipe_1.jpg	GOOD
11/26/2019	294	4677378	337089	450	300	71	CSP	294_Top of pipe_1.jpg	GOOD
11/26/2019	360	4677655	337209	375	250	71	CSP	20191126_142937.jpg	GOOD
11/25/2019	161	4678348	339110	600	400	71	CSP	161_Top of pipe_1.jpg	100mm DEEP DENT
11/25/2019	173	4678297	339023	300	200	71	PE	20191125_155503.jpg	GOOD
11/26/2019	275	4677373	337645	300	200	71	HDPE	275_Top of pipe_1.jpg	GOOD
11/26/2019	380	4677533	337578	300	200	71	CSP	20191126_145813.jpg	50mm DEEP DENT
11/25/2019	100	4678022	338547	400	260	69	CSP	100_Top of pipe_1.jpg	SEVERE DEFM.
11/26/2019	225	4677125	338563	450	290	68	CSP	225_Top of pipe_1.jpg	GOOD
11/26/2019	298	4677389	337098	375	240	68	CSP	298_Top of pipe_1.jpg	DENT
11/26/2019	316	4677302	337347	375	240	68	CSP	20191126_124610.jpg	GOOD
11/26/2019	370	4677611	337356	375	240	68	CSP	20191126_144825.jpg	GOOD
11/26/2019	221	4677196	338646	300	190	67	CSP	221_Top of pipe_1.jpg	WATER
11/26/2019	272	4677432	337649	300	190	67	HDPE	272_Top of pipe_1.jpg	GOOD
11/26/2019	378	4677543	337548	300	190	67	CSP	20191126_145657.jpg	OK
11/26/2019	220	4677206	338659	450	280	65	CSP	220_Top of pipe_1.jpg	GOOD
11/26/2019	309	4677348	337215	375	230	64	CSP	20191126_123847.jpg	GOOD
11/26/2019	317	4677297	337360	375	230	64	CSP	20191126_124646.jpg	GOOD
11/26/2019	321	4677273	337429	375	230	64	CSP	20191126_125106.jpg	GOOD
11/26/2019	342	4677508	337612	450	270	63	CSP	20191126_141437.jpg	GOOD
11/26/2019	343	4677512	337601	450	270	63	CSP	20191126_141516.jpg	GOOD
11/26/2019	222	4677191	338641	300	180	63	CSP	222_Top of pipe_1.jpg	WATER
11/26/2019	330	4677321	337624	300	180	63	CSP	20191126_125950.jpg	GOOD
11/26/2019	295	4677400	337065	375	220	61	CSP	295_Top of pipe_1.jpg	GOOD
11/26/2019	297	4677391	337092	375	220	61	CSP	297_Top of pipe_1.jpg	GOOD
11/26/2019	300	4677378	337128	375	220	61	CSP	20191126_123217.jpg	GRASS
11/26/2019	333	4677427	337636	375	220	61	CSP	20191126_130552.jpg	GOOD
11/26/2019	371	4677605	337370	375	220	61	CSP	20191126_144923.jpg	GOOD
11/25/2019	192	4677118	338533	300	170	58	CSP	20191125_165331.jpg	OK
11/26/2019	325	4677253	337488	375	210	58	CSP	20191126_125422.jpg	GOOD
11/26/2019	350	4677559	337467	375	210	58	CSP	20191126_142035.jpg	GOOD
11/26/2019	355	4677586	337388	450	250	57	CSP	20191126_142400.jpg	90mm DEEP DENT
11/25/2019	162	4678329	339134	375	200	54	CSP	162_Top of pipe_1.jpg	110mm DEEP DENT
11/25/2019	175	4678237	339018	300	160	54	CSP	20191125_155657.jpg	GOOD
11/26/2019	215	4677513	339011	450	240	54	CSP	215_Top of pipe_1.jpg	GOOD
11/26/2019	217	4677283	338747	300	160	54	CSP	217_Top of pipe_1.jpg	GOOD
11/26/2019	234	4677000	338417	450	240	54	CSP	234_Top of pipe_1.jpg	GOOD
11/26/2019	296	4677396	337076	375	200	54	CSP	296_Top of pipe_1.jpg	GOOD
11/26/2019	308	4677352	337204	375	200	54	CSP	20191126_123802.jpg	GOOD
11/26/2019	346	4677547	337502	300	160	54	CSP	20191126_141830.jpg	GOOD
11/26/2019	351	4677561	337459	375	200	54	CSP	20191126_142112.jpg	GOOD
11/26/2019	362	4677682	337152	450	240	54	CSP	20191126_143247.jpg	GOOD
11/26/2019	367	4677631	337296	450	240	54	CSP	20191126_144528.jpg	GOOD
11/26/2019	372	4677600	337384	450	240	54	CSP	20191126_145013.jpg	GOOD
11/25/2019	181	4678049	339019	450	230	51	CSP	20191125_161054.jpg	GOOD

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11/26/2019	219	4677211	338664	450	230	51	CSP	219_Top of pipe_1.jpg	GOOD
11/26/2019	305	4677359	337183	450	230	51	CSP	20191126_123601.jpg	GOOD
11/26/2019	382	4677489	337750	275	140	51	CSP	20191126_150241.jpg	COVERED
11/26/2019	313	4677316	337306	375	190	51	CSP	20191126_124306.jpg	GOOD
11/26/2019	364	4677737	337031	375	190	51	CSP	20191126_143545.jpg	GOOD
11/25/2019	109	4678161	338558	450	225	50	CSP	109_Top of pipe_1.jpg	50mm DEEP DENT
11/25/2019	143	4678512	338898	300	150	50	CSP	143_Top of pipe_1.jpg	120mm DEEP DENT
11/25/2019	152	4678438	338994	300	150	50	CSP	152_Top of pipe_1.jpg	160mm DEEP DENT
11/25/2019	174	4678287	339022	300	150	50	PE	20191125_155602.jpg	GOOD
11/26/2019	218	4677242	338700	300	150	50	CSP	218_Top of pipe_1.jpg	GOOD
11/26/2019	326	4677250	337528	300	150	50	CSP	20191126_125533.jpg	GOOD
11/25/2019	172	4678299	339009	450	220	49	CSP	20191125_155344.jpg	GOOD
11/25/2019	179	4678112	339018	450	220	49	CSP	20191125_160841.jpg	130mm DEEP DENT
11/26/2019	198	4677214	338652	450	220	49	CSP		
11/26/2019	276	4677280	337613	450	220	49	CSP	276_Top of pipe_1.jpg	GOOD
11/26/2019	336	4677475	337788	450	220	49	CSP	20191126_140859.jpg	GOOD
11/26/2019	368	4677617	337336	450	220	49	CSP	20191126_144632.jpg	GOOD
11/26/2019	320	4677277	337417	375	180	47	CSP	20191126_125017.jpg	GOOD
11/26/2019	375	4677585	337428	375	180	47	CSP	20191126_145248.jpg	GOOD
11/26/2019	306	4677358	337186	450	210	46	CSP	20191126_123632.jpg	GOOD
11/25/2019	142	4678519	338889	300	140	46	CSP	142_Top of pipe_1.jpg	150mm DEEP DENT
11/26/2019	268	4677209	338213	300	140	46	CSP	268_Top of pipe_1.jpg	COLLAPSED
11/26/2019	339	4677476	337759	300	140	46	CSP	20191126_141056.jpg	GOOD
11/26/2019	359	4677608	337325	375	170	44	CSP	20191126_142647.jpg	GOOD
11/26/2019	334	4677473	337813	200	90	44	HDPE	20191126_140716.jpg	GOOD
11/25/2019	168	4678345	339033	450	200	43	CSP	20191125_154859.jpg	150mm DEEP DENT
11/25/2019	169	4678336	339026	450	200	43	CSP	20191125_154944.jpg	250mm DEEP DENT
11/26/2019	281	4677292	337336	450	200	43	CSP	281_Top of pipe_1.jpg	OK
11/25/2019	158	4678383	339066	300	130	42	CSP	158_Top of pipe_1.jpg	140mm DEEP DENT
11/25/2019	183	4678013	339030	300	130	42	CSP	20191125_161325.jpg	CRUSHED
11/26/2019	374	4677590	337414	375	160	41	CSP	20191126_145202.jpg	GOOD
11/26/2019	328	4677254	337549	450	190	40	CSP	20191126_125708.jpg	GOOD
11/26/2019	381	4677492	337705	275	110	37	CSP	20191126_150035.jpg	GOOD
11/25/2019	159	4678375	339075	300	120	37	CSP	159_Top of pipe_1.jpg	190mm DEEP DENT
11/26/2019	265	4677325	338209	300	120	37	CSP	265_Top of pipe_1.jpg	GOOD
11/26/2019	299	4677381	337119	375	150	37	CSP	299_Top of pipe_1.jpg	GOOD
11/26/2019	329	4677260	337566	450	180	37	CSP	20191126_125801.jpg	GOOD
11/26/2019	331	4677331	337627	300	120	37	CSP	20191126_130032.jpg	70mm DEEP DENT
11/26/2019	289	4677344	337187	450	170	35	CSP	289_Top of pipe_1.jpg	GOOD
11/26/2019	304	4677363	337172	450	170	35	CSP	20191126_123523.jpg	120mm DEEP DENT
11/25/2019	138	4678334	338704	450	160	32	CSP	138_Top of pipe_1.jpg	80mm DEEP DENT
11/26/2019	310	4677323	337285	450	160	32	CSP	20191126_124120.jpg	GRASS COVER
11/26/2019	363	4677682	337151	450	160	32	CSP	20191126_143313.jpg	170mm DEEP DENT
11/26/2019	332	4677413	337634	375	130	31	CSP	20191126_130453.jpg	GOOD
11/25/2019	139	4678335	338695	450	150	29	CSP	139_Top of pipe_1.jpg	VERY CRUSHED
11/26/2019	307	4677356	337192	450	150	29	CSP	20191126_123713.jpg	90mm DEEP DENT

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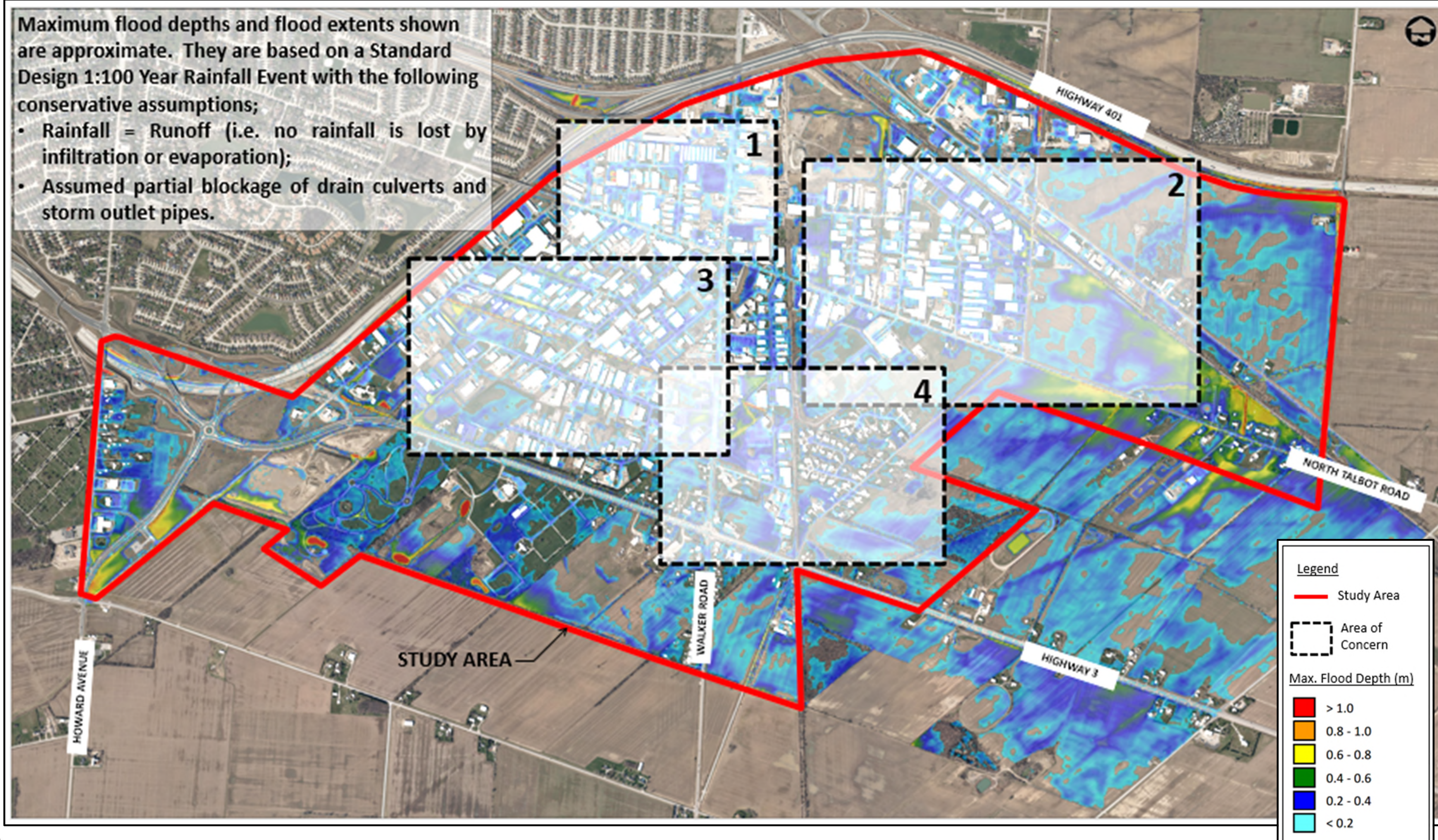
11/26/2019	373	4677596	337396	450	150	29	CSP	20191126_145103.jpg	DIRT/GRASS COVER
11/26/2019	337	4677475	337778	450	140	27	CSP	20191126_140942.jpg	RUSTED
11/25/2019	182	4678016	339017	300	90	25	CSP	20191125_161225.jpg	
11/26/2019	335	4677474	337798	300	90	25	CSP	20191126_140809.jpg	120mm DEEP DENT
11/26/2019	376	4677580	337443	450	130	24	CSP	20191126_145339.jpg	OK
11/26/2019	277	4677248	337465	450	120	21	CSP	277_Top of pipe_1.jpg	230mm DEEP DENT
11/26/2019	290	4677352	337165	450	120	21	CSP	290_Top of pipe_1.jpg	GOOD
11/26/2019	311	4677319	337296	450	110	19	CSP	20191126_124208.jpg	GRASS COVER
11/26/2019	327	4677252	337539	300	70	18	CSP	20191126_125636.jpg	170mm DEEP DENT
11/25/2019	170	4678324	339018	450	100	17	CSP	20191125_155139.jpg	260mm DEEP DENT
11/26/2019	365	4677738	337030	375	80	16	CSP	20191126_143614.jpg	90mm DEEP DENT
11/26/2019	303	4677368	337157	300	60	14	CSP	20191126_123429.jpg	COVERED
11/25/2019	147	4678465	338935	450	80	12	CSP	147_Top of pipe_1.jpg	CRUSHED
11/26/2019	280	4677289	337347	450	80	12	CSP	280_Top of pipe_1.jpg	CRUSHED
11/25/2019	184	4678003	339029	300	50	11	CSP	20191125_161425.jpg	BURIED
11/25/2019	128	4678194	338545	450	0	0	CSP	128_Top of pipe_1.jpg	COLLAPSED
11/25/2019	140	4678579	338811	450	0	0	CSP	140_Top of pipe_1.jpg	FLATTENED
11/25/2019	148	4678471	338928	450	0	0	CSP	148_Top of pipe_1.jpg	PLUGGED
11/25/2019	150	4678477	338921	150	0	0	CSP	150_Top of pipe_1.jpg	BLOCKED
11/26/2019	202	4677444	338910	450		0	CSP		UNDERWATER
11/26/2019	206	4677530	339009	450		0	PE	206_Top of pipe_1.jpg	PHRAG
11/26/2019	315	4677310	337324	375	0	0	CSP	20191126_124554.jpg	DIRT/GRASS COVER
11/26/2019	361	4677677	337161	375	0	0	CSP	20191126_143153.jpg	CRUSHED
11/26/2019	384	4677666	336370	600		0	CONC	20191126_153327.jpg	
11/25/2019	141	4678573	338819					141_Top of pipe_1.jpg	EXPOSED IN DRIVEWAY
11/25/2019	171	4678308	339010					20191125_155253.jpg	EXPOSED IN DRIVEWAY
11/25/2019	190	4677080	338489					20191125_164831.jpg	
11/26/2019	197	4677207	338654						
11/26/2019	210	4677613	339103						
11/26/2019	212	4677654	339151					212_Top of pipe_1.jpg	
11/26/2019	235	4676995	338408	450			CSP	235_Top of pipe_1.jpg	
11/26/2019	301	4677377	337131						
11/26/2019	377	4677577	337454					20191126_145431.jpg	BURIED

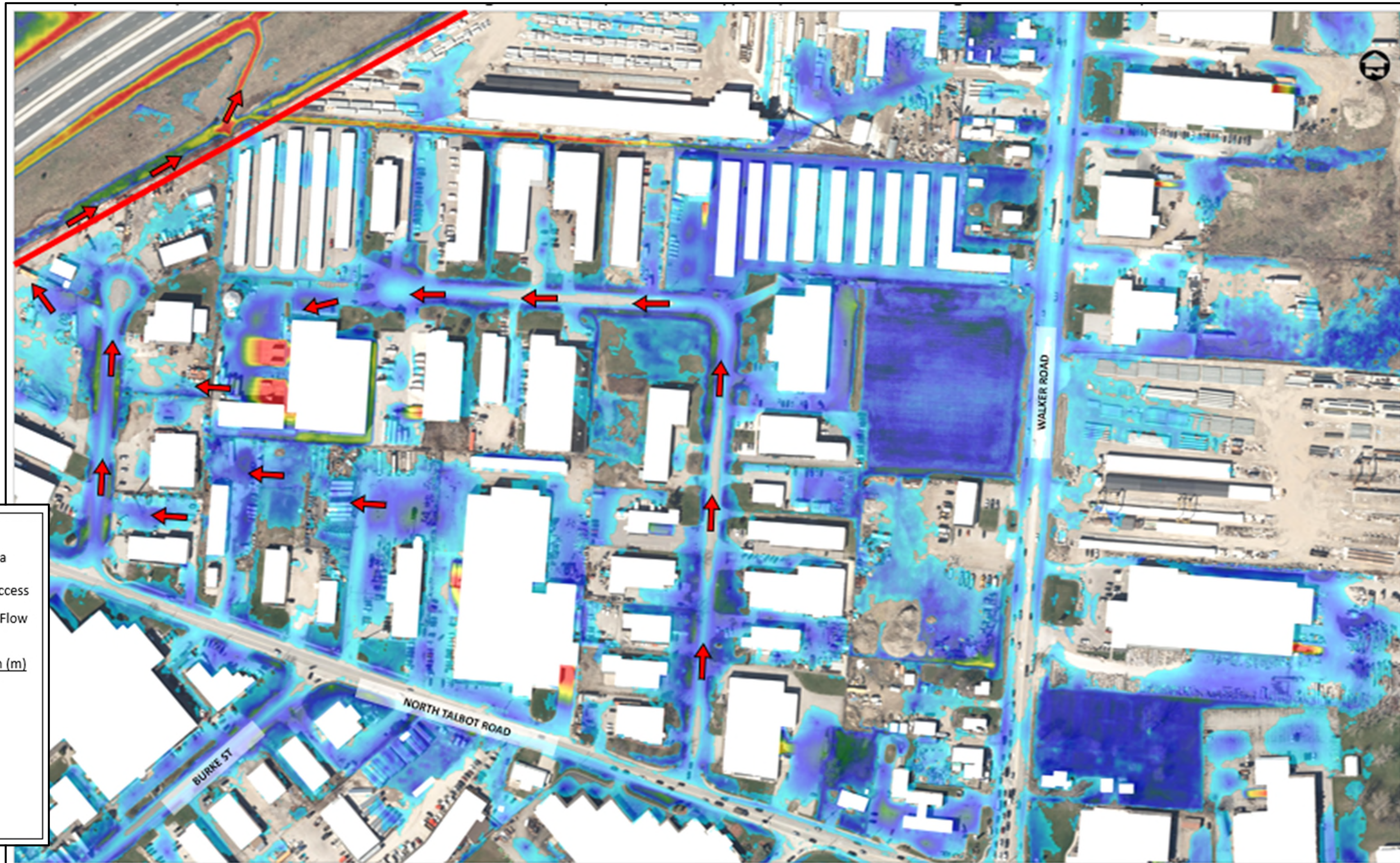
APPENDIX F

SURFACE FLOW MODEL RESULTS



Landmark Engineers Inc.

Title: SURFACE FLOW MODEL: AREAS OF CONCERN	Date: OCT. 2020 Scale: NTS	FIGURE F0
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



Legend

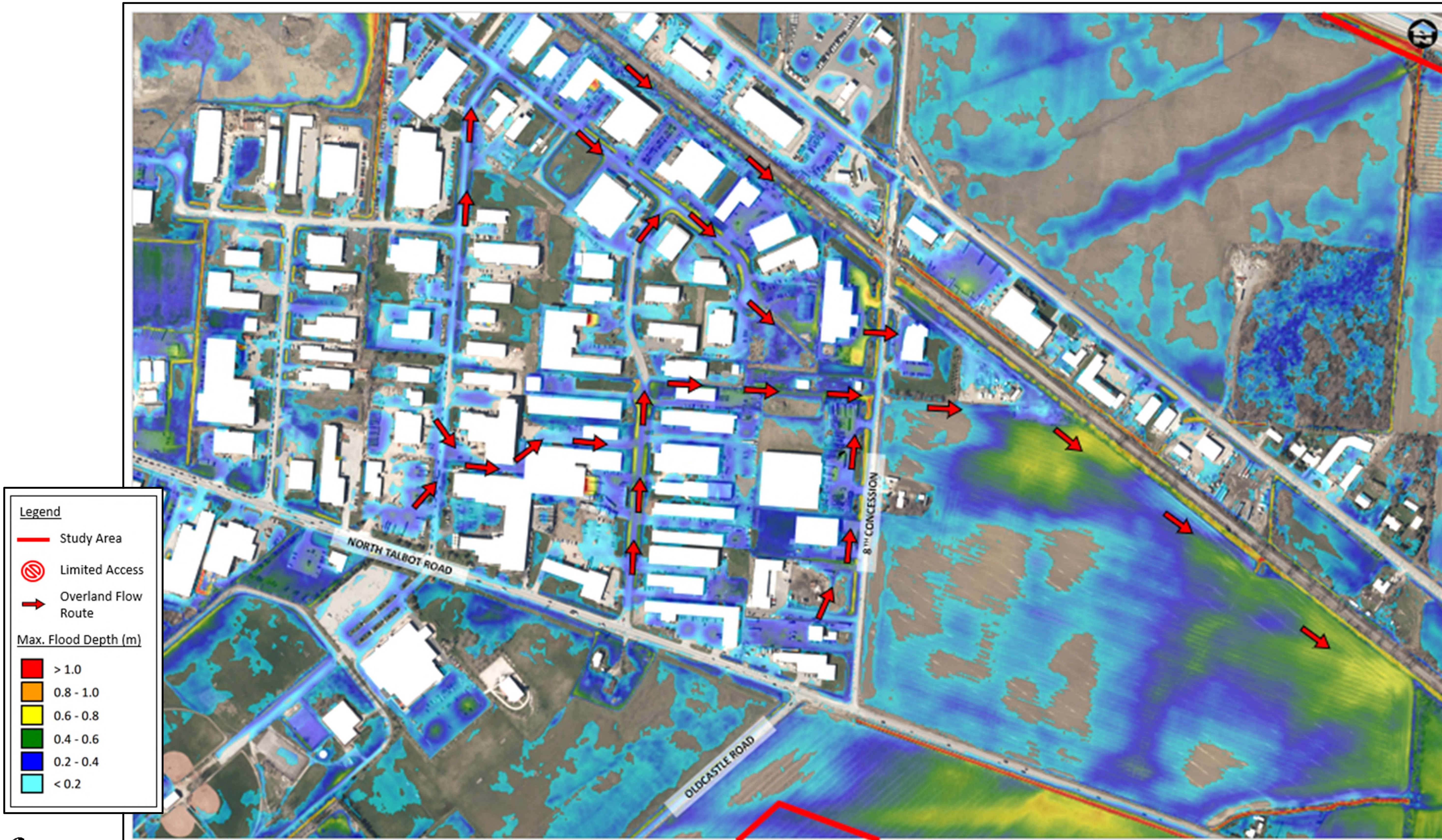
- Study Area
- Limited Access
- Overland Flow Route

Max. Flood Depth (m)

- > 1.0
- 0.8 - 1.0
- 0.6 - 0.8
- 0.4 - 0.6
- 0.2 - 0.4
- < 0.2

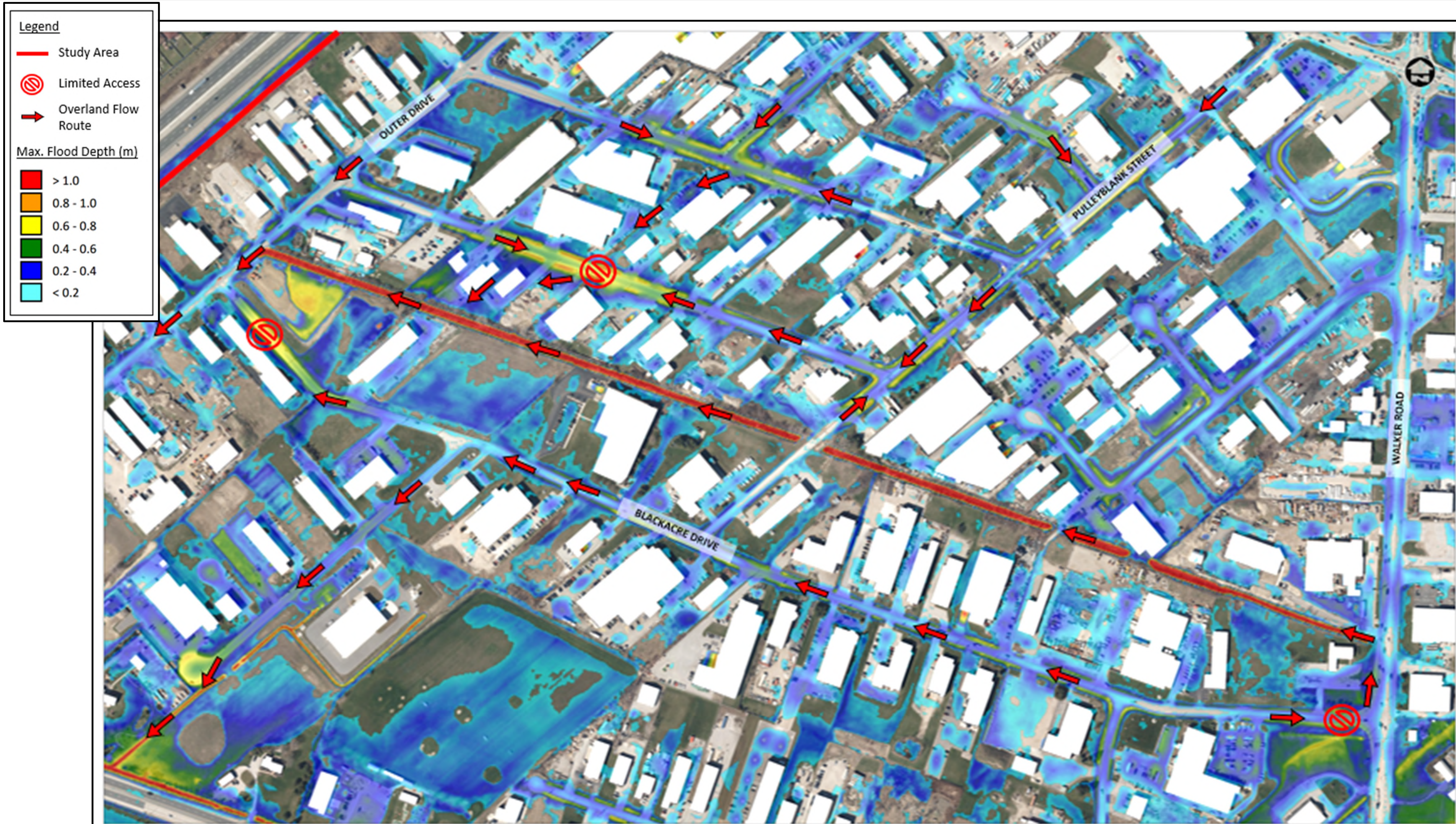
Landmark Engineers Inc.

Title	Date	FIGURE
SURFACE FLOW MODEL: AREA OF CONCERN 1	OCT. 2020	F1
	Scale NTS	
Project OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



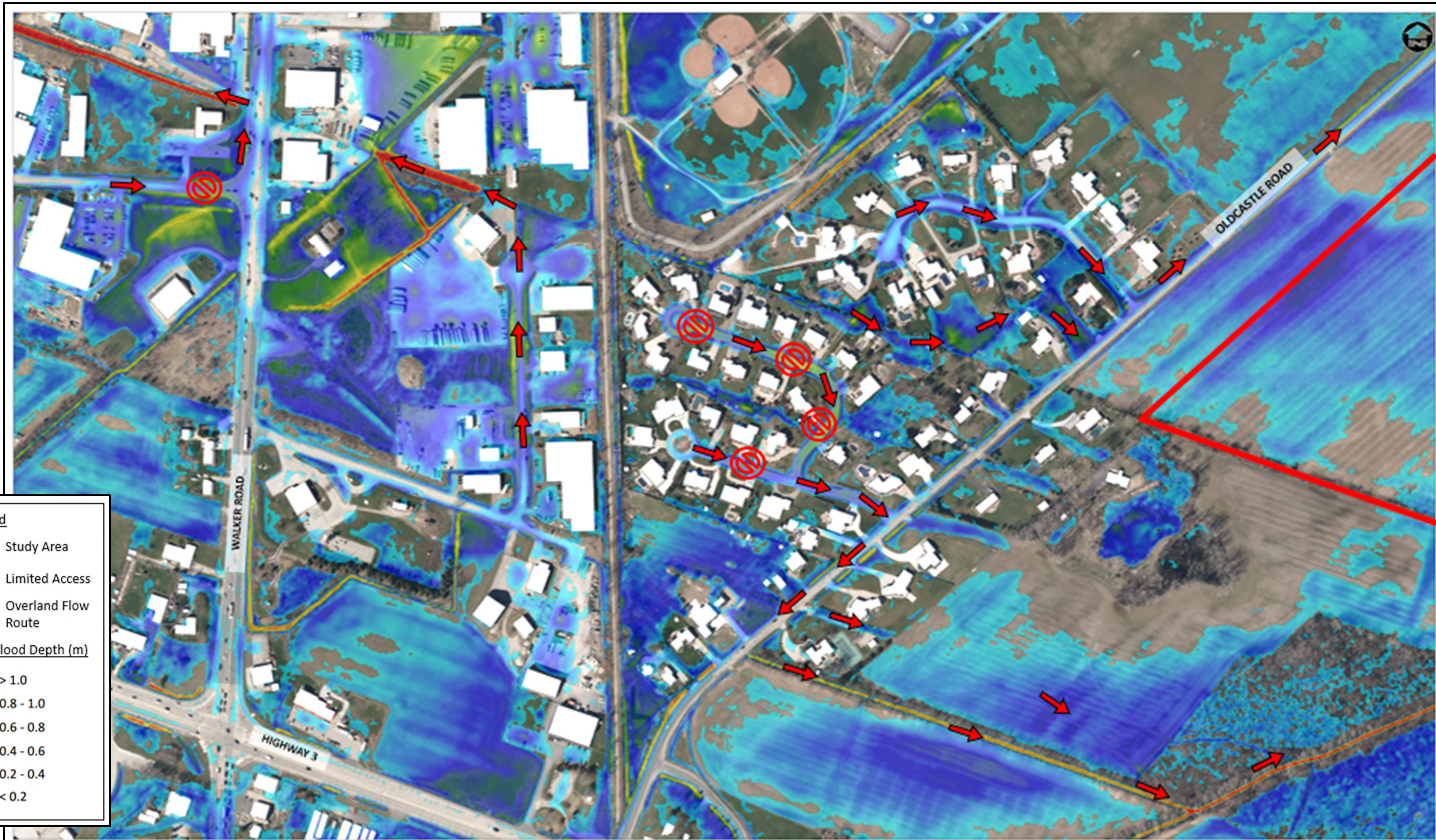
Landmark Engineers Inc.

Title	SURFACE FLOW MODEL: AREA OF CONCERN 2
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	OCT. 2020
Scale	NTS
Project No.	19-010
FIGURE	F2



Landmark Engineers Inc.

Title: SURFACE FLOW MODEL: AREA OF CONCERN 3	Date: OCT. 2020		FIGURE F3
	Scale: NTS		
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

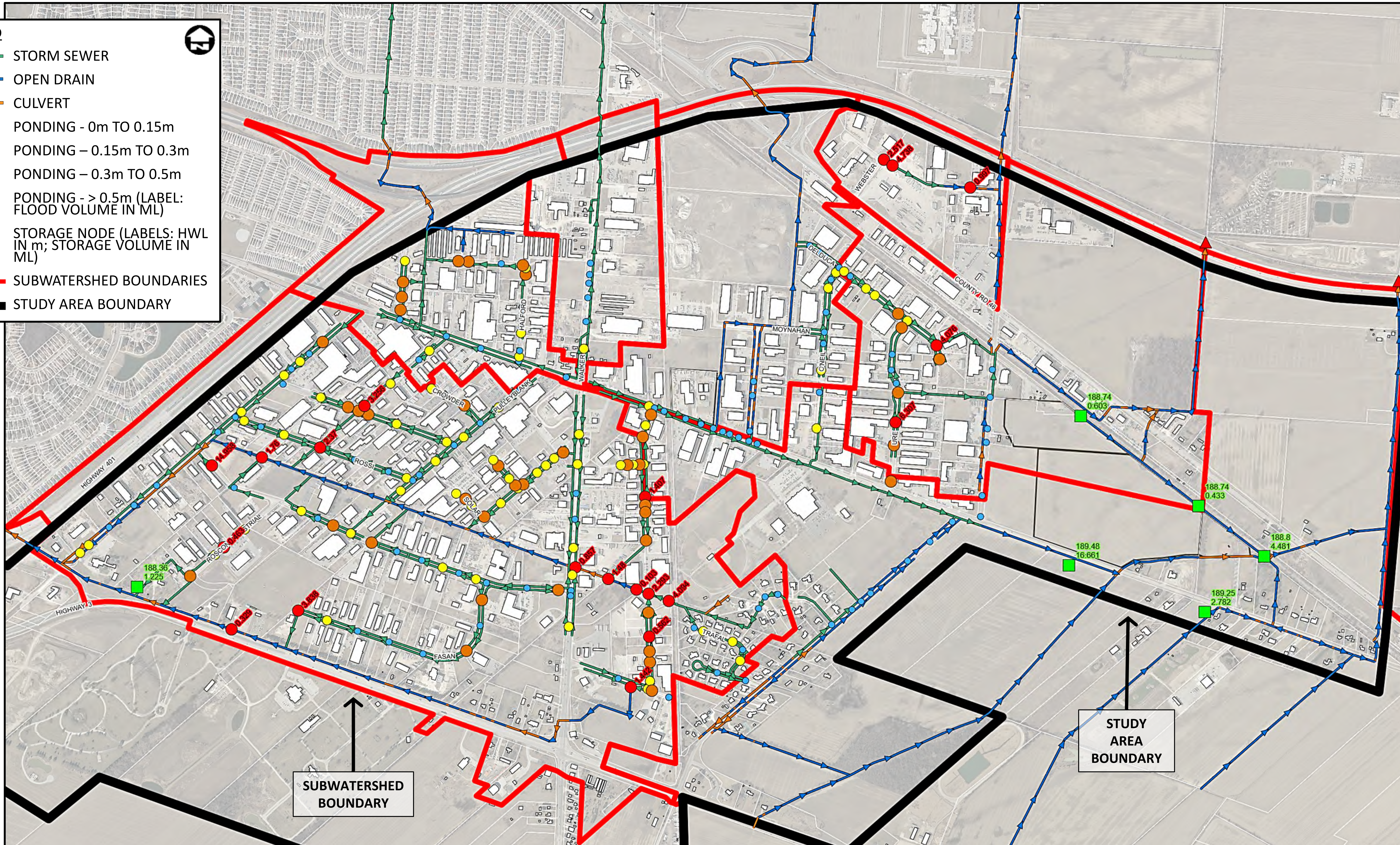


Landmark Engineers Inc.

Title: SURFACE FLOW MODEL: AREA OF CONCERN 4	Date: OCT. 2020	FIGURE F4
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	

APPENDIX G

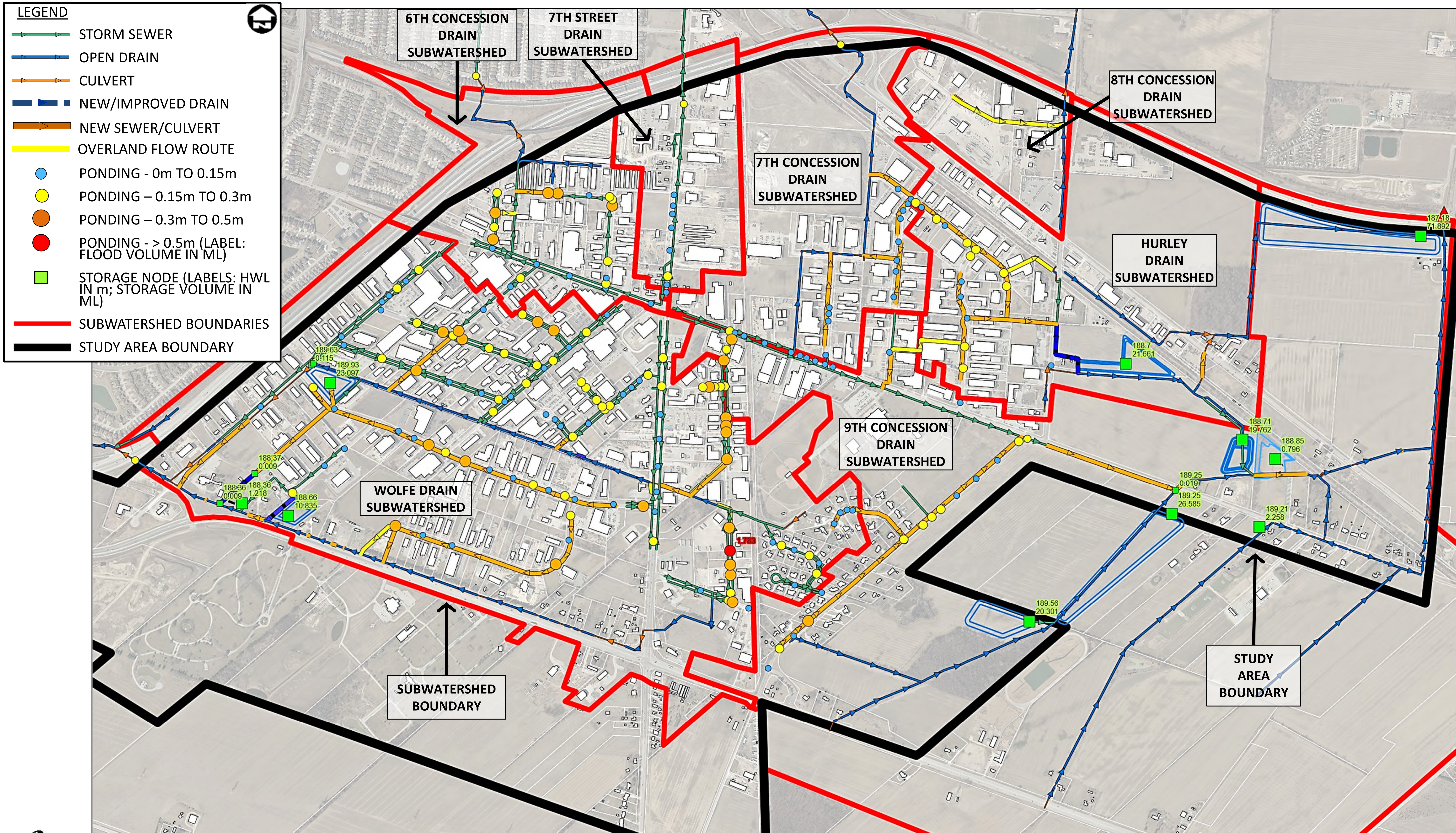
MAJOR STORM SYSTEM MODEL RESULTS



Landmark Engineers Inc.

Title	EXISTING CONDITIONS: 100-YEAR 4-HOUR STORM
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	OCT. 2020
Scale	NTS
Project No.	19-010

FIGURE G1

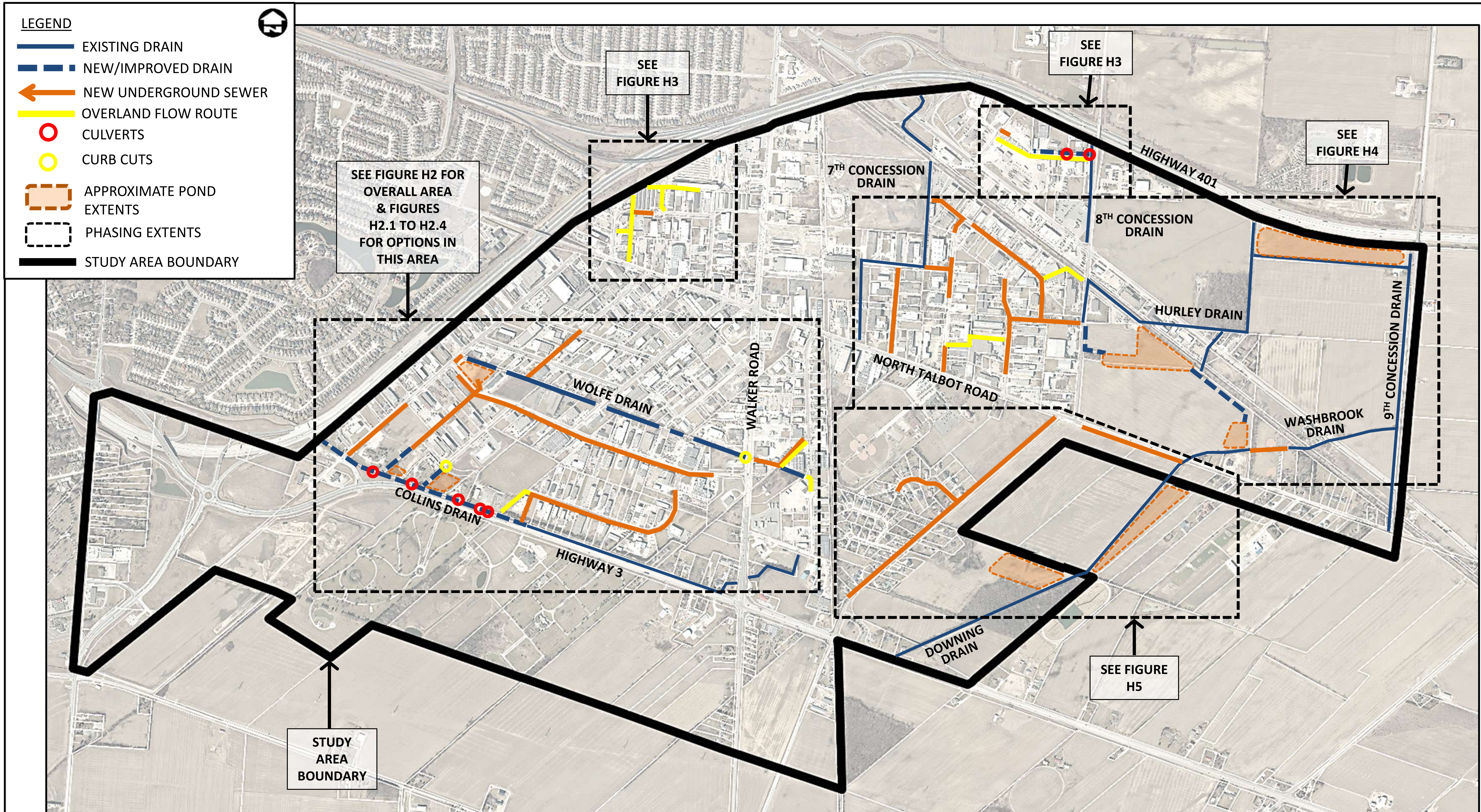


Landmark Engineers Inc.

Title: PROPOSED CONDITIONS: 100-YEAR 4-HOUR STORM	Date: JAN 2022	FIGURE G2
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	

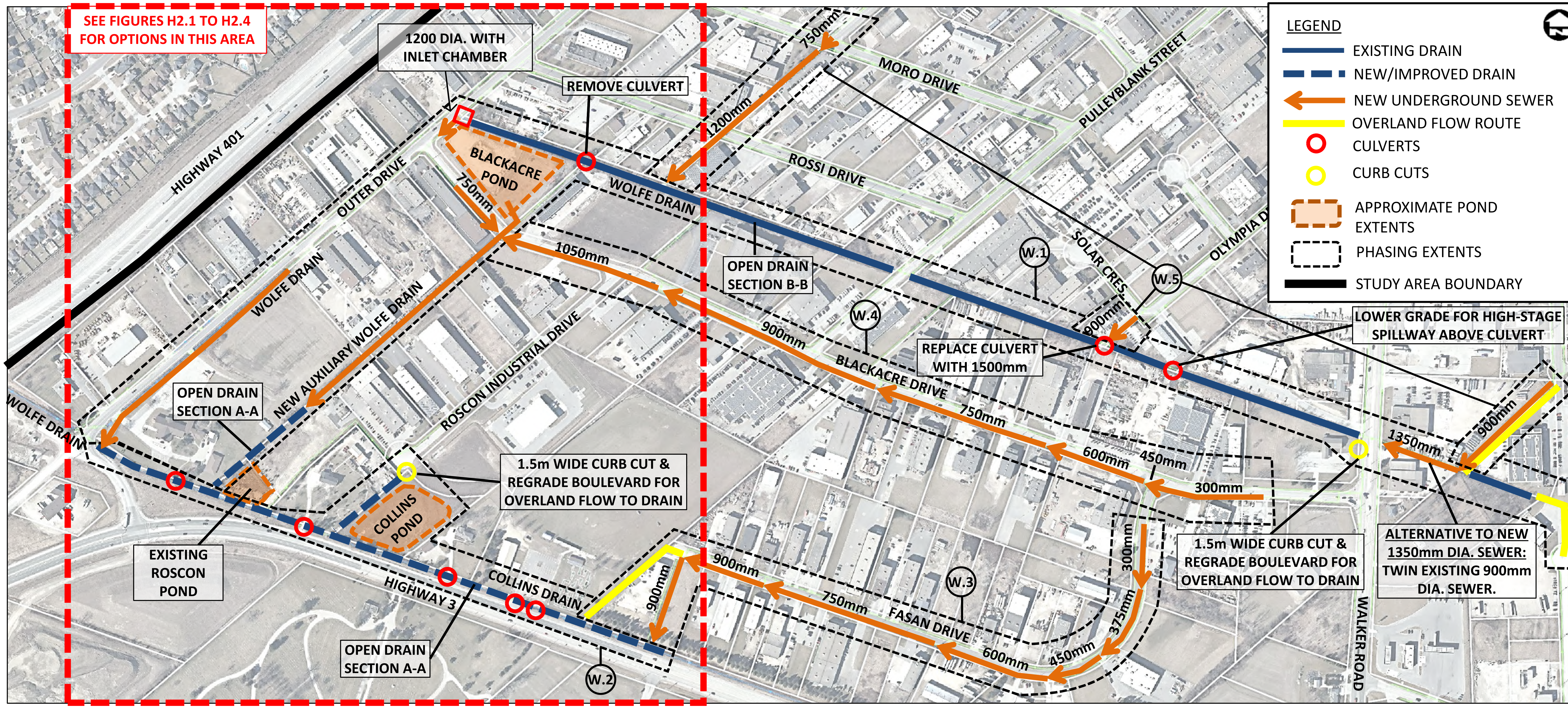
APPENDIX H

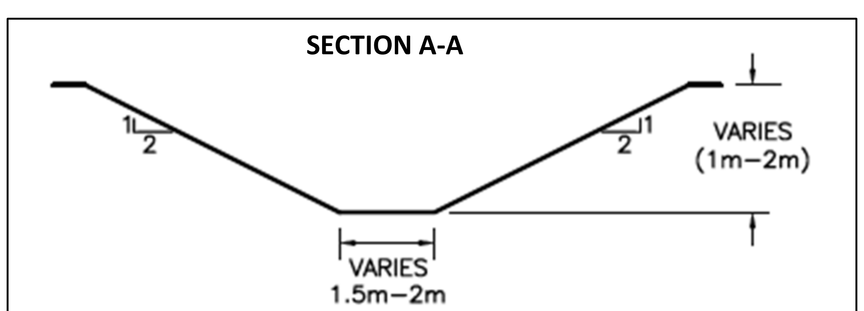
PROPOSED IMPROVEMENTS

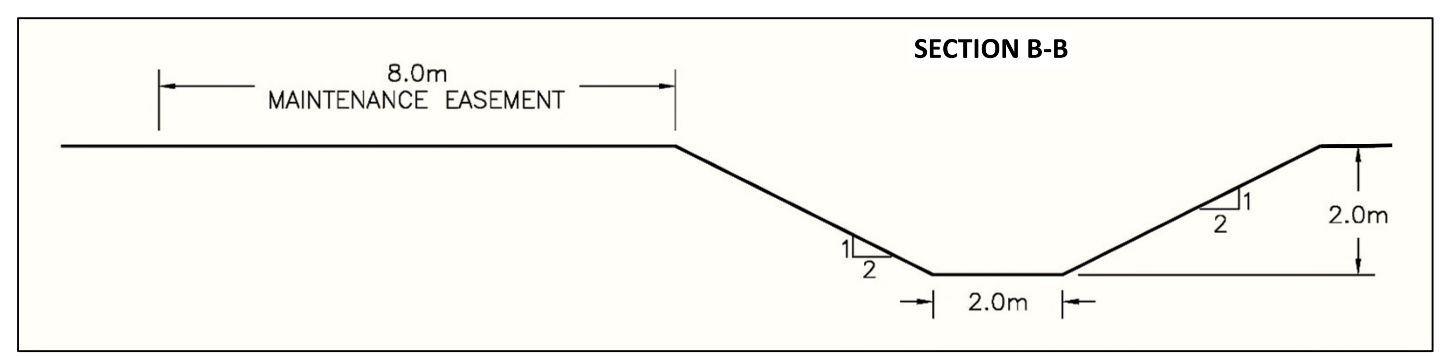


Landmark Engineers Inc.

Title: PROPOSED IMPROVEMENTS: OVERALL PLAN	Date: JAN. 2022	Scale: NTS	FIGURE H1
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		







Landmark Engineers Inc.

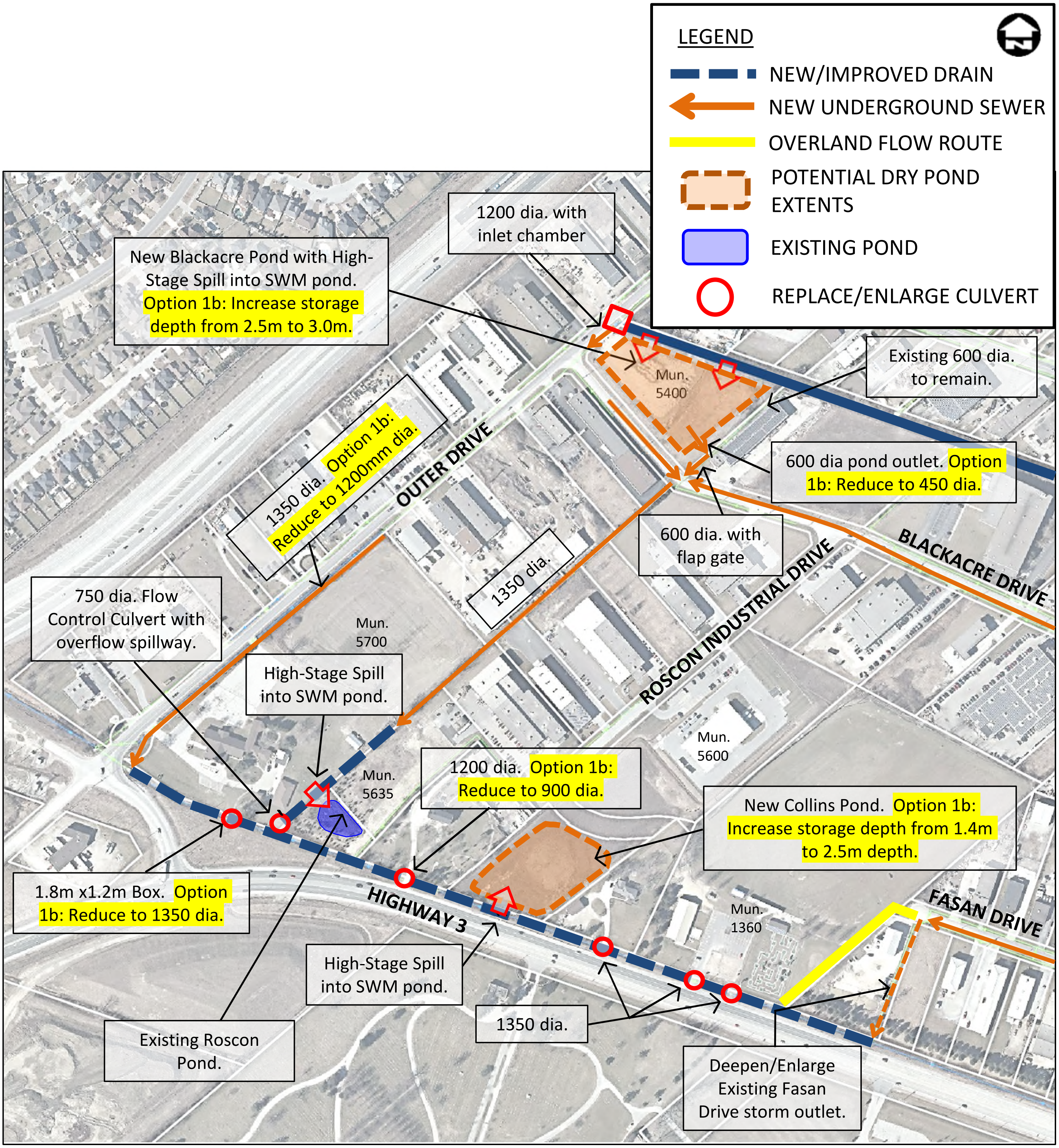
Title PROPOSED IMPROVEMENTS: WOLFE DRAIN AREA	Date APR. 2022	FIGURE
	Scale NTS	H2
Project OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	

WOLFE DRAIN WATERSHED IMPROVEMENT OPTIONS

OPTION	Re-route Fasan Drive storm sewer to new Collins Pond	Deepen/Enlarge Collins Drain	New Blackacre Pond (2.5m Deep Storage)	New Blackacre Pond (3.0m Deep Storage)	New Collins Pond (1.5m Deep Storage)	New Collins Pond (2.5m Deep Storage)	Flow Control on proposed new Auxiliary Wolfe Drain	**1:100 Year Peak Flow to City (m^3/s)[1]**
1a		x	x		x		x	**7.55**
1b		x		x		x	x	**6.63**
2	x		x		x		x	**7.59**
3*		x	x				x	**8.92**
4*		x						**12.54**

Note 1: Existing 1:100 Year Peak Flow to City is 7.7 m^3/s. Parkway Design Flow is 6.1 m^3/s. See Figure J4 of Appendix J for flow reference location and flow hydrographs.

* Option is only valid if the ongoing Turkey Creek Study findings determine that the downstream receivers can safely convey the peak flow rate.

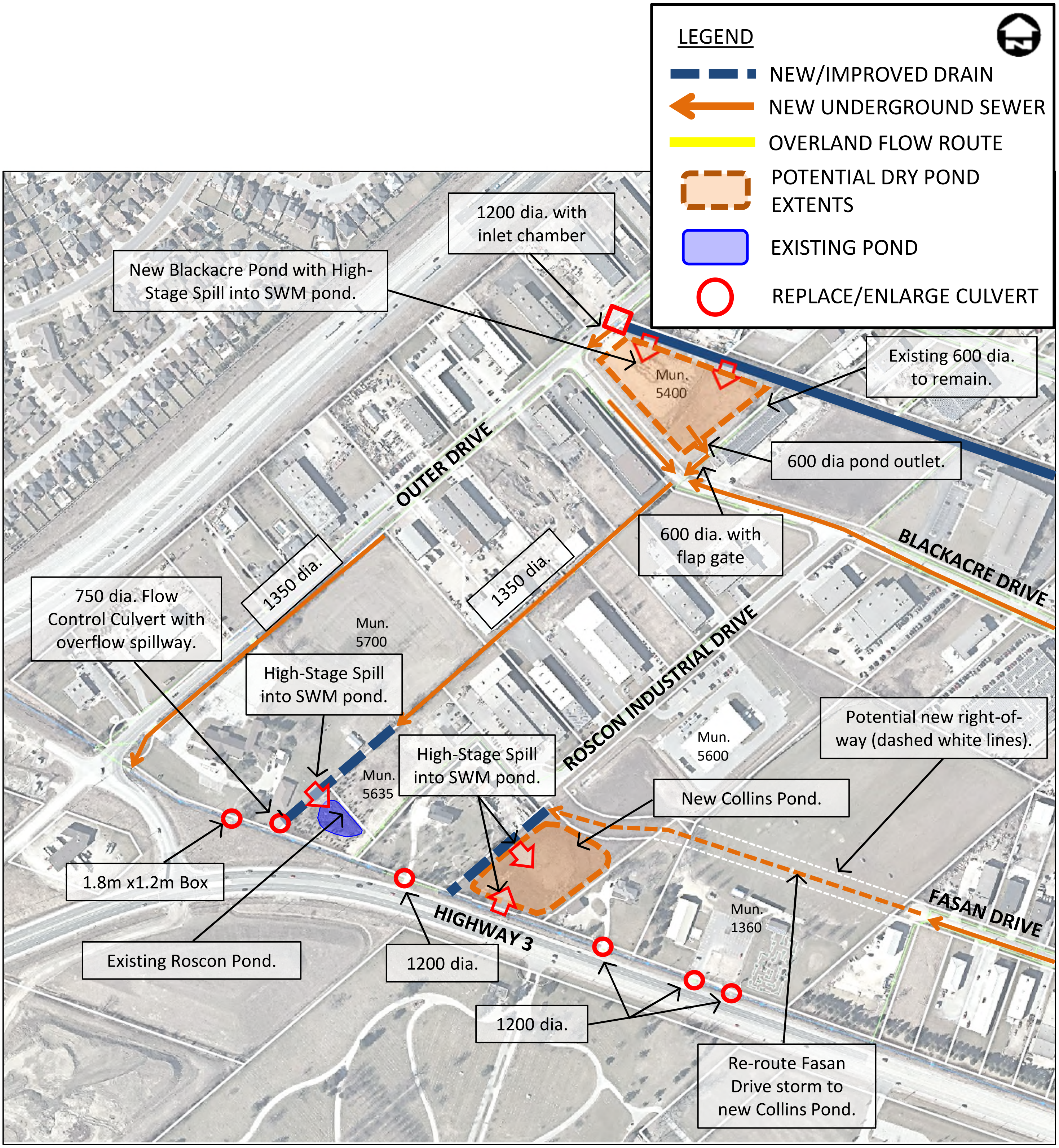


WOLFE DRAIN 1:100 YEAR PEAK FLOW DOWNSTREAM OF HIGHWAY 401 CROSSING:

- Option 1a = 7.55 m^3/s.
- Option 1b = 6.63 m^3/s.

Landmark Engineers Inc.

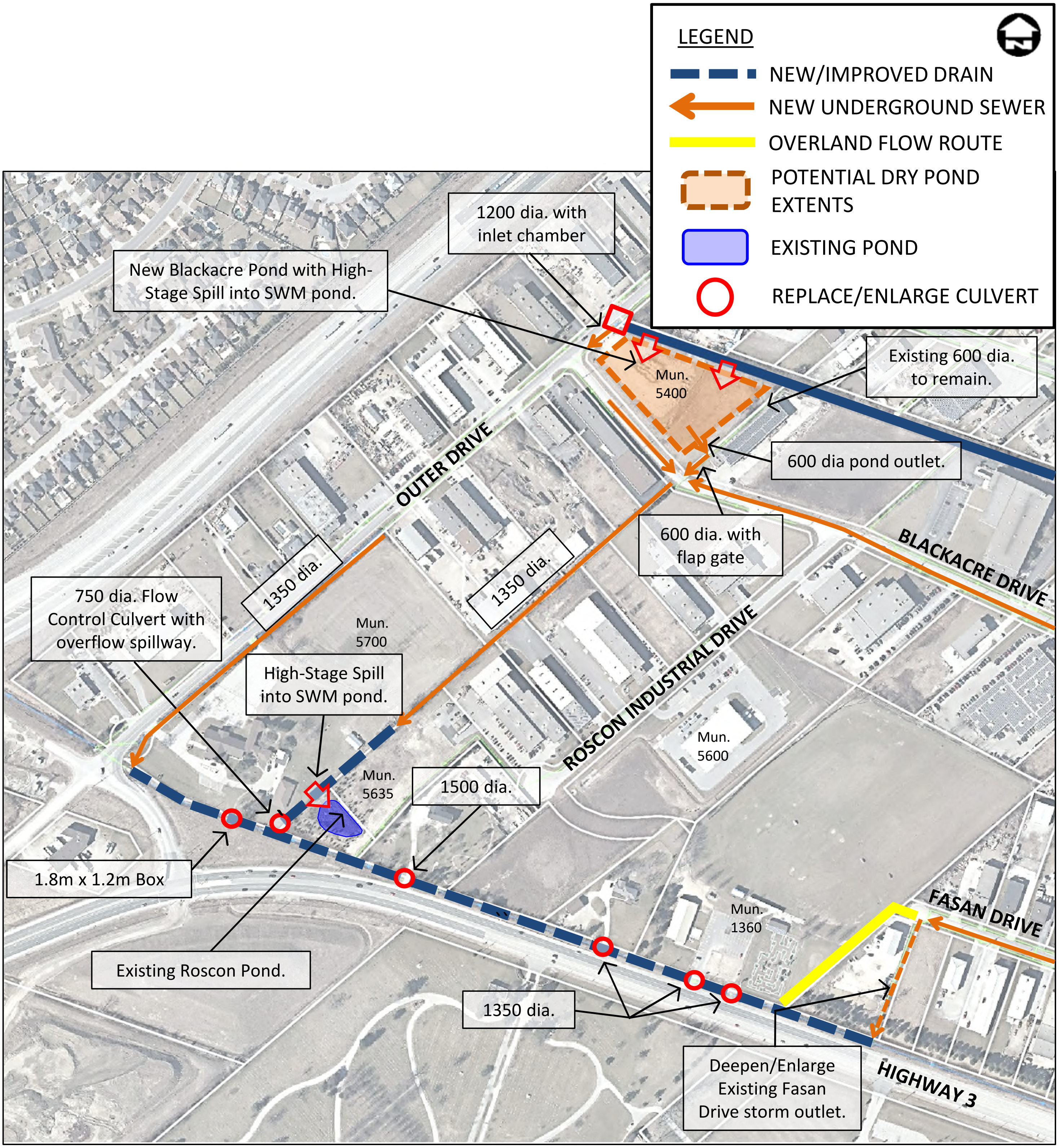
Title	Date	FIGURE
WOLFE DRAIN IMPROVEMENTS – OPTIONS 1A & 1B	JAN 2022	H2.1
Project	Scale: NTS	
OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



WOLFE DRAIN 1:100 YEAR PEAK FLOW DOWNSTREAM OF HIGHWAY 401 CROSSING = 7.59 m^3/s.

Landmark Engineers Inc.

Title: WOLFE DRAIN IMPROVEMENTS – OPTION 2	Date: JAN 2022	Scale: NTS	FIGURE
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		H2.2

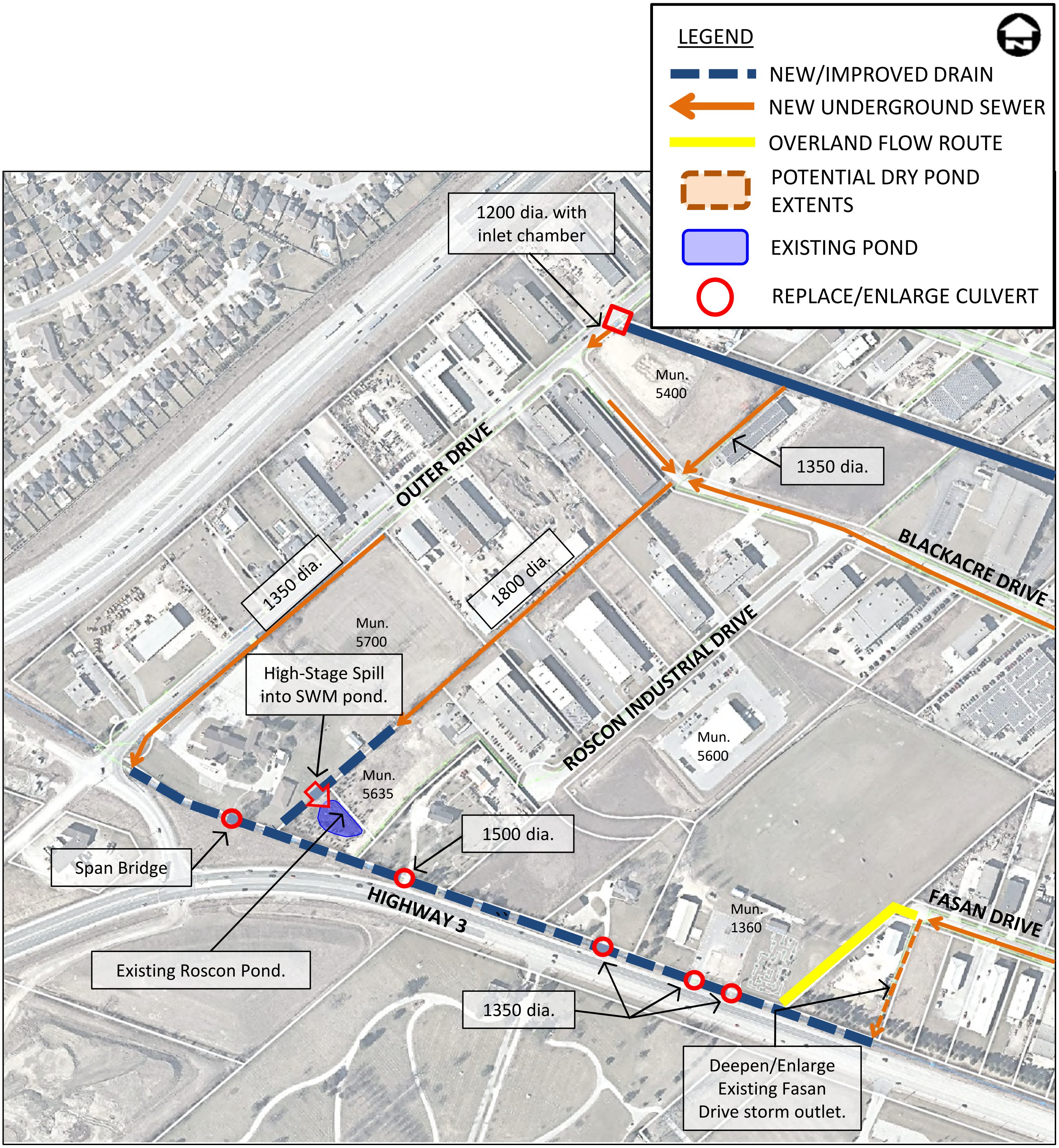


WOLFE DRAIN 1:100 YEAR PEAK FLOW DOWNSTREAM OF HIGHWAY 401 CROSSING = 8.92 m^3/s.

* Option 3 is only valid if the ongoing Turkey Creek Study findings determine that the downstream receivers can safely convey the peak flow rate of 8.92 m^3/s.

Landmark Engineers Inc.

Title: WOLFE DRAIN IMPROVEMENTS – OPTION 3*	Date: JAN 2022	Scale: NTS	FIGURE H2.3
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

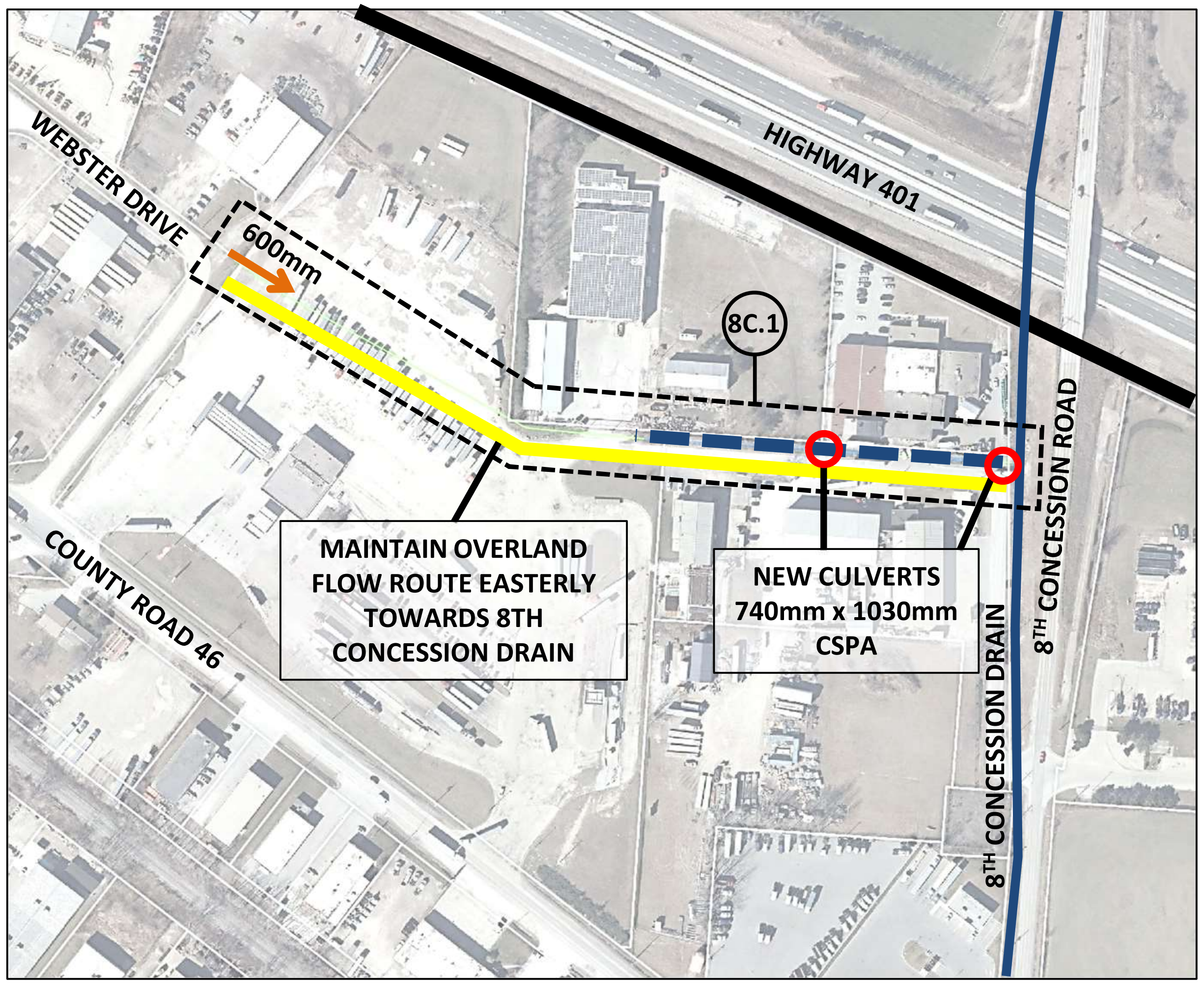


WOLFE DRAIN 1:100 YEAR PEAK FLOW DOWNSTREAM OF HIGHWAY 401 CROSSING = 12.54 m^3/s.

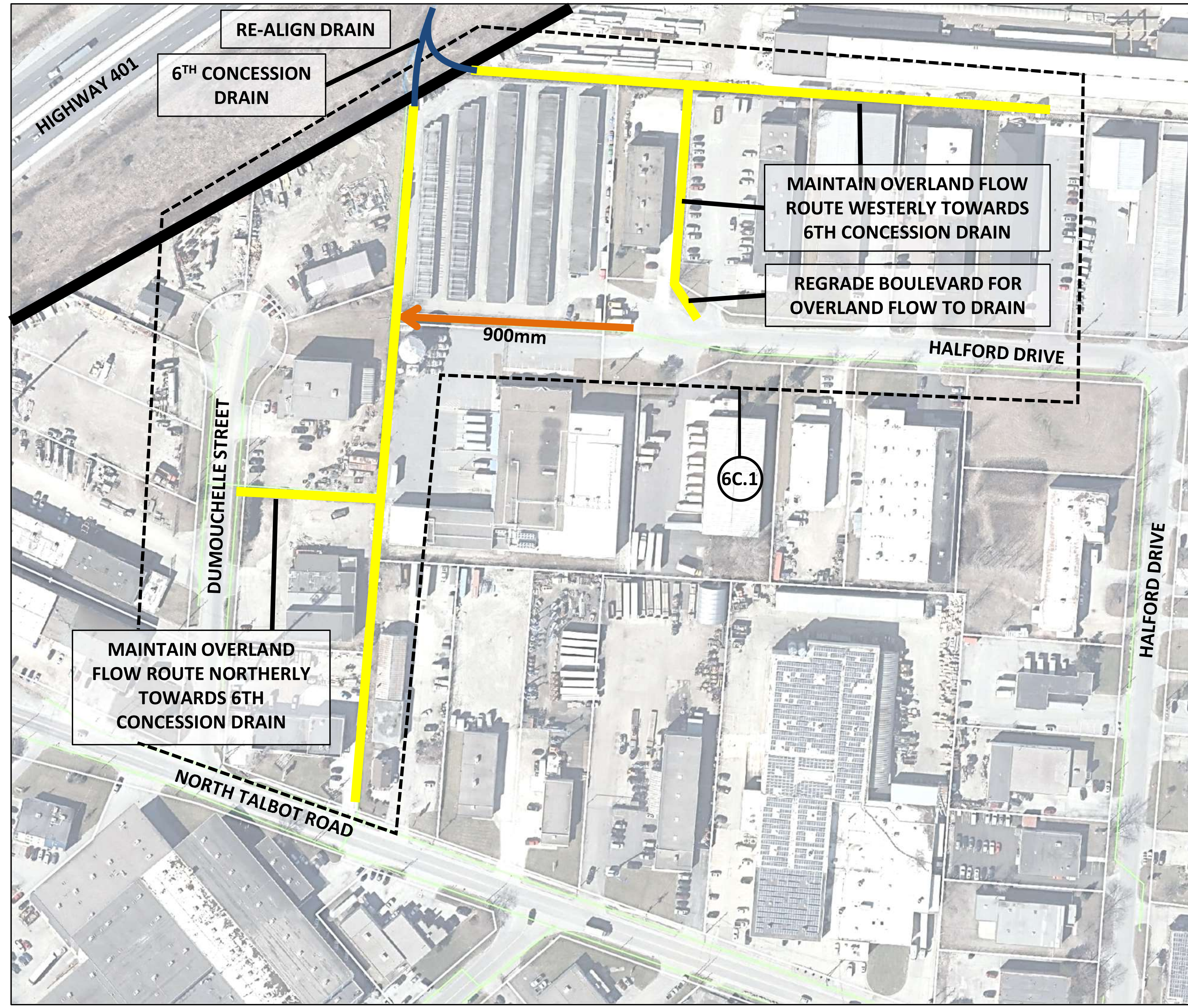
* Option 4 is only valid if the ongoing Turkey Creek Study findings determine that the downstream receivers can safely convey the peak flow rate of 12.54 m^3/s.

Landmark Engineers Inc.

Title: WOLFE DRAIN IMPROVEMENTS – OPTION 4*	Date: JAN 2022	FIGURE
	Scale: NTS	H2.4
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



8TH CONCESSION DRAIN AREA



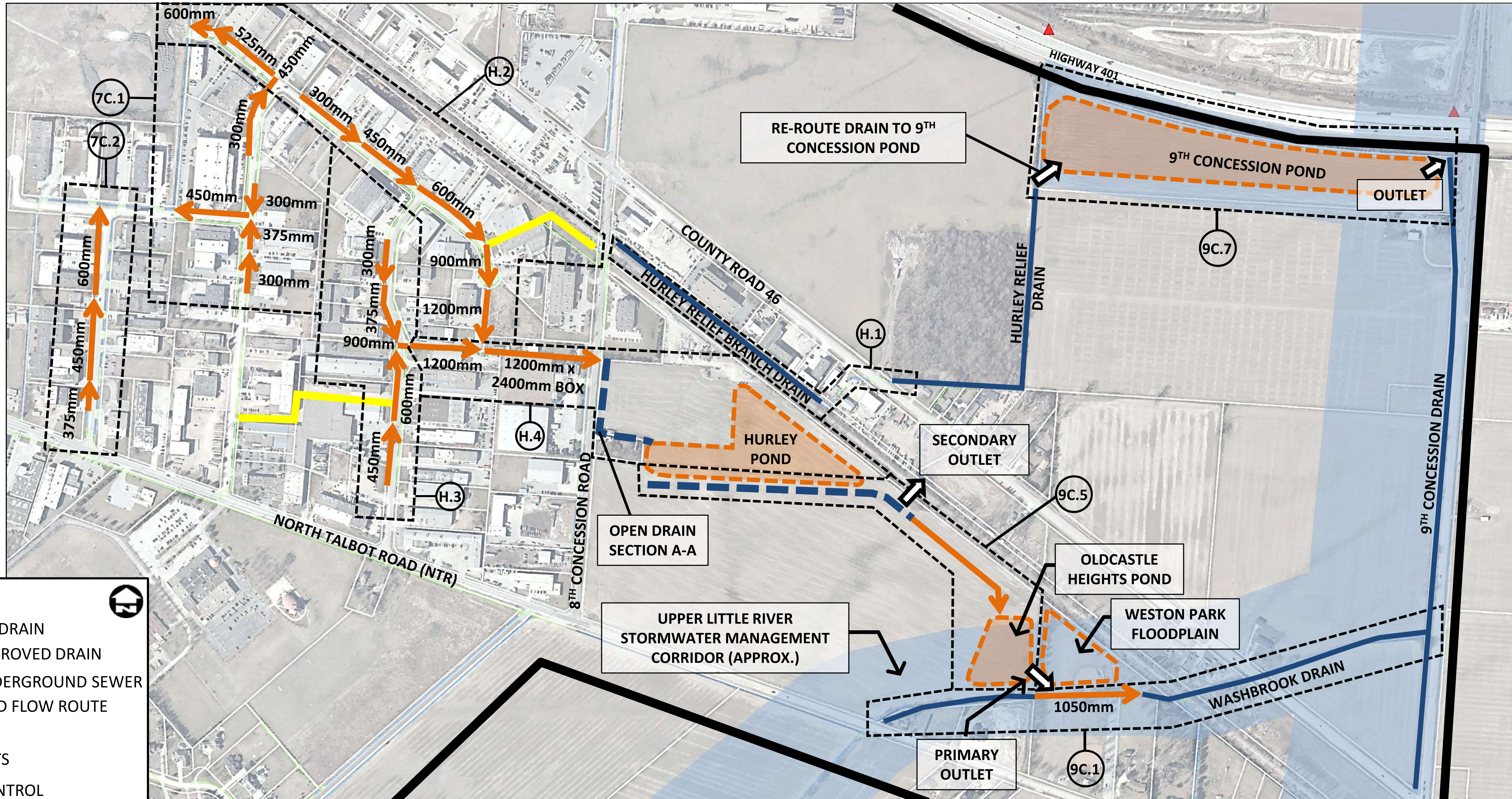
6TH CONCESSION DRAIN AREA

LEGEND

- EXISTING DRAIN
- NEW/IMPROVED DRAIN
- NEW UNDERGROUND SEWER
- OVERLAND FLOW ROUTE
- CULVERTS
- CURB CUTS
- FLOW CONTROL STRUCTURE
- APPROXIMATE POND EXTENTS
- PHASING EXTENTS
- STUDY AREA BOUNDARY

Landmark Engineers Inc.

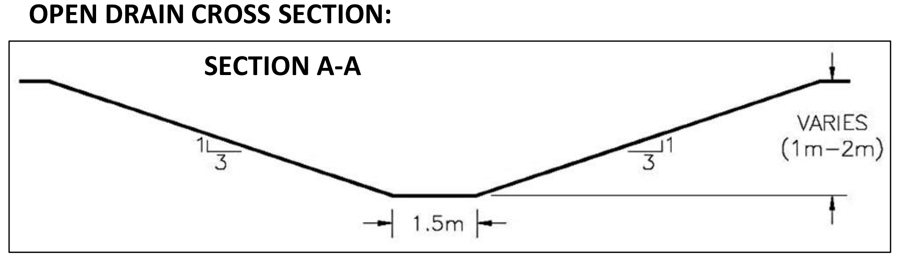
Title: PROPOSED IMPROVEMENTS: 6TH & 8TH CONCESSION DRAIN AREAS	Date: JAN. 2022	Scale: NTS	FIGURE H3
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



LEGEND

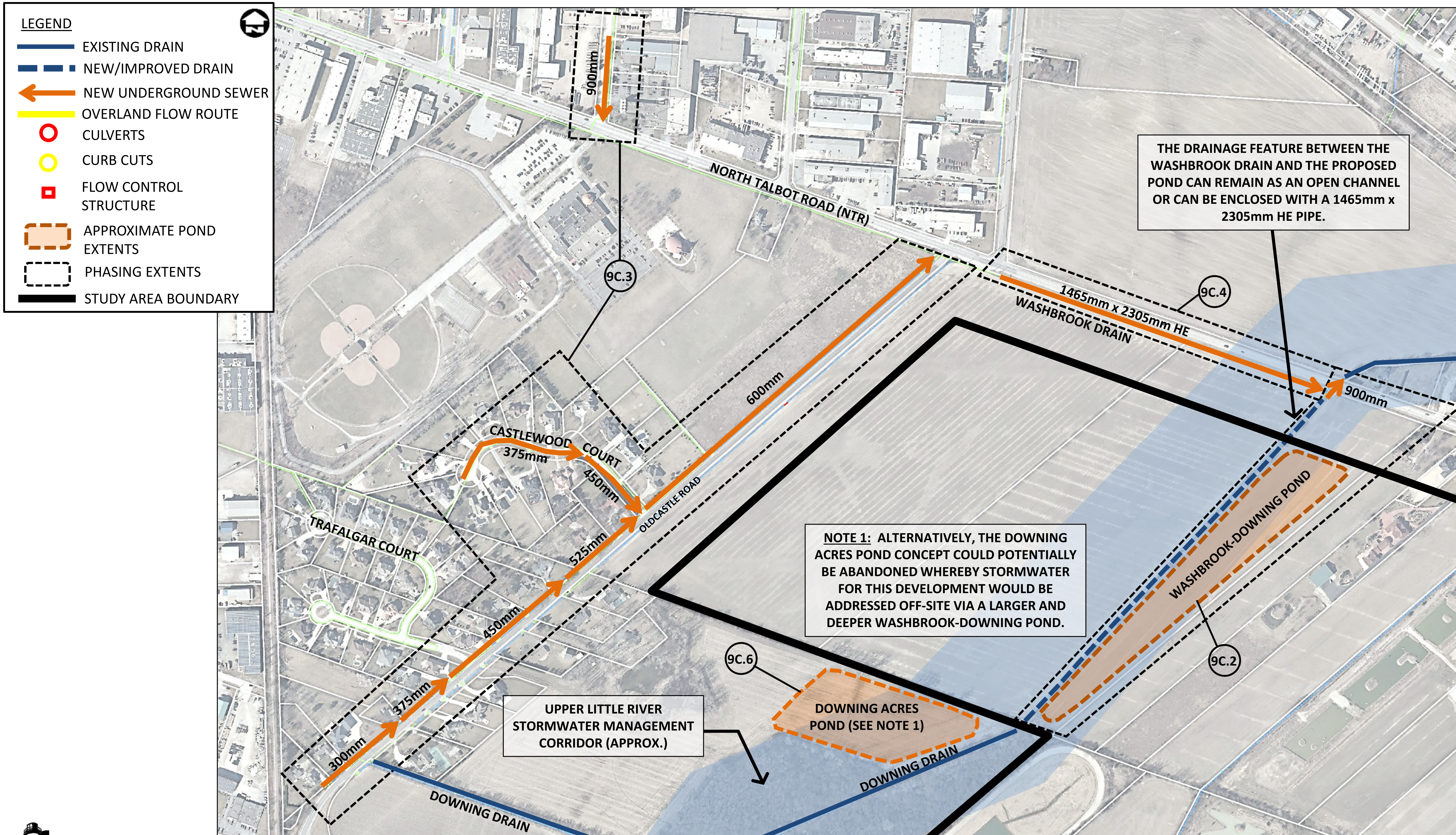
- EXISTING DRAIN
- NEW/IMPROVED DRAIN
- NEW UNDERGROUND SEWER
- OVERLAND FLOW ROUTE
- CULVERTS
- CURB CUTS
- FLOW CONTROL STRUCTURE
- APPROXIMATE POND EXTENTS
- PHASING EXTENTS
- STUDY AREA BOUNDARY

OPEN DRAIN CROSS SECTION:



Landmark Engineers Inc.

Title: PROPOSED IMPROVEMENTS: HURLEY & 9TH CONCESSION DRAIN AREAS – NORTH OF NTR	Date: JAN. 2022	Scale: NTS	FIGURE H4
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		



Landmark Engineers Inc.

Title: PROPOSED IMPROVEMENTS: 9TH CONCESSION DRAIN AREA – SOUTH OF NTR	Date: JAN. 2022	Scale: NTS	FIGURE H5
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

APPENDIX I

COST ESTIMATES

PRELIMINARY BUDGET COST ESTIMATE: SUMMARY

ITEM NO.	DESCRIPTION	TOTAL COST
Section W: Wolfe Drain Subwatershed Area		
Option 1a		
W.1	Wolfe Drain Improvements	$3,590,000
W.2	Collins Drain Improvements	$1,020,000
W.3	New Storm Sewer along Fasan Drive	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Option 1a:	**$8,900,000**
Option 1b		
W.1	Wolfe Drain Improvements	$3,560,000
W.2	Collins Drain Improvements	$1,130,000
W.3	New Storm Sewer along Fasan Drive	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Option 1b:	**$8,980,000**
Option 2		
W.1	Wolfe Drain Improvements	$3,590,000
W.2	Collins Drain Improvements	$710,000
W.3	New Storm Sewer along Fasan Drive	$1,980,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Option 2:	**$9,230,000**
Option 3		
W.1	Wolfe Drain Improvements	$3,590,000
W.2	Collins Drain Improvements	$600,000
W.3	New Storm Sewer along Fasan Drive	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Option 3:	**$8,480,000**

ITEM NO.	DESCRIPTION	TOTAL COST
Option 4		
W.1	Wolfe Drain Improvements	$3,420,000
W.2	Collins Drain Improvements	$620,000
W.3	New Storm Sewer along Fasan Drive	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Option 4:	**$8,330,000**
	Total Section W (assuming Opt. 1b):	**$8,980,000**
Section 6C: 6th Concession Drain Area		
6C.1	Replace Halford Drive Storm Outlet	$60,000
	Total Section 6:	**$60,000**
Section 7C: 7th Concession Drain Area		
7C.1	New Storm Sewers along O'Neil Dr. & Moynahan St	$230,000
7C.2	New Storm Sewers along Hennin Street	$370,000
	Total Section 7:	**$600,000**
Section 8C: 8th Concession Drain Area		
8C.1	Improvements to Demonte Drain	$100,000
	Total Section 8:	**$100,000**

ITEM NO.	DESCRIPTION	TOTAL COST
Section H: Hurley Relief Drain Area		
H.1	Hurley Relief Branch Drain Improvements	$50,000
H.2	New Storm Sewer along Del Duca	$1,000,000
H.3	New Storm Sewers along Ure Street	$450,000
H.4	Enlarge & Re-route Hurley Drain to Hurley Pond	$3,320,000
	Total Section H:	**$4,820,000**
Section 9C: 9th Concession Drain Area		
9C.1	Washbrook Drain Improvements	$620,000
9C.2	Washbrook-Downing Pond	$2,200,000
9C.3	New Storm Sewers	$1,880,000
9C.4	Extension of Washbrook Drain Enclosure	$4,170,000
9C.5*	Oldcastle Heights Pond	$1,310,000
9C.6*	Downing Acres Pond	$1,630,000
9C.7*	9th Concession Pond	$5,660,000
	Total Section 9:	**$17,470,000**
	GRAND TOTAL (Sections W+6C+7C+8C+H+9C):	**$32,030,000**
*	Allocation to Ponds for Future Development	$8,600,000
	Additional Cost for Short-Term Interim Improvements	$290,000

PRELIMINARY BUDGET COST ESTIMATE: WOLFE DRAIN - OPTION 1A

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section W: Wolfe Drain Area					
1	**Wolfe Drain Improvements**	**Lump Sum**			**$3,590,000**
a.	Clear and grub all trees and brush	Lump Sum			$25,000
b.	Seed & mulch - Wolfe Drain	Sq. M.	9,600	$4	$38,400
c.	New 1200mm dia. with inlet chamber	Lump Sum			$40,000
d.	New 1350mm dia. along Outer Drive	Lin. M.	340	$1,630	$554,200
e.	Replace Culvert at Olympia Drive w/ 1500mm dia.	Lin. M.	22	$1,940	$42,680
f.	Replace sewer east of Walker w/ 1350mm dia.	Lin. M.	120	$1,630	$195,600
g.	750mm dia. relief sewer for Blackacre Dr. sag	Lin. M.	91	$850	$77,350
h.	New 1350mm dia. - Auxiliary Wolfe Drain	Lin. M.	350	$1,630	$570,500
i.	Excavate 160m lg. channel - Auxiliary Wolfe Drain	Cu. M.	1,440	$25	$36,000
j.	Seed & mulch new channel	Sq. M.	2,240	$4	$8,960
k.	Excavate/Grade Blackacre Pond	Cu. M.	21,200	$25	$530,000
l.	Seed & mulch pond	Sq. M.	10,900	$4	$43,600
m.	Pond landscaping & supplementary items (20%)	Lump Sum			$115,000
n.	600mm dia. pond outlet	Lin. M.	25	$460	$11,500
o.	600mm dia. with flap gate - D/S of Blackacre Pond	Lump Sum			$20,000
p.	Regrade overland routes (Roscon, Halford, Walker)	Lump Sum			$5,000
	Subtotal				$2,313,790
	Engineering Allowance (25%)				$579,000
	Contingency Allowance (30%)				$695,000
2	**Collins Drain Improvements**	**Lump Sum**			**$1,020,000**
a.	Clear and grub all trees and brush	Lump Sum			$20,000
b.	Deepen (enlarge) 700 metres of drain	Cu. M.	7,000	$25	$175,000
c.	Seed & mulch drain	Sq. M.	3,500	$4	$14,000
d.	Replace Culvert w/ 1200mm dia.	Lin. M.	57	$1,330	$75,810
e.	Replace Culvert w/ 1350mm dia.	Lin. M.	29	$1,630	$47,270
f.	Replace Culvert w/ 1.8m x 1.2m box culvert	Lin. M.	6	$3,090	$18,540
g.	Excavate/Grade Collins Pond	Cu. M.	8,900	$25	$222,500
h.	Seed & mulch pond	Sq. M.	7,500	$4	$30,000
i.	Pond landscaping & supplementary items (20%)	Lump Sum			$51,000
	Subtotal				$654,120
	Engineering Allowance (25%)				$164,000
	Contingency Allowance (30%)				$197,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
3	**New Storm Sewer along Fasan Drive**	**Lump Sum**			**$1,340,000**
a.	300mm dia.	Lin. M.	71	$630	$44,730
b.	375mm dia.	Lin. M.	116	$660	$76,560
c.	450mm dia.	Lin. M.	75	$680	$51,000
d.	600mm dia.	Lin. M.	151	$790	$119,290
e.	750mm dia.	Lin. M.	244	$1,060	$258,640
f.	900mm dia.	Lin. M.	242	$1,250	$302,500
g.	Regrade overland route at Fasan cul-de-sac	Lump Sum			$6,000
	Subtotal				$858,720
	Engineering Allowance (25%)				$215,000
	Contingency Allowance (30%)				$258,000
4	**New Storm Sewer along Blackacre Drive**	**Lump Sum**			**$1,870,000**
a.	375mm dia.	Lin. M.	113	$660	$74,580
b.	450mm dia.	Lin. M.	48	$680	$32,640
c.	600mm dia.	Lin. M.	144	$790	$113,760
d.	750mm dia.	Lin. M.	226	$1,060	$239,560
e.	900mm dia.	Lin. M.	316	$1,250	$395,000
f.	1050mm dia.	Lin. M.	220	$1,570	$345,400
	Subtotal				$1,200,940
	Engineering Allowance (25%)				$301,000
	Contingency Allowance (30%)				$361,000
5	**Replace Storm Outlets to Wolfe Drain**	**Lump Sum**			**$1,080,000**
a.	750mm dia.	Lin. M.	14	$850	$11,900
b.	900mm dia.	Lin. M.	217	$1,040	$225,680
c.	1200mm dia.	Lin. M.	285	$1,580	$450,300
d.	Regrade overland route at Brendan Lane	Lump Sum			$8,000
	Subtotal				$695,880
	Engineering Allowance (25%)				$174,000
	Contingency Allowance (30%)				$209,000

PRELIMINARY BUDGET COST ESTIMATE: WOLFE DRAIN - OPTION 1B

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section W: Wolfe Drain Area					
1	**Wolfe Drain Improvements**	**Lump Sum**			**$3,560,000**
a.	Clear and grub all trees and brush	Lump Sum			$25,000
b.	Seed & mulch - Wolfe Drain	Sq. M.	9,600	$4	$38,400
c.	New 1200mm dia. with inlet chamber	Lump Sum			$40,000
d.	New 1200mm dia. along Outer Drive	Lin. M.	340	$1,330	$452,200
e.	Replace Culvert at Olympia Drive w/ 1500mm dia.	Lin. M.	22	$1,940	$42,680
f.	Replace sewer east of Walker w/ 1350mm dia.	Lin. M.	120	$1,630	$195,600
g.	750mm dia. relief sewer for Blackacre Dr. sag	Lin. M.	91	$850	$77,350
h.	New 1350mm dia. - Auxiliary Wolfe Drain	Lin. M.	350	$1,630	$570,500
i.	Excavate 160m lg. channel - Auxiliary Wolfe Drain	Cu. M.	1,440	$25	$36,000
j.	Seed & mulch new channel	Sq. M.	2,240	$4	$8,960
k.	Excavate/Grade Blackacre Pond	Cu. M.	24,000	$25	$600,000
l.	Seed & mulch pond	Sq. M.	10,900	$4	$43,600
m.	Pond landscaping & supplementary items (20%)	Lump Sum			$129,000
n.	450mm dia. pond outlet	Lin. M.	25	$380	$9,500
o.	600mm dia. with flap gate - D/S of Blackacre Pond	Lump Sum			$20,000
p.	Regrade overland routes (Roscon, Halford, Walker)	Lump Sum			$5,000
	Subtotal				$2,293,790
	Engineering Allowance (25%)				$574,000
	Contingency Allowance (30%)				$689,000
2	**Collins Drain Improvements**	**Lump Sum**			**$1,130,000**
a.	Clear and grub all trees and brush	Lump Sum			$20,000
b.	Deepen (enlarge) 700 metres of drain	Cu. M.	7,000	$25	$175,000
c.	Seed & mulch drain	Sq. M.	3,500	$4	$14,000
d.	Replace Culvert w/ 900mm dia.	Lin. M.	57	$870	$49,590
e.	Replace Culvert w/ 1350mm dia.	Lin. M.	35	$1,630	$57,050
g.	Excavate/Grade Collins Pond	Cu. M.	12,500	$25	$312,500
h.	Seed & mulch pond	Sq. M.	7,500	$4	$30,000
i.	Pond landscaping & supplementary items (20%)	Lump Sum			$69,000
	Subtotal				$727,140
	Engineering Allowance (25%)				$182,000
	Contingency Allowance (30%)				$219,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
3	**New Storm Sewer along Fasan Drive**	**Lump Sum**			**$1,340,000**
a.	300mm dia.	Lin. M.	71	$630	$44,730
b.	375mm dia.	Lin. M.	116	$660	$76,560
c.	450mm dia.	Lin. M.	75	$680	$51,000
d.	600mm dia.	Lin. M.	151	$790	$119,290
e.	750mm dia.	Lin. M.	244	$1,060	$258,640
f.	900mm dia.	Lin. M.	242	$1,250	$302,500
g.	Regrade overland route at Fasan cul-de-sac	Lump Sum			$6,000
	Subtotal				$858,720
	Engineering Allowance (25%)				$215,000
	Contingency Allowance (30%)				$258,000
4	**New Storm Sewer along Blackacre Drive**	**Lump Sum**			**$1,870,000**
a.	375mm dia.	Lin. M.	113	$660	$74,580
b.	450mm dia.	Lin. M.	48	$680	$32,640
c.	600mm dia.	Lin. M.	144	$790	$113,760
d.	750mm dia.	Lin. M.	226	$1,060	$239,560
e.	900mm dia.	Lin. M.	316	$1,250	$395,000
f.	1050mm dia.	Lin. M.	220	$1,570	$345,400
	Subtotal				$1,200,940
	Engineering Allowance (25%)				$301,000
	Contingency Allowance (30%)				$361,000
5	**Replace Storm Outlets to Wolfe Drain**	**Lump Sum**			**$1,080,000**
a.	750mm dia.	Lin. M.	14	$850	$11,900
b.	900mm dia.	Lin. M.	217	$1,040	$225,680
c.	1200mm dia.	Lin. M.	285	$1,580	$450,300
d.	Regrade overland route at Brendan Lane	Lump Sum			$8,000
	Subtotal				$695,880
	Engineering Allowance (25%)				$174,000
	Contingency Allowance (30%)				$209,000

PRELIMINARY BUDGET COST ESTIMATE: WOLFE DRAIN - OPTION 2

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section W: Wolfe Drain Area					
1	**Wolfe Drain Improvements**	**Lump Sum**			**$3,590,000**
a.	Clear and grub all trees and brush	Lump Sum			$25,000
b.	Seed & mulch - Wolfe Drain	Sq. M.	9,600	$4	$38,400
c.	New 1200mm dia. with inlet chamber	Lump Sum			$40,000
d.	New 1350mm dia. along Outer Drive	Lin. M.	340	$1,630	$554,200
e.	Replace Culvert at Olympia Drive w/ 1500mm dia.	Lin. M.	22	$1,940	$42,680
f.	Replace sewer east of Walker w/ 1350mm dia.	Lin. M.	120	$1,630	$195,600
g.	750mm dia. relief sewer for Blackacre Dr. sag	Lin. M.	91	$850	$77,350
h.	New 1350mm dia. - Auxiliary Wolfe Drain	Lin. M.	350	$1,630	$570,500
i.	Excavate 160m lg. channel - Auxiliary Wolfe Drain	Cu. M.	1,440	$25	$36,000
j.	Seed & mulch new channel	Sq. M.	2,240	$4	$8,960
k.	Excavate/Grade Blackacre Pond	Cu. M.	21,200	$25	$530,000
l.	Seed & mulch pond	Sq. M.	10,900	$4	$43,600
m.	Pond landscaping & supplementary items (20%)	Lump Sum			$115,000
n.	600mm dia. pond outlet	Lin. M.	25	$460	$11,500
o.	600mm dia. with flap gate - D/S of Blackacre Pond	Lump Sum			$20,000
p.	Regrade overland routes (Roscon, Halford, Walker)	Lump Sum			$5,000
	Subtotal				$2,313,790
	Engineering Allowance (25%)				$579,000
	Contingency Allowance (30%)				$695,000
2	**Collins Drain Improvements**	**Lump Sum**			**$710,000**
a.	Clear and grub all trees and brush	Lump Sum			$20,000
b.	Replace Culvert w/ 1200mm dia.	Lin. M.	86	$1,330	$114,380
c.	Replace Culvert w/ 1.8m x 1.2m box culvert	Lin. M.	6	$3,090	$18,540
d.	Excavate/Grade Collins Pond	Cu. M.	8,900	$25	$222,500
e.	Seed & mulch pond	Sq. M.	6,800	$4	$27,200
f.	Pond landscaping & supplementary items (20%)	Lump Sum			$50,000
	Subtotal				$452,620
	Engineering Allowance (25%)				$114,000
	Contingency Allowance (30%)				$136,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
3	**New Storm Sewer along Fasan Drive**	**Lump Sum**			**$1,980,000**
a.	300mm dia.	Lin. M.	71	$630	$44,730
b.	375mm dia.	Lin. M.	116	$660	$76,560
c.	450mm dia.	Lin. M.	75	$680	$51,000
d.	600mm dia.	Lin. M.	151	$790	$119,290
e.	750mm dia.	Lin. M.	244	$1,060	$258,640
f.	900mm dia.	Lin. M.	122	$1,250	$152,500
g.	1050mm dia.	Lin. M.	180	$1,350	$243,000
h.	1200mm dia.	Lin. M.	180	$1,580	$284,400
i.	Deepen Drain adjacent to Collins Pond	Cu. M.	1,400	$25	$35,000
j.	Regrade overland route at Fasan cul-de-sac	Lump Sum			$6,000
	Subtotal				$1,271,120
	Engineering Allowance (25%)				$318,000
	Contingency Allowance (30%)				$382,000
4	**New Storm Sewer along Blackacre Drive**	**Lump Sum**			**$1,870,000**
a.	375mm dia.	Lin. M.	113	$660	$74,580
b.	450mm dia.	Lin. M.	48	$680	$32,640
c.	600mm dia.	Lin. M.	144	$790	$113,760
d.	750mm dia.	Lin. M.	226	$1,060	$239,560
e.	900mm dia.	Lin. M.	316	$1,250	$395,000
f.	1050mm dia.	Lin. M.	220	$1,570	$345,400
	Subtotal				$1,200,940
	Engineering Allowance (25%)				$301,000
	Contingency Allowance (30%)				$361,000
5	**Replace Storm Outlets to Wolfe Drain**	**Lump Sum**			**$1,080,000**
a.	750mm dia.	Lin. M.	14	$850	$11,900
b.	900mm dia.	Lin. M.	217	$1,040	$225,680
c.	1200mm dia.	Lin. M.	285	$1,580	$450,300
d.	Regrade overland route at Brendan Lane	Lump Sum			$8,000
	Subtotal				$695,880
	Engineering Allowance (25%)				$174,000
	Contingency Allowance (30%)				$209,000

PRELIMINARY BUDGET COST ESTIMATE: WOLFE DRAIN - OPTION 3

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section W: Wolfe Drain Area					
1	**Wolfe Drain Improvements**	**Lump Sum**			**$3,590,000**
a.	Clear and grub all trees and brush	Lump Sum			$25,000
b.	Seed & mulch - Wolfe Drain	Sq. M.	9,600	$4	$38,400
c.	New 1200mm dia. with inlet chamber	Lump Sum			$40,000
d.	New 1350mm dia. along Outer Drive	Lin. M.	340	$1,630	$554,200
e.	Replace Culvert at Olympia Drive w/ 1500mm dia.	Lin. M.	22	$1,940	$42,680
f.	Replace sewer east of Walker w/ 1350mm dia.	Lin. M.	120	$1,630	$195,600
g.	750mm dia. relief sewer for Blackacre Dr. sag	Lin. M.	91	$850	$77,350
h.	New 1350mm dia. - Auxiliary Wolfe Drain	Lin. M.	350	$1,630	$570,500
i.	Excavate 160m lg. channel - Auxiliary Wolfe Drain	Cu. M.	1,440	$25	$36,000
j.	Seed & mulch new channel	Sq. M.	2,240	$4	$8,960
k.	Excavate/Grade Blackacre Pond	Cu. M.	21,200	$25	$530,000
l.	Seed & mulch pond	Sq. M.	10,900	$4	$43,600
m.	Pond landscaping & supplementary items (20%)	Lump Sum			$115,000
n.	600mm dia. pond outlet	Lin. M.	25	$460	$11,500
o.	600mm dia. with flap gate - D/S of Blackacre Pond	Lump Sum			$20,000
p.	Regrade overland routes (Roscon, Halford, Walker)	Lump Sum			$5,000
	Subtotal				$2,313,790
	Engineering Allowance (25%)				$579,000
	Contingency Allowance (30%)				$695,000
2	**Collins Drain Improvements**	**Lump Sum**			**$600,000**
a.	Clear and grub all trees and brush	Lump Sum			$20,000
b.	Deepen (enlarge) 700 metres of drain	Cu. M.	7,000	$25	$175,000
c.	Seed & mulch drain	Sq. M.	3,500	$4	$14,000
d.	Replace Culvert w/ 1350mm dia.	Lin. M.	29	$1,630	$47,270
e.	Replace Culvert w/ 1500mm dia.	Lin. M.	57	$1,940	$110,580
f.	Replace Culvert w/ 1.8m x 1.2m box culvert	Lin. M.	6	$3,090	$18,540
	Subtotal				$385,390
	Engineering Allowance (25%)				$97,000
	Contingency Allowance (30%)				$116,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
3	**New Storm Sewer along Fasan Drive**	**Lump Sum**			**$1,340,000**
a.	300mm dia.	Lin. M.	71	$630	$44,730
b.	375mm dia.	Lin. M.	116	$660	$76,560
c.	450mm dia.	Lin. M.	75	$680	$51,000
d.	600mm dia.	Lin. M.	151	$790	$119,290
e.	750mm dia.	Lin. M.	244	$1,060	$258,640
f.	900mm dia.	Lin. M.	242	$1,250	$302,500
g.	Regrade overland route at Fasan cul-de-sac	Lump Sum			$6,000
	Subtotal				$858,720
	Engineering Allowance (25%)				$215,000
	Contingency Allowance (30%)				$258,000
4	**New Storm Sewer along Blackacre Drive**	**Lump Sum**			**$1,870,000**
a.	375mm dia.	Lin. M.	113	$660	$74,580
b.	450mm dia.	Lin. M.	48	$670	$32,160
c.	600mm dia.	Lin. M.	144	$790	$113,760
d.	750mm dia.	Lin. M.	226	$1,060	$239,560
e.	900mm dia.	Lin. M.	316	$1,250	$395,000
f.	1050mm dia.	Lin. M.	220	$1,570	$345,400
	Subtotal				$1,200,460
	Engineering Allowance (25%)				$301,000
	Contingency Allowance (30%)				$361,000
5	**Replace Storm Outlets to Wolfe Drain**	**Lump Sum**			**$1,080,000**
a.	750mm dia.	Lin. M.	14	$850	$11,900
b.	900mm dia.	Lin. M.	217	$1,040	$225,680
c.	1200mm dia.	Lin. M.	285	$1,580	$450,300
d.	Regrade overland route at Brendan Lane	Lump Sum			$8,000
	Subtotal				$695,880
	Engineering Allowance (25%)				$174,000
	Contingency Allowance (30%)				$209,000

PRELIMINARY BUDGET COST ESTIMATE: WOLFE DRAIN - OPTION 4

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section W: Wolfe Drain Area					
1	**Wolfe Drain Improvements**	**Lump Sum**			**$3,420,000**
a.	Clear and grub all trees and brush	Lump Sum			$25,000
b.	Seed & mulch - Wolfe Drain	Sq. M.	9,600	$4	$38,400
c.	New 1200mm dia. with inlet chamber	Lump Sum			$40,000
d.	New 1350mm dia. along Outer Drive	Lin. M.	340	$1,630	$554,200
e.	Replace Culvert at Olympia Drive w/ 1500mm dia.	Lin. M.	22	$1,940	$42,680
f.	Replace sewer east of Walker w/ 1350mm dia.	Lin. M.	120	$1,630	$195,600
g.	750mm dia. relief sewer for Blackacre Dr. sag	Lin. M.	91	$850	$77,350
h.	New 1350mm dia. - Auxiliary Wolfe Drain	Lin. M.	150	$1,630	$244,500
i.	New 1800mm dia. - Auxiliary Wolfe Drain	Lin. M.	350	$2,680	$938,000
j.	Excavate 160m lg. channel - Auxiliary Wolfe Drain	Cu. M.	1,440	$25	$36,000
k.	Seed & mulch new channel	Sq. M.	2,240	$4	$8,960
l.	Regrade overland routes (Roscon, Halford, Walker)	Lump Sum			$5,000
	Subtotal				$2,205,690
	Engineering Allowance (25%)				$552,000
	Contingency Allowance (30%)				$662,000
2	**Collins Drain Improvements**	**Lump Sum**			**$620,000**
a.	Clear and grub all trees and brush	Lump Sum			$20,000
b.	Deepen (enlarge) 700 metres of drain	Cu. M.	7,000	$25	$175,000
c.	Seed & mulch drain	Sq. M.	3,500	$4	$14,000
d.	Replace Culvert w/ 1350mm dia.	Lin. M.	29	$1,630	$47,270
e.	Replace Culvert w/ 1500mm dia.	Lin. M.	57	$1,940	$110,580
f.	Replace Culvert w/ Span Bridge	Lump Sum			$30,000
	Subtotal				$396,850
	Engineering Allowance (25%)				$100,000
	Contingency Allowance (30%)				$120,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
3	**New Storm Sewer along Fasan Drive**	**Lump Sum**			**$1,340,000**
a.	300mm dia.	Lin. M.	71	$630	$44,730
b.	375mm dia.	Lin. M.	116	$660	$76,560
c.	450mm dia.	Lin. M.	75	$680	$51,000
d.	600mm dia.	Lin. M.	151	$790	$119,290
e.	750mm dia.	Lin. M.	244	$1,060	$258,640
f.	900mm dia.	Lin. M.	242	$1,250	$302,500
g.	Regrade overland route at Fasan cul-de-sac	Lump Sum			$6,000
	Subtotal				$858,720
	Engineering Allowance (25%)				$215,000
	Contingency Allowance (30%)				$258,000
4	**New Storm Sewer along Blackacre Drive**	**Lump Sum**			**$1,870,000**
a.	375mm dia.	Lin. M.	113	$660	$74,580
b.	450mm dia.	Lin. M.	48	$680	$32,640
c.	600mm dia.	Lin. M.	144	$790	$113,760
d.	750mm dia.	Lin. M.	226	$1,060	$239,560
e.	900mm dia.	Lin. M.	316	$1,250	$395,000
f.	1050mm dia.	Lin. M.	220	$1,570	$345,400
	Subtotal				$1,200,940
	Engineering Allowance (25%)				$301,000
	Contingency Allowance (30%)				$361,000
5	**Replace Storm Outlets to Wolfe Drain**	**Lump Sum**			**$1,080,000**
a.	750mm dia.	Lin. M.	14	$850	$11,900
b.	900mm dia.	Lin. M.	217	$1,040	$225,680
c.	1200mm dia.	Lin. M.	285	$1,580	$450,300
d.	Regrade overland route at Brendan Lane	Lump Sum			$8,000
	Subtotal				$695,880
	Engineering Allowance (25%)				$174,000
	Contingency Allowance (30%)				$209,000

PRELIMINARY BUDGET COST ESTIMATE: 6TH CONC. DRAIN

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section 6C: 6th Concession Drain Area					
1	**Replace Halford Drive Storm Outlet**	**Lump Sum**			**$60,000**
a.	900 mm dia.	Lin. M.	97	$1,040	$25,000
b.	Regrade overland routes	Lump Sum			$3,500
c.	Re-align drainage ditch east of 6th Conc. Drain outlet	Lump Sum			$5,000
	Subtotal				$33,500
	Engineering Allowance (25%)				$9,000
	Contingency Allowance (30%)				$11,000

PRELIMINARY BUDGET COST ESTIMATE: 7TH CONC. DRAIN

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section 7C: 7th Concession Drain Area					
1	**New Storm Sewers along O'Neil Dr. & Moynahan St**	**Lump Sum**			**$230,000**
a.	300mm dia.	Lin. M.	159	$630	$25,000
b.	375mm dia.	Lin. M.	56	$660	$36,960
c.	450mm dia.	Lin. M.	126	$680	$85,680
	Subtotal				$147,640
	Engineering Allowance (25%)				$37,000
	Contingency Allowance (30%)				$45,000
2	**New Storm Sewer along Hennin Street**	**Lump Sum**			**$370,000**
a.	375mm dia.	Lin. M.	34	$660	$22,440
b.	450mm dia.	Lin. M.	143	$680	$97,240
e.	600mm dia.	Lin. M.	147	$790	$116,130
	Subtotal				$235,810
	Engineering Allowance (25%)				$59,000
	Contingency Allowance (30%)				$71,000

PRELIMINARY BUDGET COST ESTIMATE: 8TH CONC. DRAIN

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section 8C: 8th Concession Drain Area					
1	**Improvements to Demonte Drain**	**Lump Sum**			**$100,000**
a.	Clean, clear and grub drain and culverts[1]	Lump Sum			$25,000
b.	600mm dia.	Lin. M.	35	$460	$16,100
c.	740mm x 1030mm CSPA	Lin. M.	25	$870	$21,750
	Subtotal				$62,850
	Engineering Allowance (25%)				$16,000
	Contingency Allowance (30%)				$19,000

Note 1: It is our understanding that the Demonte Drain may have contaminants that will require specific disposal measures. As such, we have assumed an allowance of $25,000 for the purpose of this estimate, however, please note that this cost may vary significantly as determined by the detailed design of improvement works currently being undertaken under the Drainage Act.

PRELIMINARY BUDGET COST ESTIMATE: HURLEY RELIEF DRAIN

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
Section H: Hurley Relief Drain Area					
1	**Hurley Relief Branch Drain Improvements**	**Lump Sum**			**$40,000**
a.	Clean, clear and grub drain and culverts[1]	Lump Sum			$25,000
	Subtotal				$25,000
	Engineering Allowance (25%)				$7,000
	Contingency Allowance (30%)				$8,000
2	**New Storm Sewer along Del Duca**	**Lump Sum**			**$1,000,000**
a.	300mm dia.	Lin. M.	114	$630	$71,820
b.	450mm dia.	Lin. M.	144	$680	$97,920
c.	525mm dia.	Lin. M.	138	$730	$100,740
d.	600mm dia.	Lin. M.	181	$790	$142,990
e.	900mm dia.	Lin. M.	63	$1,250	$78,750
f.	1200mm dia.	Lin. M.	82	$1,800	$147,600
	Subtotal[2]				$639,820
	Engineering Allowance (25%)				$160,000
	Contingency Allowance (30%)				$192,000
3	**New Storm Sewers along Ure Street**	**Lump Sum**			**$450,000**
a.	300mm dia.	Lin. M.	82	$630	$51,660
b.	375mm dia.	Lin. M.	77	$660	$50,820
c.	450 mm dia.	Lin. M.	100	$680	$68,000
d.	600 mm dia.	Lin. M.	122	$790	$96,380
e.	900 mm dia.	Lin. M.	18	$1,250	$22,500
	Subtotal				$289,360
	Engineering Allowance (25%)				$73,000
	Contingency Allowance (30%)				$87,000
4	**Enlarge & Re-route Hurley Drain to Hurley Pond**	**Lump Sum**			**$3,320,000**
a.	1200mm dia.	Lin. M.	153	$1,580	$241,740
b.	1200mm x 2400mm box culvert	Lin. M.	176	$4,340	$763,840
c.	Excavate 200 metres of new open channel	Cu. M.	1,800	$25	$45,000
d.	Seed & mulch new channel	Sq. M.	2,100	$4	$8,400
e.	Excavate/Grade new Hurley Pond	Cu. M.	32,800	$25	$820,000
f.	Seed & mulch new pond	Sq. M.	19,400	$4	$77,600
g.	Pond landscaping & supplementary items (20%)	Lump Sum			$180,000
	Subtotal				$2,136,580

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
	Engineering Allowance (25%)				$535,000
	Contingency Allowance (30%)				$641,000

Note 1: Estimate per Hurley Relief Branch Drain & Upper Part of Hurley Relief Drain report by Rood Engineering dated Nov 20, 2019.

Note 2: Stantec Consulting Preliminary Opinion of Probable Cost for Tendering purposes was estimated as approximately $620,000.

PRELIMINARY BUDGET COST ESTIMATE: 9TH CONC. DRAIN

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST

Section 9C: 9th Concession Drain Area

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
1	**Washbrook Drain Improvements**	**Lump Sum**			**$620,000**
a.	Clean, clear and grub drain and culverts	Lump Sum			$25,000
b.	Restore grade from NTR to CR46	Cu. M.	4,200	$25	$105,000
c.	Seed & mulch - Wolfe Drain	Sq. M.	2,100	$4	$8,400
d.	Replace Culvert w/ 1050mm dia.	Lin. M.	184	$1,100	$202,400
e.	Replace Culvert w/ 1360mm x 1780mm SPCSPA	Lin. M.	8	$1,940	$15,520
f.	Weston Floodplain - Berming	Cu. M.	1,000	$25	$25,000
g.	Seed & mulch berm	Sq. M.	3,000	$4	$12,000
	Subtotal				$393,320
	Engineering Allowance (25%)				$99,000
	Contingency Allowance (30%)				$118,000
2	**Washbrook-Downing Pond**	**Lump Sum**			**$2,200,000**
a.	Excavation & grading	Cu. M.	41,000	$25	$1,025,000
b.	Seed & mulch	Sq. M.	38,300	$4	$153,200
c.	Pond landscaping & supplementary items (20%)	Lump Sum			$235,600
d.	Deepen 630 metres of Downing Drain	Cu. M.	2,200	$25	$55,000
	Subtotal				$1,413,800
	Engineering Allowance (25%)				$354,000
	Contingency Allowance (30%)				$425,000
3	**New Storm Sewers**	**Lump Sum**			**$1,880,000**
a.	300mm dia. - Oldcastle Rd	Lin. M.	143	$630	$90,090
b.	375mm dia. - Oldcastle Rd	Lin. M.	83	$660	$54,780
c.	450 mm dia. - Oldcastle Rd	Lin. M.	213	$680	$144,840
d.	525 mm dia. - Oldcastle Rd	Lin. M.	152	$730	$110,960
e.	600mm dia. - Oldcastle Rd	Lin. M.	541	$790	$427,390
f.	375mm dia. - Castlewood Court	Lin. M.	230	$660	$151,800
g.	450 mm dia. - Castlewood Court	Lin. M.	96	$680	$65,280
h.	900 mm dia. - O'Neil Drive	Lin. M.	133	$1,250	$166,250
	Subtotal				$1,211,390
	Engineering Allowance (25%)				$303,000
	Contingency Allowance (30%)				$364,000

ITEM NO.	DESCRIPTION	UNIT	EST. QTY	UNIT COST	TOTAL COST
4	**Extension of Washbrook Drain Enclosure**	**Lump Sum**			**$4,170,000**
a.	1465mm x 2305mm HE Conc. Pipe	Lin. M.	640	$4,200	$2,688,000
	Subtotal				$2,688,000
	Engineering Allowance (25%)				$672,000
	Contingency Allowance (30%)				$807,000
5	**Oldcastle Heights Pond**	**Lump Sum**			**$1,310,000**
a.	Excavation & grading	Cu. M.	26,000	$25	$650,000
b.	Seed & mulch	Sq. M.	12,700	$4	$50,800
c.	Pond landscaping & supplementary items (20%)	Lump Sum			$140,200
	Subtotal				$841,000
	Engineering Allowance (25%)				$211,000
	Contingency Allowance (30%)				$253,000
6	**Downing Acres Pond**	**Lump Sum**			**$1,630,000**
a.	Excavation & grading	Cu. M.	35,000	$25	$875,000
b.	Seed & mulch	Sq. M.	18,900	$4	$75,600
c.	Pond landscaping & supplementary items (20%)	Lump Sum			$95,100
	Subtotal				$1,045,700
	Engineering Allowance (25%)				$262,000
	Contingency Allowance (30%)				$314,000
7	**9th Concession Pond**	**Lump Sum**			**$5,660,000**
a.	Excavation & grading	Cu. M.	123,300	$25	$3,082,500
b.	Seed & mulch	Sq. M.	58,200	$4	$232,800
c.	Landscaping & supplementary items (10%)	Lump Sum			$331,500
	Subtotal				$3,646,800
	Engineering Allowance (25%)				$912,000
	Contingency Allowance (30%)				$1,095,000

PRELIMINARY BUDGET COST ESTIMATE: SHORT-TERM

ITEM NO.	DESCRIPTION	TOTAL COST
Section W: Wolfe Drain Subwatershed Area		
W.1	Wolfe Drain Improvements	$3,560,000
W.3*	Culvert Replacements (200m) along Fasan Drive	$100,000
W.4*	Culvert Replacements (160m) along Blackacre Drive	$80,000
	Total Section W:	**$3,740,000**
Section 6C: 6th Concession Drain Area		
6C.1(b,c)	Replace Halford Drive Storm Outlet	$15,000
	Total Section 6:	**$15,000**
Section 7C: 7th Concession Drain Area		
	Total Section 7:	**$0**
Section 8C: 8th Concession Drain Area		
8C.1	Improvements to Demonte Drain	$100,000
	Total Section 8:	**$100,000**
Section H: Hurley Relief Drain Area		
H.1*	Hurley Relief Branch Drain Improvements	$50,000
H.2	New Storm Sewer along Del Duca	$1,000,000
H.3	New Storm Sewers along Ure Street	$450,000
	Total Section H:	**$1,500,000**
Section 9C: 9th Concession Drain Area		
9C.1	Washbrook Drain Improvements	$620,000
9C.3*	Improve West Roadside Drainage along Oldcastle Rd	$60,000
	Total Section 9:	**$680,000**
	GRAND TOTAL (Sections W+6C+7C+8C+H+9C):	**$6,035,000**
*	Interim Improvements	$290,000

PRELIMINARY BUDGET COST ESTIMATE: MEDIUM-TERM

ITEM NO.	DESCRIPTION	TOTAL COST
Section W: Wolfe Drain Subwatershed Area		
W.2	Collins Drain Improvements	$1,130,000
W.3	New Storm Sewer along Fasan Drive	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	$1,870,000
W.5	Replace Storm Sewer Outlets to Wolfe Drain	$1,080,000
	Total Section W:	**$5,420,000**
Section 6C: 6th Concession Drain Area		
6C.1(a)	Replace Halford Drive Storm Outlet	$60,000
	Total Section 6:	**$60,000**
Section 7C: 7th Concession Drain Area		
7C.1	New Storm Sewers along O'Neil Dr. & Moynahan St	$230,000
	Total Section 7:	**$230,000**
Section 8C: 8th Concession Drain Area		
	Total Section 8:	**$0**
Section H: Hurley Relief Drain Area		
H.4	Enlarge & Re-route Hurley Drain to Enbridge Pond	$3,320,000
	Total Section H:	**$3,320,000**
Section 9C: 9th Concession Drain Area		
9C.2	Washbrook-Downing Stage 1 Pond	$2,200,000
	Total Section 9:	**$2,200,000**
	GRAND TOTAL (Sections W+6C+7C+8C+H+9C):	**$11,230,000**

PRELIMINARY BUDGET COST ESTIMATE: LONG-TERM

ITEM NO.	DESCRIPTION	TOTAL COST
Section W: Wolfe Drain Subwatershed Area		
	Total Section W:	**$0**
Section 6C: 6th Concession Drain Area		
	Total Section 6:	**$0**
Section 7C: 7th Concession Drain Area		
7C.2	New Storm Sewers along Hennin Street	$370,000
	Total Section 7:	**$370,000**
Section 8C: 8th Concession Drain Area		
	Total Section 8:	**$0**
Section H: Hurley Relief Drain Area		
	Total Section H:	**$0**
Section 9C: 9th Concession Drain Area		
9C.3	New Storm Sewers	$1,880,000
9C.4	Extension of Washbrook Drain Enclosure	$4,170,000
	Total Section 9:	**$6,050,000**
	GRAND TOTAL (Sections W+6C+7C+8C+H+9C):	**$6,420,000**

APPENDIX
J

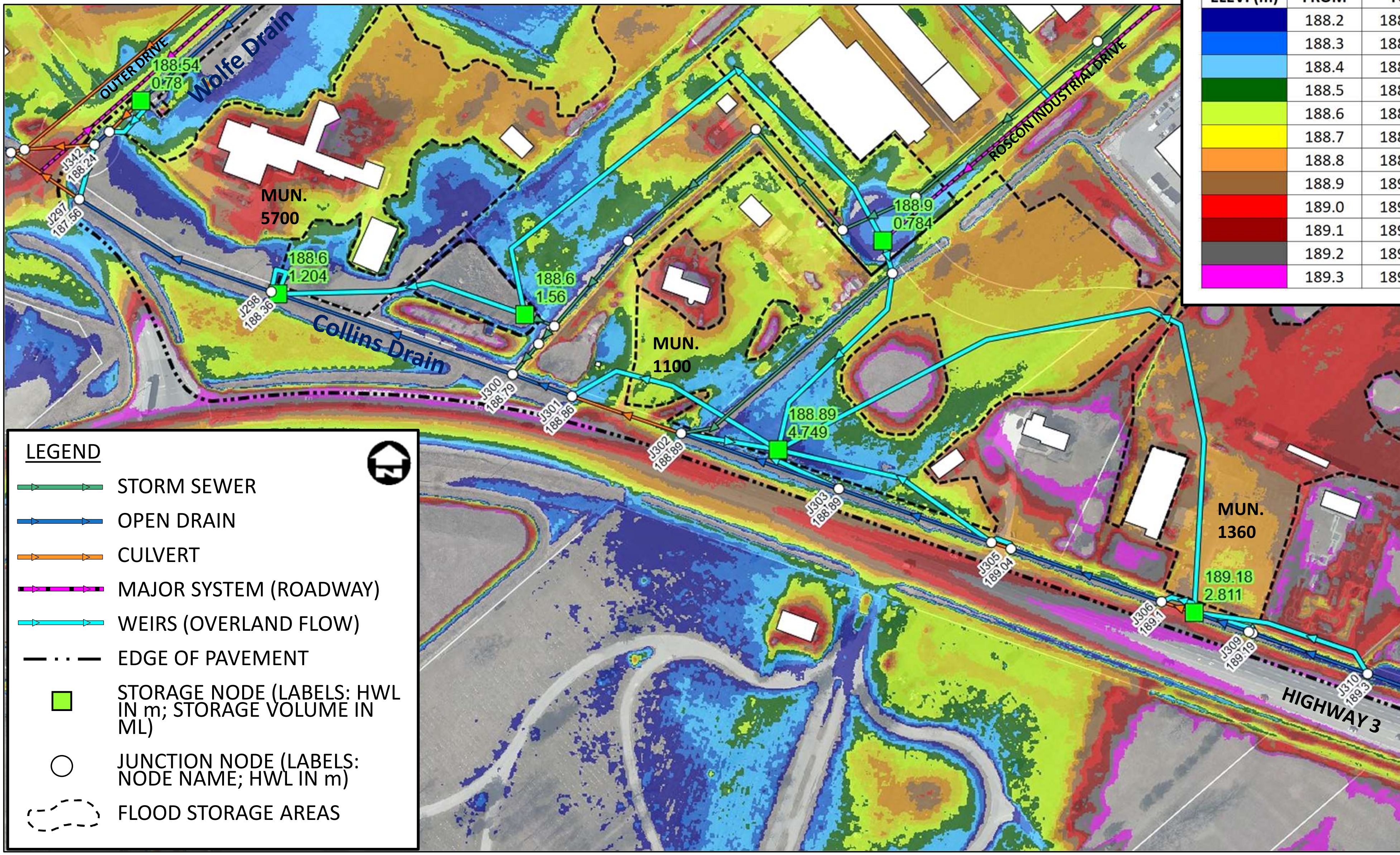
WOLFE DRAIN IMPROVEMENT OPTIONS
MODEL RESULTS

WOLFE DRAIN WATERSHED IMPROVEMENT OPTIONS

OPTION	Re-route Fasan Drive storm sewer to new Collins Pond	Deepen/Enlarge Collins Drain	New Blackacre Pond (2.5m Deep Storage)	New Blackacre Pond (3.0m Deep Storage)	New Collins Pond (1.5m Deep Storage)	New Collins Pond (2.5m Deep Storage)	Flow Control on proposed new Auxiliary Wolfe Drain	**1:100 Year Peak Flow to City (m^3/s)[1]**
1a		x	x		x		x	**7.55**
1b		x		x		x	x	**6.63**
2	x		x		x		x	**7.59**
3*		x	x				x	**8.92**
4*		x						**12.54**

Note 1: Existing 1:100 Year Peak Flow to City is 7.7 m^3/s. Parkway Design Flow is 6.1 m^3/s. See Figure J4 of Appendix J for flow reference location and flow hydrographs.

* Option is only valid if the ongoing Turkey Creek Study findings determine that the downstream receivers can safely convey the peak flow rate.



TOPO LEGEND

ELEV. (m)	FROM	TO
	188.2	188.3
	188.3	188.4
	188.4	188.5
	188.5	188.6
	188.6	188.7
	188.7	188.8
	188.8	188.9
	188.9	189.0
	189.0	189.1
	189.1	189.2
	189.2	189.3
	189.3	189.4

Landmark Engineers Inc.

Title
EXISTING CONDITION: 100-YEAR STORM

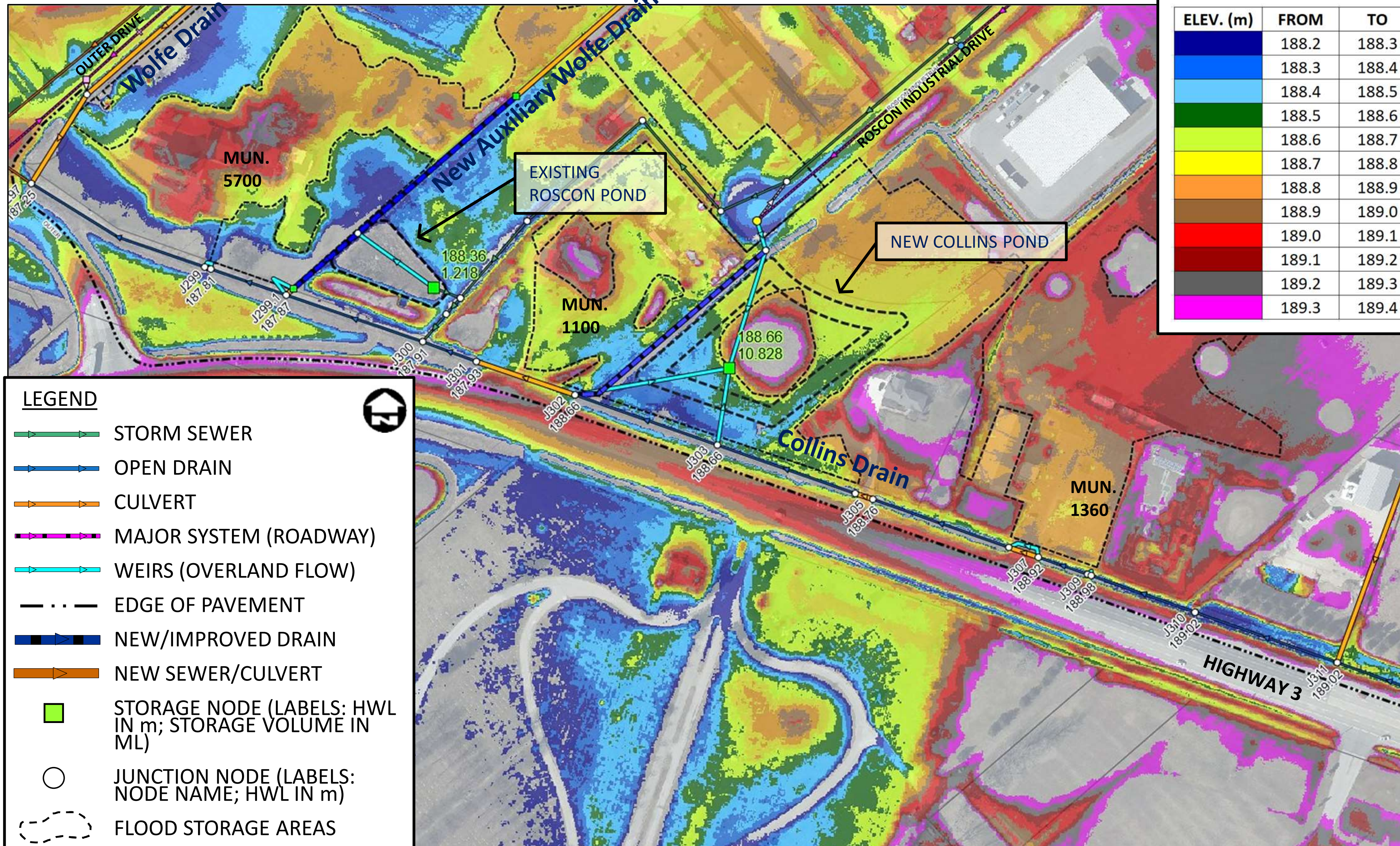
Project
OLDCASTLE STORMWATER MASTER PLAN

Date
JUNE 2021

Scale
NTS

Project No.
19-010

FIGURE
J1



TOPO LEGEND

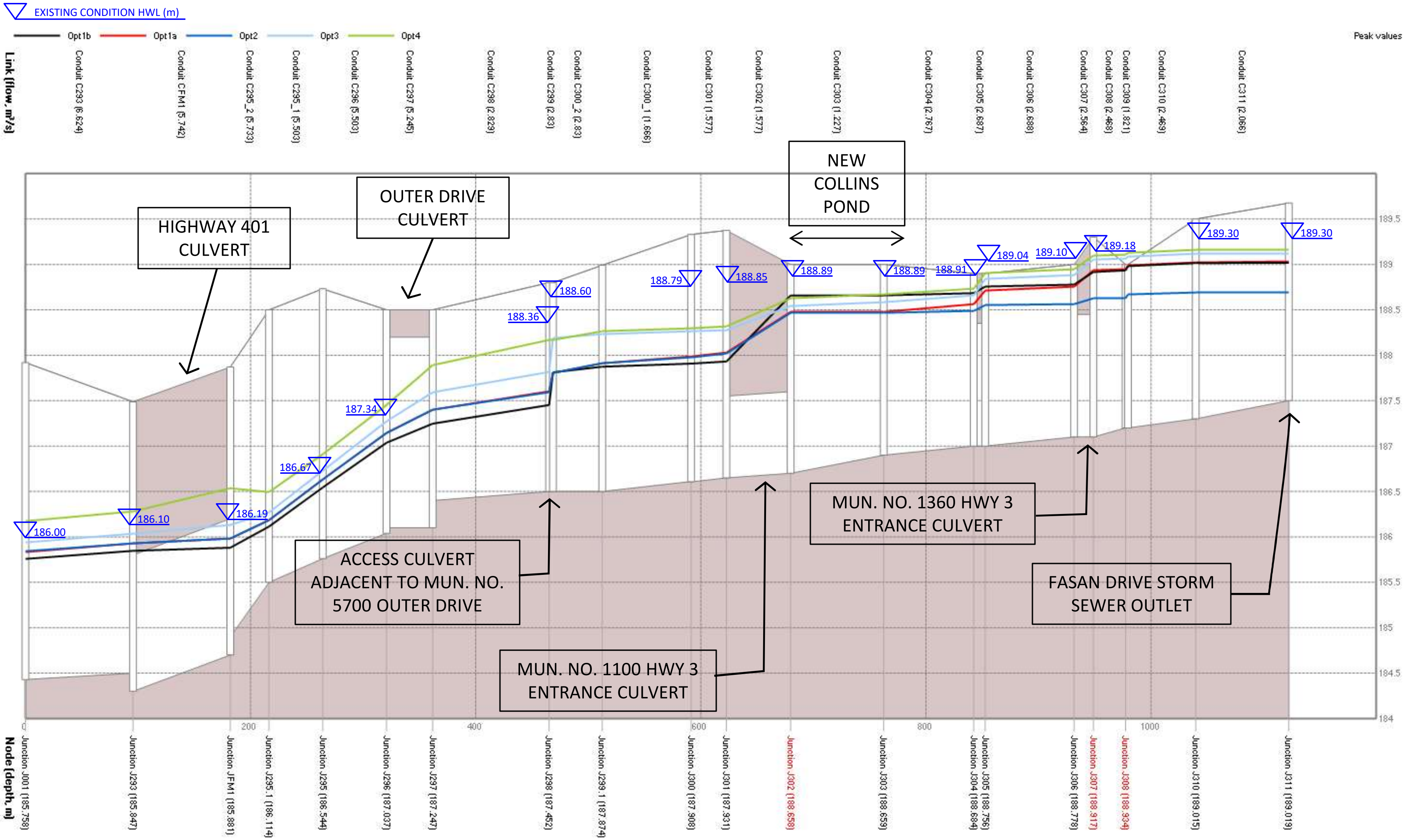
ELEV. (m)	FROM	TO
	188.2	188.3
	188.3	188.4
	188.4	188.5
	188.5	188.6
	188.6	188.7
	188.7	188.8
	188.8	188.9
	188.9	189.0
	189.0	189.1
	189.1	189.2
	189.2	189.3
	189.3	189.4

LEGEND

- STORM SEWER
- OPEN DRAIN
- CULVERT
- MAJOR SYSTEM (ROADWAY)
- WEIRS (OVERLAND FLOW)
- EDGE OF PAVEMENT
- NEW/IMPROVED DRAIN
- NEW SEWER/CULVERT
- STORAGE NODE (LABELS: HWL IN m; STORAGE VOLUME IN ML)
- JUNCTION NODE (LABELS: NODE NAME; HWL IN m)
- FLOOD STORAGE AREAS

Landmark Engineers Inc.

Title	RECOMMENDED OPTION 1B: 100-YEAR STORM
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	JAN 2022
Scale	NTS
Project No.	19-010
FIGURE	J2

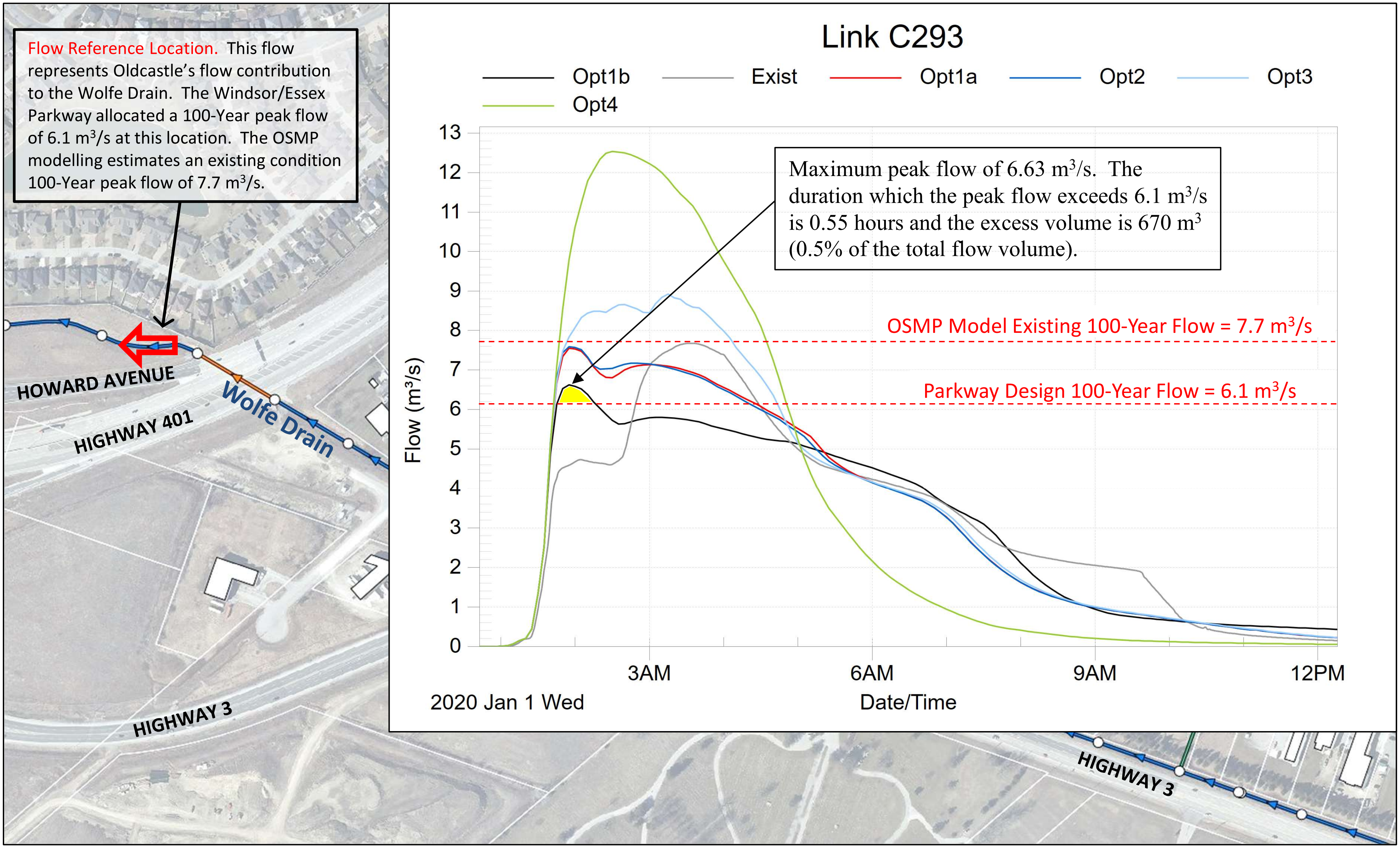


Landmark Engineers Inc.

NOTES:
1. PROFILE SHOWN, INCLUDING VALUES NOTED ARE BASED ON OPTION 1B.

Title	COLLINS DRAIN 100-YEAR HGL PROFILES
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	JAN 2022
Scale	NTS
Project No.	19-010

FIGURE J3



It should be acknowledged that the Wolfe Drain downstream of the study area (i.e., from Highway 401 to Howard Avenue) includes of a relatively wide floodplain as well as a stormwater pond at the northeast corner of Howard Avenue and Highway 401. Thus, the marginal excess volume can reasonably be expected to have no adverse impact on the downstream receivers.

Landmark
Engineers Inc.

Title: WOLFE DRAIN 100-YEAR OUTFLOW HYDROGRAPHS	Date: JAN 2022	Scale: NTS	FIGURE J4
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010		

APPENDIX
K

SWM DESIGN

1.0 STORMWATER MANAGEMENT DESIGN

This appendix outlines key design elements assumed as part of our overall model assessment. It also provides brief design narratives to explain the design intent and bridge the information gap between the summary of the report and the design inputs entered in the model. We wish to re-iterate that it is not expected that the parameters herein be strictly followed, however, the design intent should be maintained, or alternatively, any significant proposed deviations should be re-evaluated within the overall context and modelling analysis of the OSMP.

This appendix also serves to explain the rationale and design basis for the infill development SWM criteria, which are summarized in the report.

1.1 STORMWATER MANAGEMENT PONDS

The ponds serve to accommodate future development and/or to attenuate flows from the Town's drainage system. Stormwater quality and quantity requirements for the future development blocks (designated in Figure A3) are to be addressed by the proposed pond design, consistent with the Windsor/Essex Region Stormwater Management Standards Manual (December 2018). Refer to Appendix H for Figures showing pond locations. Note that the sizes and locations shown are only intended to illustrate approximate extents based on the stage-storage relationships summarized in this section – detailed design of the ponds may adjust the ultimate shape, size and location.

All ponds are outside of the designated airport zone range of 4 km, as depicted on Stantec Drawing No. 3 included in Appendix A. Additional discussion can be found in section 7.1 of the Upper Little River Watershed Master Drainage and Stormwater Management Plan Environmental Study Report.

1.1.1 Oldcastle Heights Pond / Hurley Pond / Weston Park Floodplain

The Oldcastle Heights Pond is intended to accommodate the proposed 21.4-hectare Oldcastle Heights Development. This pond is ultimately intended to be integrated as a regional stormwater facility for a catchment area of 65.3 hectares, consisting of two ponds (Hurley Pond and Oldcastle Pond), connected by a linear drain as well as an emergency storage floodplain in the Weston Park ball diamond area. The key design elements are as follows:

1. A restricted flow of 91 L/s – based on an agricultural rate of 6 L/s/ha, with an existing assessment area of 15.2 ha to the Washbrook Drain.
2. A primary outlet from the Oldcastle Heights Pond to the Washbrook Drain. We have presumed a 40m long 300mm dia. outlet pipe (with backflow prevention) as a suitable flow control to achieve the desired flow restriction.
3. A secondary outlet via the existing 900mm dia. CSP culvert crossing the railway for additional outflow during larger, less frequent storm events.
4. A linear drain along the northern limit of the Oldcastle Heights development with a northern bank elevation of 188.30m, dropping to 188.0m for a minimum 20m length at the east limit of the drain prior to entering the proposed drain enclosure. This is also the southern bank of the Hurley Pond and acts as an overflow spill into the high-stage dry pond storage provided by the Hurley Pond.

Landmark

Conversely, detailed design could also consider a wet pond design. The Hurley Pond has been sized to account for potential future development of the Enbridge property up to an imperviousness level of 90%.

5. A minimum 20m wide weir with a spill elevation of 189.0m along the eastern bank of the Oldcastle Heights Pond for emergency relief to the Weston Park Floodplain.
6. The pond should include a minimum permanent pool volume of 1,700 m^3 for normal level of water quality control of the proposed Oldcastle Heights development; preferably a permanent pool volume of 5,200 m^3 to provide additional water quality control for the overall catchment area as part of the regional stormwater facility.
7. The pond is sized based on an overall impervious level of 60% for the Oldcastle Heights development.
8. Stage-storage relationships:

Oldcastle Heights Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	185.50	0	380	0	0	0
	186.00	0.5	4010	1098	1098	0
	186.50	1.0	5280	2323	3420	0
NWL	187.00	1.5	6220	2875	6295	0
Interim NWL	187.40	1.9	7040	2652	8947	2652
	187.50	2.0	7250	715	9662	3367
	188.90	3.4	9830	11956	21618	15323
Top of Bank	189.10	3.6	10225	2006	23623	17328
	189.30	3.8	12675	2290	25913	19618

Note: As per RC Spencer Detailed Design.

Hurley Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	187.30	0	12,700	0	0	0
	188.30	1.0	16,700	14,700	14,700	14,700
Top of Bank	189.30	2.0	19,400	18,050	32,750	32,750

Note: 5:1 side slopes.

Weston Park Floodplain Storage

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	188.80	0	8,600	0	0	0
Top of Bank	189.30	0.5	13,200	5,450	5,450	5,450

1.1.2 Washbrook-Downing Pond

The Washbrook-Downing Pond is intended to provide flow attenuation for the Washbrook Drain. The key design elements are as follows:

1. The Washbrook Drain flows are to be controlled via a 900mm dia. culvert crossing North Talbot Road. Immediately upstream of this crossing, the Downing Drain connects to the Washbrook Drain. Excess flows that exceed the culvert crossing capacity will flow southerly (upstream) into the Washbrook-Downing Pond.
2. The Washbrook-Downing Pond is effectively a high-stage floodplain for storage. This storage will be located within the wedged shaped portion of the land within property that lies immediately east of the Downing Drain. The stage-storage relationship is as follows:

Washbrook-Downing Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	188.30	0	24,500	0	0	0
Top of Bank	189.60	1.3	33,800	37,900	37,900	37,900

Note: 6:1 side slopes; 6m wide access.

1.1.3 Downing Acres Pond

The Downing Acres Pond is intended to accommodate the potential future 31.2-hectare development of the Downing Acres property. The key design elements are as follows:

1. The Downing Drain is to be deepened to provide a gravity outlet for the Downing Acres Pond. This will also maintain the channel flow depth for more frequent events and mitigate frequent spill into onto the proposed high-stage floodplain.
2. A restricted flow of 190 L/s – based on an agricultural rate of 6 L/s/ha.
3. The pond should include a minimum permanent pool volume of 2,500 m^3 for normal level of water quality control and low flow control for minimum 24-hour drawdown time.
4. The pond is sized based on an impervious level of 60%.
5. Stage-storage relationship:

Downing Acres Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
NWL	188.10	0	11,100	0	0	0
Top of Bank	190.10	2.0	18,900	30,000	30,000	30,000

Note: 7:1 side slopes; 10m wide access.

Alternatively, if the Downing Drain deepening and proposed Downing Acres Pond concept is abandoned in favor of a single stormwater facility serving both the Washbrook Drain as well as the future Downing Acres development – then the Washbrook-Downing Pond stage-storage relationship would be:

Washbrook-Downing Pond (incl. Downing Acres)

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
NWL	187.50	0	27,700	0	0	0
Top of Bank	189.60	2.1	42,600	73,900	73,900	73,900

Note: 6:1 side slopes; 6m wide access.

1.1.4 9th Concession Pond

The 9th Concession Pond is designed to accommodate 86 hectares of potential future industrial development generally bounded by: Highway 401 to the north, County Road 46 to the south, 8th Concession Road to the west and 9th Concession Road to the east. This pond will also accept and attenuate flows from the re-routed Hurley Relief Drain, with a catchment area of approximately 75.7 hectares. The key design elements are as follows:

1. A maximum discharge rate of 820 L/s – based on a rate of 5.1 L/s/ha.
2. The pond should include a minimum permanent pool volume of 6,900 m^3 for normal level of water quality control.
3. The pond is sized based on an impervious level of 90%.
4. Stage-storage relationships:

9th Concession Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
NWL	185.60	0	37,200	0	0	0
HWL	187.60	2.0	58,200	95,400	95,400	95,400
Top of Bank	187.90	2.3	58,200	17,460	112,860	112,860

Note: 7:1 side slopes; 14m wide buffer from MTO corridor; 10m wide access on west and east sides; 4.5m wide access on south side.

1.1.5 Collins Pond

The Collins Pond provides storage to offset the increase in peak flows resulting from the proposed conveyance improvements within the Wolfe Drain watershed. This pond is intended to provide high-stage storage to attenuate high flows in the Collins Drain during infrequent storm events. The key design elements are as follows:

1. The east bank of the existing open channel along the west side of the pond should be set to a lower elevation of 188.0m for at least 50m length to facilitate spill into the pond during infrequent storm events.
2. The southern bank of the Collins Pond (which is also the adjacent northern bank of the Collins Drain) should also be set to a lower elevation of 188.0m for at least 80m length to accommodate spills during larger storm events.

3. Stage-storage relationships:

Collins Pond (Options 1a and 2)

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	187.20	0	3,600	0	0	0
Top of Bank	188.90	1.70	6,800	8,840	8,840	8,840

Note: 6:1 side slopes; 14m wide buffer from MTO corridor; 5m wide access on east side.

Collins Pond (Option 1b)

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	186.20	0	2,400	0	0	0
Top of Bank	188.90	2.70	6,800	12,420	12,420	12,420

Note: 6:1 side slopes; 14m wide buffer from MTO corridor; 5m wide access on east side.

1.1.6 Blackacre Pond

The Blackacre Pond provides storage to offset the increase in peak flows resulting from the proposed conveyance improvements within the Wolfe Drain watershed. This pond is intended to provide high-stage storage to attenuate high flows in the Wolfe Drain during infrequent storm events. The key design elements are as follows:

1. The northern bank of the Blackacre Pond (which is also the adjacent southern bank of the Wolfe Drain) should also be set to a lower elevation of 189.0m for at least 120m length to accommodate spills during larger storm events.
2. Stage-storage relationship:

Blackacre Pond

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	187.50	0	6,000	0	0	0
Top of Bank	190.00	2.5	10,900	21,125	21,125	21,125

Note: 5:1 side slopes; 5m wide access.

Blackacre Pond (Option 1b)

Description	Stage	Depth	Area	Incr. Vol.	Cumul. Vol.	Active Vol.
	m	m	m^2	m^3	m^3	m^3
Bottom	187.00	0	5,000	0	0	0
Top of Bank	190.00	3.0	10,900	23,850	23,850	23,850

Note: 5:1 side slopes; 5m wide access.

1.2 INFILL DEVELOPMENT

As discussed in the report, the SMP has categorized infill development SWM requirements under four levels: Normal, Exempt, Basic and Enhanced. The varying levels provide some flexibility to the Town and the Developer with a means to apply tailored and easy to implement SWM requirements based on the size and nature of the proposed development. The discussion and graphs below explain the design basis to support the SWM criteria summarized in the report.

1.2.1 SWM – Normal

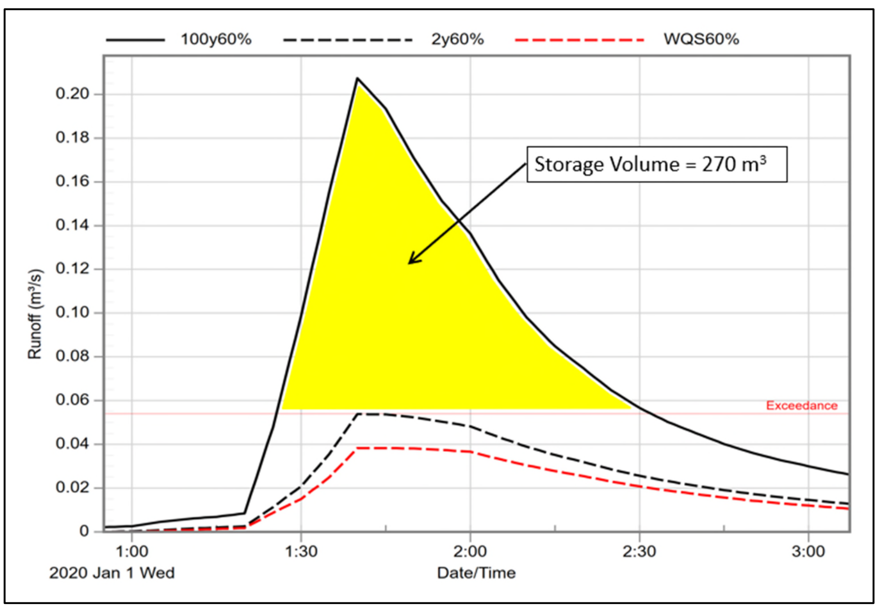
The calibrated SMP model has evaluated the overall drainage system and concluded that the system generally has the capacity to convey peak flows from a 2-year storm with 60% imperviousness. This assessment has considered a full buildout condition of 60% imperviousness for all properties currently less than 60% and has considered the actual measured imperviousness for all properties currently equal or greater than 60% imperviousness. Based on the foregoing, the allowable release rate is 0.054 m^3/s/ha. An interim condition rate of 0.038 m^3/s/ha (based on the WQS) is specified for areas where the existing drainage system is deficient.

The foregoing rates were developed based on unit hydrographs (i.e., hydrographs for a representative 1.00 ha property), which were derived based on the following hydrologic parameters:

- Area = 1.00 ha; Impervious = 60%
- Flow Length = 100 m; Slope = 0.1%
- N Impervious = 0.013; N Pervious = 0.15
- Dstore Imperv. = 2.5 mm; Dstore Perv. = 7.5 mm
- Subarea Routing = 75% Impervious routed to Pervious
- Green-Ampt Infiltration: Su = 180 mm; k = 1.0 mm/hr; IMD = 0.21

Graph 1 on the next page depicts these unit graphs for the WQS, 2-year and 100-year 4-hour Chicago design storms.

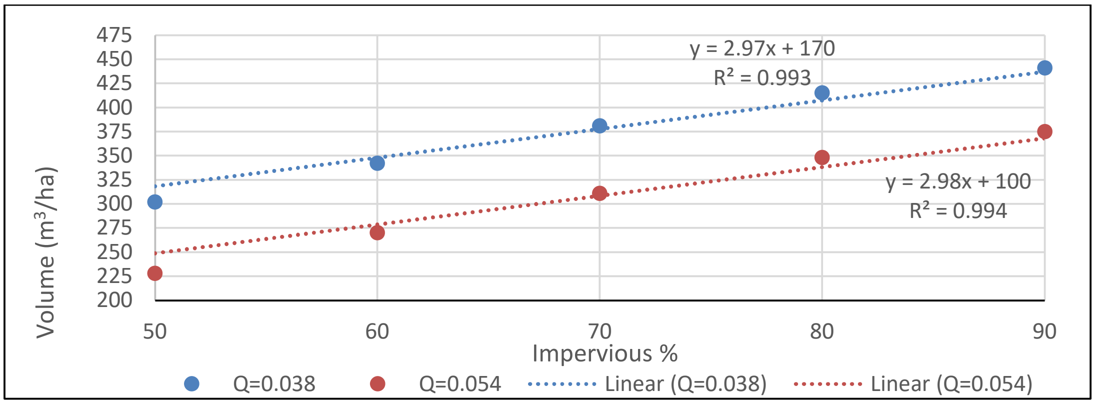
Graph 1: Unit Rate Peak Flows @ 60% Impervious



The graph also illustrates an example of 100-year storage requirements for a property with 60% imperviousness. For normal SWM measures, the SMP recommends storage requirements based on an assumed constant release rate. While it is understood that this assumption does not represent the actual varying outflow of a gravity outlet, it provides a consistent and equitable standard for all properties, irrespective of the varying conveyance capacity and hydrodynamics of the local sewer under any given storm event. Moreover, it is a practical standard that does not place undue burden on individual properties – properties that should be considered as infill development from a stormwater perspective.

The foregoing approach was applied for a range of imperviousness from 50% to 90% and for both constant flow rates of 0.054 $m^3/s/ha$ (2-year allowable flow rate) and 0.038 $m^3/s/ha$ (WQS allowable flow rate). Graph 2 below depicts the results and line of best fit.

Graph 2: 100-Year Unit Storage Volumes



<u>7th Street Drain</u>

The 7th Street Drain was designed to a 5-year level of service based on February 2007 (i.e., date of report and design) land uses in the Town of Tecumseh. The land use is currently designated as Business Park and has been assumed to have considered an overall C value of 0.70 at that time. The 5-year design intensity for the lower reach of the 7th Street Drain design is estimated to be in the order of 50 mm/hr based on the following:

- City of Windsor 5-year IDF curve: I (in/hr) = 125 / (T+20), where T in minutes; and,
- T = 2100 metres overall storm sewer length / assumed 0.8 m/s flow velocity = 44 minutes.

Based on the foregoing, we used the Rational Method to estimate a 5-year design flow of 2.86 cubic metres per second (m^3/s) for the overall subcatchment area of 29.42 hectares (i.e., the portion of the 7th Street Drain catchment area that lies within the Oldcastle limits), which equates to a per hectare flow rate of 0.097 $m^3/s/ha$.

The foregoing 5-year design flow compares well to the free flow capacity of 2.92 m^3/s for the receiving 1500mm-dia. pipe @ 0.17% grade and also closely matches the existing condition 100-year modelled flow of 2.9 m^3/s. An existing condition 5-year flow of 1.9 m^3/s was estimated by the model. When comparing the Rational Method flows to the model flows, it should be acknowledged that:

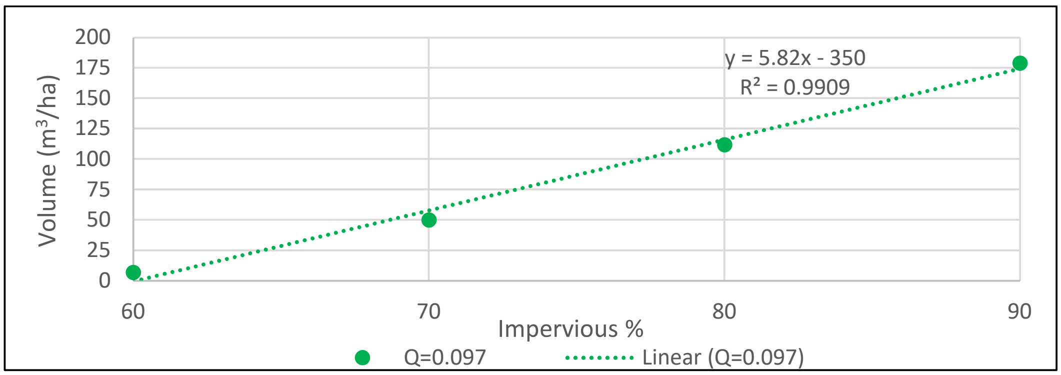
- the model captures high infiltration capacity of Hydrologic Group A type soil within the subject lands; and,
- the model captures the existing buildout conditions and accounts for peak flow attenuation from greater depression storage in large gravel areas.

Storage requirements were estimated based on: unit hydrographs (i.e., hydrographs for a representative 1.00 ha property) for a range of imperviousness from 50% to 90%; and, a constant flow rate of 0.097 m^3/s/ha (5-year allowable flow rate). The unit hydrographs were derived based on the following hydrologic parameters:

- Area = 1.00 ha;
- Flow Length = 200 m; Slope = 0.1%
- N Impervious = 0.013; N Pervious = 0.15
- Dstore Imperv. = 2.5 mm; Dstore Perv. = 7.5 mm
- Subarea Routing = 75% Impervious routed to Pervious
- Green-Ampt Infiltration: Su = 100 mm; k = 9.5 mm/hr; IMD = 0.33

Graph 3 below depicts the results and line of best fit.

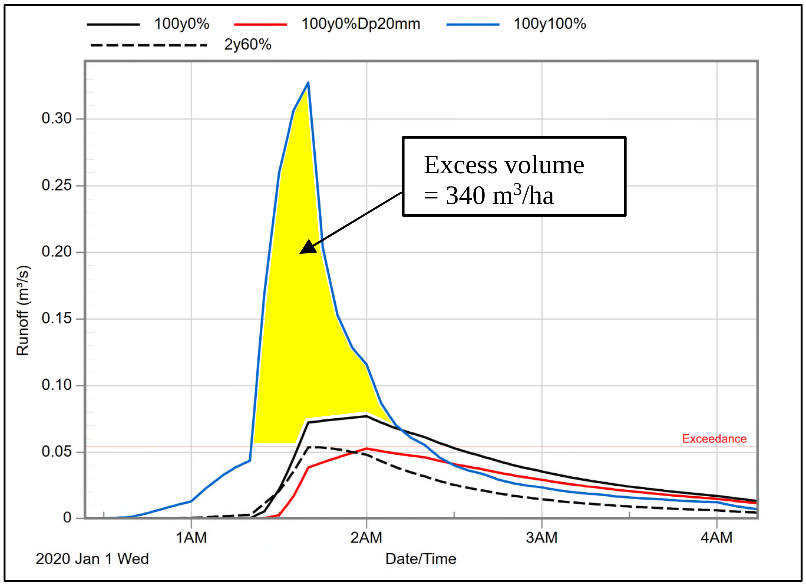
Graph 3: 100-Year Unit Storage Volumes



1.2.2 SWM – Basic

Graph 4 below depicts the normal 2-year allowable release rate (2y60%) compared to the 100-year undeveloped peak flow under the following conditions: good drainage conditions – described by the hydrologic parameters on page 5 herein and depicted as the solid black line; and, poor drainage conditions – represented by increasing depression storage (Dstore Perv.) from 7.5mm to 20mm and depicted by the solid red line. As the graph illustrates: the recommended 2-year peak flow is very similar to the 100-year undeveloped peak flow rate with poor drainage; and, the 2-year flow is less than the 100-year undeveloped rate with good drainage.

Graph 4: Unit Rate Peak Flows – Undeveloped vs Developed



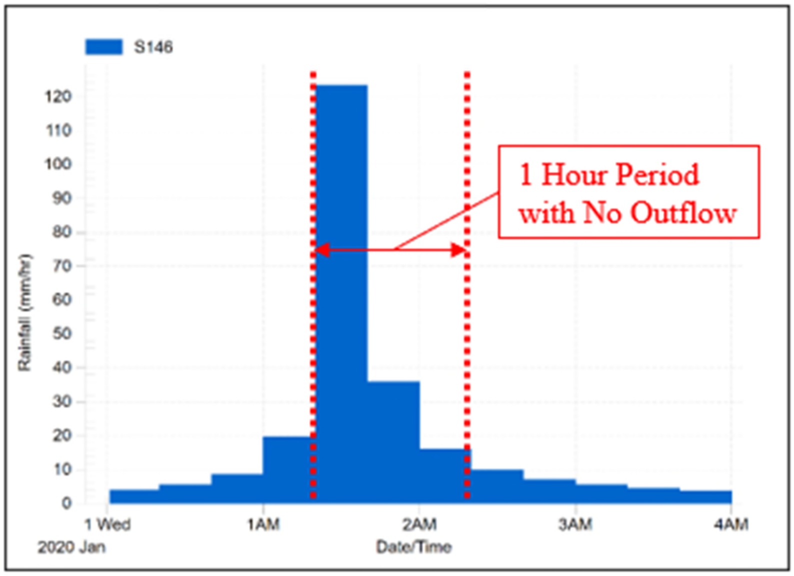
Under the basic SWM requirements, the property is already substantially developed and it is assumed that the pervious area drainage is good (i.e., no significant standing water as represented by 20mm depression storage). As such, the basic level of SWM is achieved by providing storage equivalent to the excess volume created by the proposed increase in impervious area, which corresponds to the difference between the solid blue line (100y100%) and the solid black line (100y0%) – or 340 m^3/ha.

1.2.3 SWM – Enhanced

The additional storage volume due to Backwater considers the potential that the receiving storm sewer in the Town's right-of-way will experience temporary surcharging during short-duration high-intensity rainfall events, which will subsequently limit the gravity outflow from the private service connections attempting to convey flows from the property into the Town's sewer.

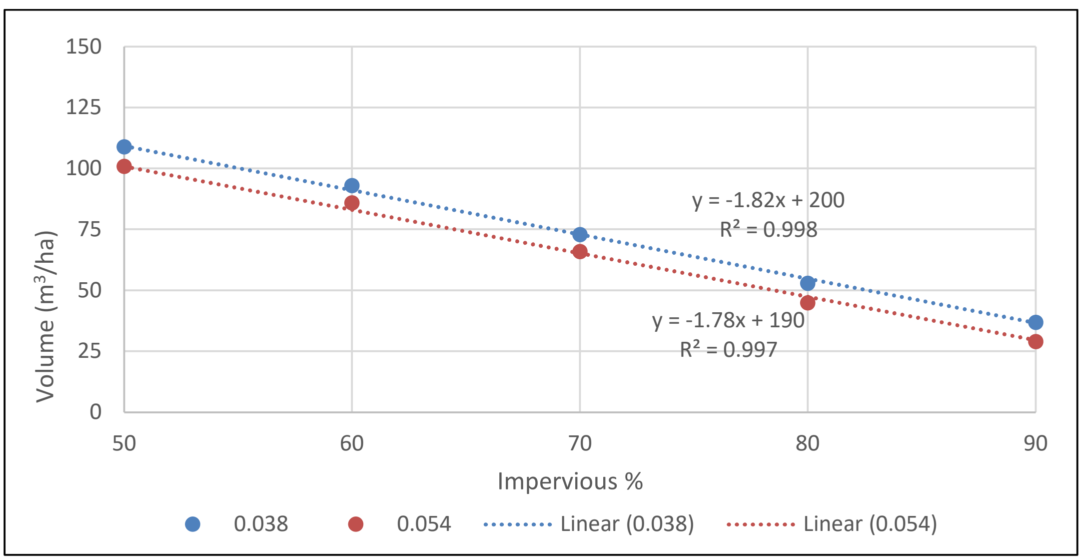
As a simplified measure to account for this condition, it is assumed that the site would have no (zero) outflow for a 1-hour duration (3,600 seconds). When fitting this period on a design 100-year 4-hour Chicago storm as depicted on Graph 4, this period assumes that surcharging will take effect during the two 20-minute intense rainfall periods exceeding 20 mm/hr as well as a third 20-minute lag period following the peak intensities. It is possible that site-specific conditions could reasonably allow for a reduced, yet non-zero outflow during the peak rainfall period.

Graph 4: 100-Year 4-Hour Rainfall Hyetograph



The additional storage volume for the Stress Test is estimated using the same approach and parameters as described in the foregoing SWM – Normal section, which one exception being a conductivity (k) value of 3.0 mm/hr in lieu of 1.0 mm/hr. Graph 5 below represents the difference between the storage volume calculated for the 100-year and Stress Test design storms (i.e., the additional storage volume required over and above the 100-year storage requirements).

Graph 5: Additional Stress Test Unit Storage Volumes



Landmark

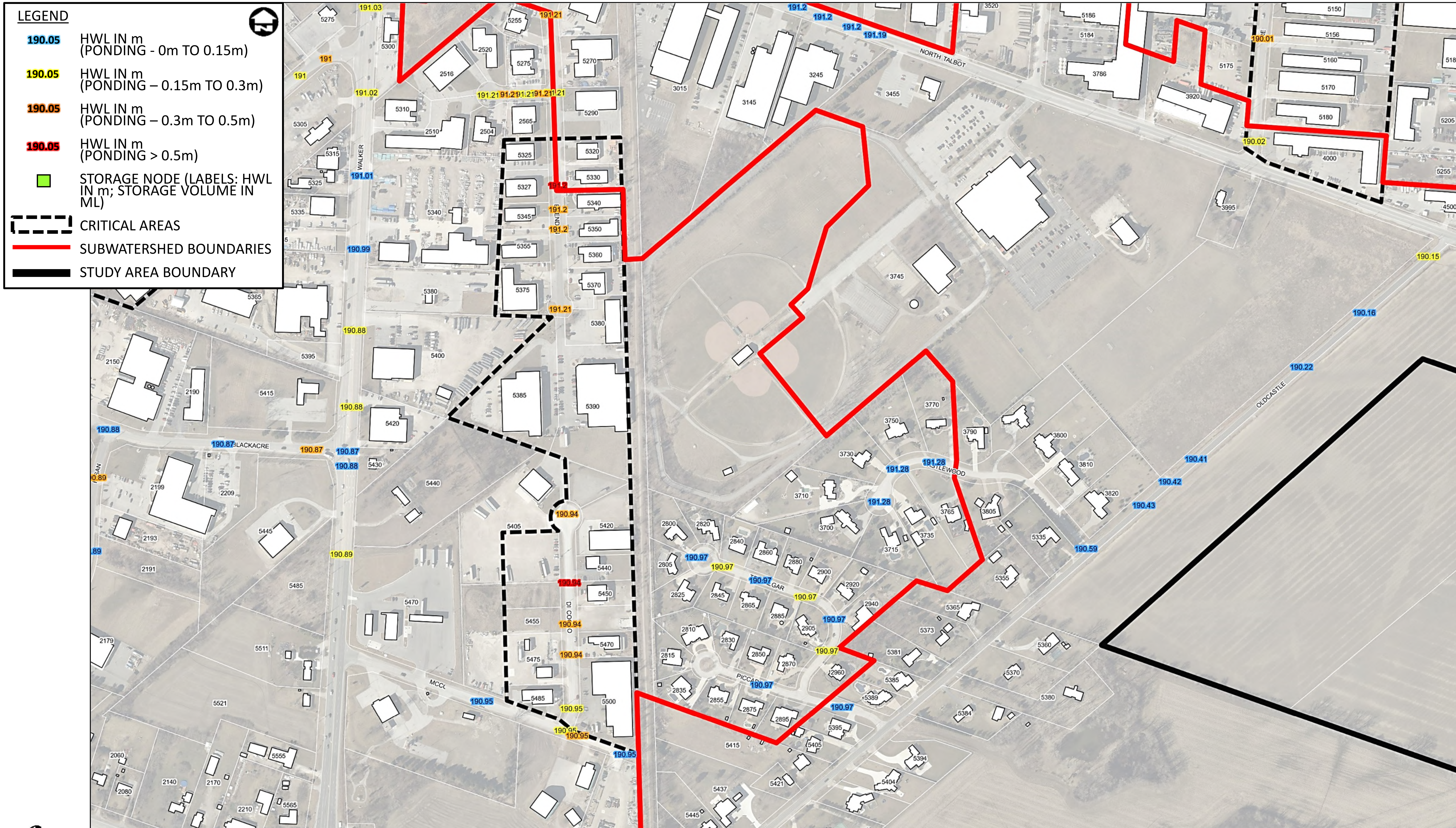
APPENDIX
L

100-YEAR WATER LEVELS

Landmark Engineers Inc.

NOTE: THE 100-YEAR ELEVATIONS NOTED HEREIN ARE FOR INFORMATION PURPOSES. THEY ARE NOT REGULATORY FLOODLINE ELEVATIONS AND ARE NOT INTENDED TO BE RELIED UPON AS A FLOODPROOFING REQUIREMENT. REFER TO SECTION 5.7 OF THE REPORT FOR FURTHER DISCUSSION AND RECOMMENDATIONS.

Title: ESTIMATED 100-YEAR WATER LEVELS: WOLFE DRAIN AREA (WEST)	Date: OCT. 2020	FIGURE L1
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No.: 19-010	



Landmark Engineers Inc.

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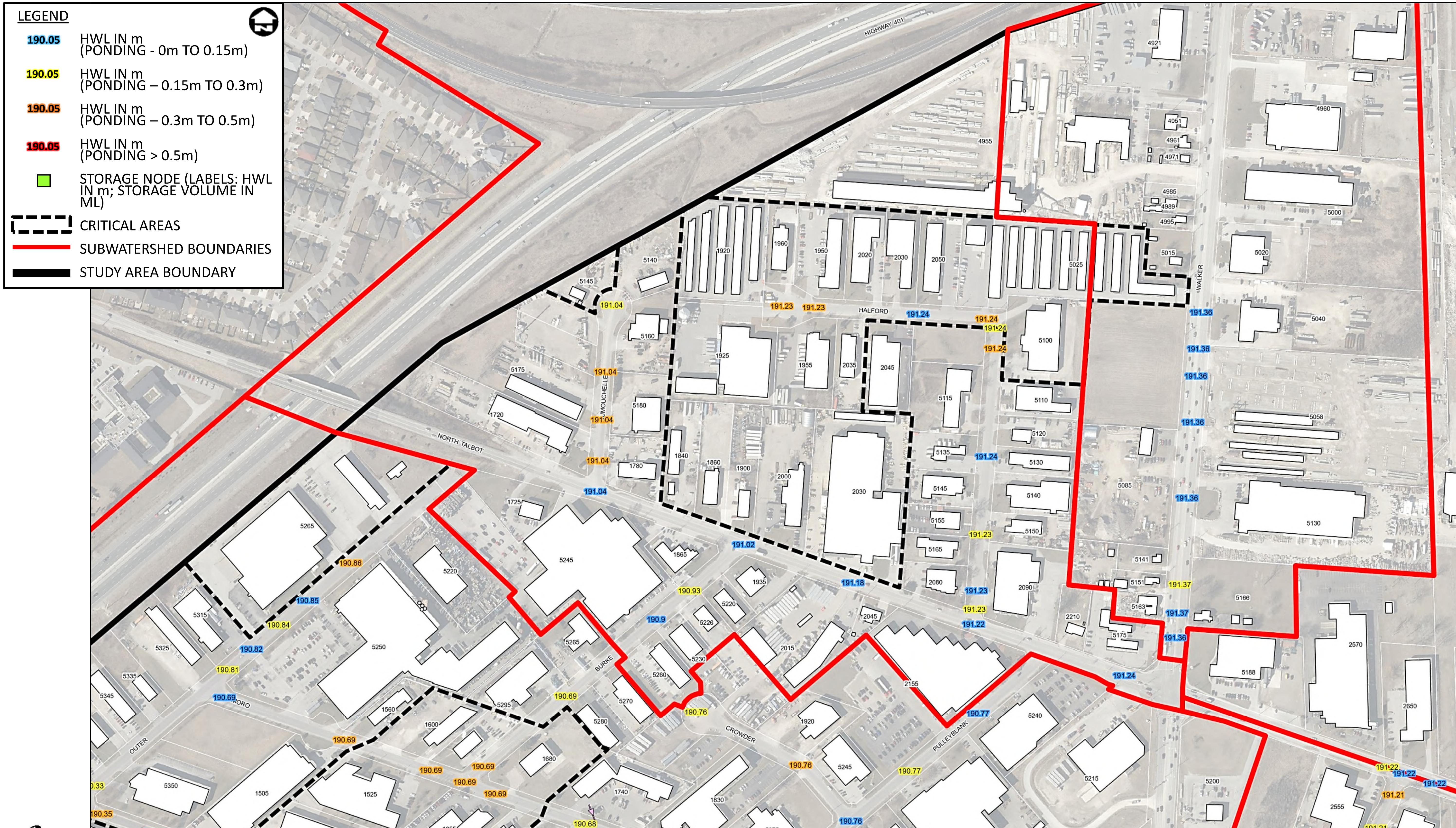
Title: ESTIMATED 100-YEAR WATER LEVELS: WOLFE DRAIN AREA (EAST) & OLDCASTLE ROAD	Date: OCT. 2020	FIGURE L2
	Scale: NTS	
Project: OLDCASTLE STORMWATER MASTER PLAN	Project No. 19-010	



Landmark Engineers Inc.

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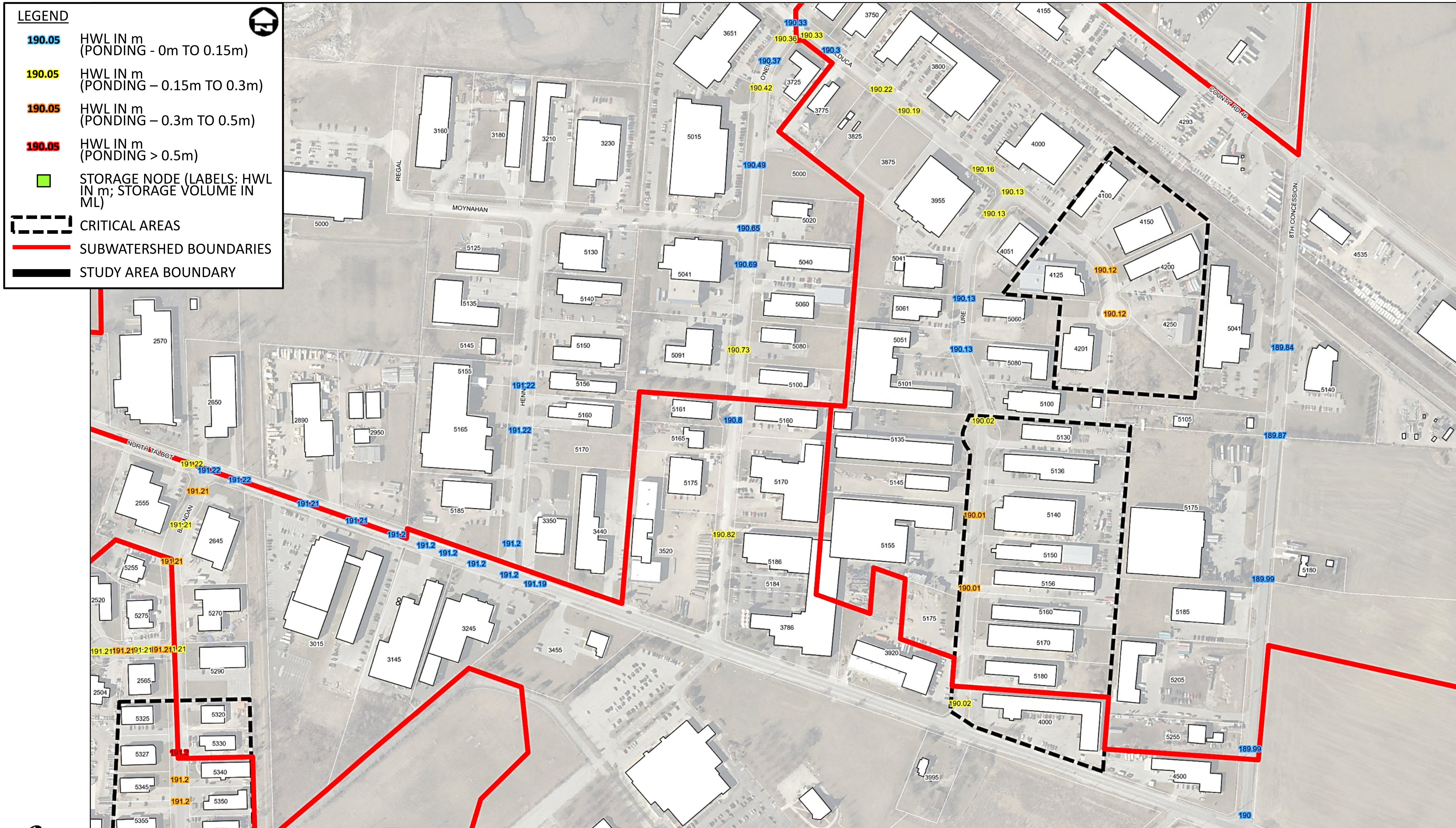
Title	ESTIMATED 100-YEAR WATER LEVELS: WOLFE DR. (NORTH) & 6TH CONC. DR. AREAS
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	OCT. 2020
Scale	NTS
Project No.	19-010
FIGURE	L3



Landmark Engineers Inc.

NOTE: THE 100-YEAR ELEVATIONS NOTED HEREIN ARE FOR INFORMATION PURPOSES. THEY ARE NOT REGULATORY FLOODLINE ELEVATIONS AND ARE NOT INTENDED TO BE RELIED UPON AS A FLOODPROOFING REQUIREMENT. REFER TO SECTION 5.7 OF THE REPORT FOR FURTHER DISCUSSION AND RECOMMENDATIONS.

Title	ESTIMATED 100-YEAR WATER LEVELS: 7TH CONC. & HURLEY DRAIN AREAS
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	OCT. 2020
Scale	NTS
Project No.	19-010
FIGURE	L4

APPENDIX M

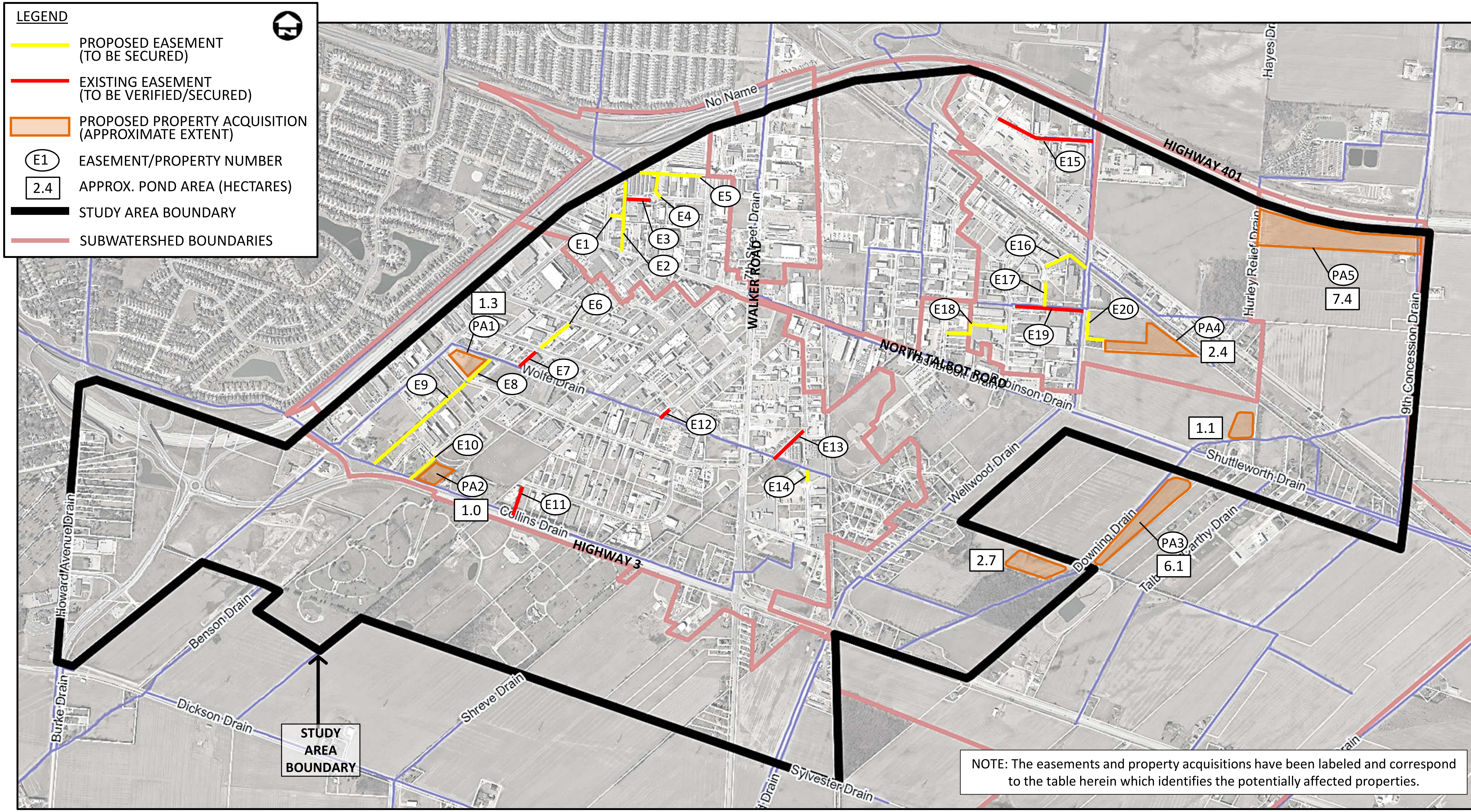
EASEMENTS

LIST OF IMPROVEMENT PROJECTS

Project ID	Project Description	Planning and Approval Process	Watershed	Subwatershed	Easement / Property Acquisitions	Timeframe[1]	Preliminary Budget Cost Estimate[2]
W.1	Wolfe Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	E8, E9, E14 and PA1	Short-Term	$3,550,000
8C.1	Demonte Drain Improvements	Drainage Act	Little River	9th Concession Drain	E15	Short-Term	$100,000
H.1	Hurley Relief Branch Drain Improvements	Drainage Act	Little River	Hurley Drain	-	Short-Term	$50,000
H.2	New Storm Sewer along Del Duca Drive	Schedule B	Little River	Hurley Drain	E16 and E17	Short-Term	$1,000,000
H.3	New Storm Sewer along Ure Street	Schedule B	Little River	Hurley Drain	E19	Short-Term	$450,000
9C.1	Washbrook Drain Improvements	Drainage Act	Little River	9th Concession Drain	-	Short-Term	$620,000
W.2	Collins Drain Improvements	Drainage Act	Turkey Creek	Wolfe Drain	E10 and PA2	Medium-Term	$1,130,000
W.3	New Storm Sewer along Fasan Drive	Schedule B	Turkey Creek	Wolfe Drain	E11	Medium-Term	$1,340,000
W.4	New Storm Sewer along Blackacre Drive	Schedule A	Turkey Creek	Wolfe Drain	-	Medium-Term	$1,870,000
W.5	Replace Storm Outlets to Wolfe Drain	Schedule B	Turkey Creek	Wolfe Drain	E6, E7, E12 and E13	Medium-Term	$1,080,000
6C.1	Replace Halford Drive Storm Outlet	Schedule B	Little River	6th Concession Drain	E1 to E5	Medium-Term	$60,000
7C.1	New Storm Sewers along O'Neil Dr. & Moyhanan St.	Schedule A	Little River	7th Concession Drain	-	Medium-Term	$230,000
H.4	Enlarge & Re-route Hurley Drain to New Hurley Pond	Schedule B	Little River	Hurley Drain	E19, E20 and PA4	Medium-Term	$3,320,000
9C.2	New Washbrook-Downing Pond	Schedule B	Little River	9th Concession Drain	PA3	Medium-Term	$2,200,000
7C.2	New Storm Sewer along Hennin Street	Schedule A	Little River	7th Concession Drain	-	Long-Term	$370,000
9C.3	New Storm Sewer along Oldcastle Road, Castlewood Court and O'Neil Drive	Schedule A	Little River	9th Concession Drain	-	Long-Term	$1,880,000
9C.4	Extension of Washbrook Drain Enclosure	Drainage Act	Little River	9th Concession Drain	-	Long-Term	$4,170,000
9C.5	Oldcastle Heights Pond	Schedule B	Little River	9th Concession Drain	-	-	$1,310,000
9C.6	Downing Acres Pond	Schedule B	Little River	9th Concession Drain	-	-	$1,630,000
9C.7	9th Concession Pond	Schedule B	Little River	9th Concession Drain	PA5	-	$5,660,000

[1] Recommended Timeframe: Short-Term = 1-2 years; Medium-Term = within 10 years; Long-Term = within 20 years.

[2] Preliminary Budget Costs for Section W: Wolfe Drain Subwatershed Improvement Costs are based on Option 1b.



Landmark Engineers Inc.

Title	EASEMENTS AND PROPERTY ACQUISITION MAP
Project	OLDCASTLE STORMWATER MASTER PLAN
Date	JAN. 2022
Scale	NTS
Project No.	19-010

FIGURE M1

EASEMENT#	EASEMENT ADDRESS		OWNER(S)	MAILING ADDRESS
E1	5160	DUMOUCHELLE ST	FACCHINATO HOLDINGS LTD	5160 Dumouchelle st., RR1 Windsor, ON N9A 6J3 Johnf@maidstonemoulding.com
	5180	DUMOUCHELLE ST	FACCHINATO HOLDINGS LTD	
E2	5140	DUMOUCHELLE ST	NASCI TRUCKING LIMITED	5140 Dumouchelle St., RR 1 Windsor, ON N9A 6J3 519-737-1129
	5160	DUMOUCHELLE ST	FACCHINATO HOLDINGS LTD	5160 Dumouchelle st., RR1 Windsor, ON N9A 6J3 Johnf@maidstonemoulding.com
	5180	DUMOUCHELLE ST	FACCHINATO HOLDINGS LTD	
	1780	N TALBOT RD	957474 ONTARIO LIMITED	1780 North Talbot Rd., RR 1 Windsor, ON N9A 6J3
	1840	N TALBOT RD	BAHCELI, KEMAL & SUAT	294 Russel Woods Dr. Tecumseh, ON N8N 4K5
	1920	HALFORD RD	363148 ONTARIO LIMITED	1920 Halford Rd., RR 1 Windsor, ON N9A 6J3
	1925	HALFORD RD	2693316 ONTARIO LIMITED	10 Four Seasons Place Toronto, ON N8N 1W9
E3		HALFORD RD	TECUMSEH TOWN	
E4	1920	HALFORD RD	363148 ONTARIO LIMITED	1920 Halford Rd., RR 1 Windsor, ON N9A 6J3
	1960	HALFORD RD	1352192 ONTARIO LTD	4810 Walker Rd., Windsor, ON N9A 6J3
E5	1920	HALFORD RD	363148 ONTARIO LIMITED	1920 Halford Rd., RR 1 Windsor, ON N9A 6J3
	1960	HALFORD RD	1352192 ONTARION LTD	4810 Walker Rd., Windsor, ON N9A 6J3
	1950	HALFORD RD	1787954 ONTARIO LTD	1950 Halford Rd., RR 1 Windsor, ON N9A 6J3
	2020	HALFORD RD	OFFERFAIR INC	2020 Halford Rd., RR 1 Windsor, ON N9A 6J3
	2030	HALFORD RD	CROATIA MACHINE TOOL OF CANADA	2030 Halford, Rd., RR 1 Windsor, ON N9A 6J3
	2050	HALFORD RD	SCWI ENTERPRISES INC	5255 Brendan Lane Suite 1, RR 1 Oldcastle, ON N0R 1L0

EASEMENT#	EASEMENT ADDRESS		OWNER(S)	MAILING ADDRESS
E6	1525	MORO DR	DDS SOFTWARE SOLUTIONS INC	1485 Dunn Road Harrow, ON N0R 1G0
	1580	ROSSI DR	ACENZIA INC	1580 Rossi Dr., RR 1 Oldcastle, ON N0R 1L0
	1620	ROSSI DR	388456 ONTARIO LIMITED	1620 Rossi Dr., RR 1 Oldcastle, ON N0R 1L0
E7	1615	ROSSI DR	BRICASA INC	1740 St. Clair Rd. Stoney Point, ON N0R 1L0
	1625	ROSSI DR	1277032 ONTARIO INC	1625 Rossi Dr., RR 1 Windsor, ON N9A 6J3
E8	5400	OUTER DR	470698 ONTARIO LTD TRUSTEE	5590 Outer Dr., RR 1 Windsor, ON N9A 6J3
	1840	BLACKACRE DR	CARLESIMO HOLDINGS INC	c/o Adriano Carlesimo 688 Gauthier Dr. Windsor, ON N8N 3P8
E9	5420	OUTER DR	OLIVIA ENTERPRISES INC	5420 Outer Dr. Windsor, ON N9A 6J3
	5450	OUTER DR	520589 ONTARIO INC	5450 Outer Dr., RR 1 Windsor, ON N9A 6J3
	5500	OUTER DR	DALLA, BONA MARIO	5590 Outer Dr., RR 1 Windsor, ON N9A 6J3
	5540	OUTER DR	470698 ONTARIO LTD	5590 Outer Dr., RR 1 Windsor, ON N9A 6J3
	5600	OUTER DR	470698 ONTARIO LTD	
	5700	OUTER DR	CONGREGATION OF THE ORDER ANTONIN MARONITE IN ONTARIO	5700 Outer Dr. Windsor, On N9A 6J3
	5425	R0SCON INDUSTRIAL	813978 ONTARIO LTD	5425 Roscon Industrial Dr., RR 1 Oldcastle, ON N0R 1L0
	5455	ROSCON INDUSTRIAL	2443176 ONTARIO LTD	5455 Roscon Industrial Dr., RR 1 Oldcastle, ON N0R 1L0
	5485	ROSCON INDUSTRIAL	ROSATI DEVELOPMENT CORP	6555 Malden Rd. LaSalle, ON N9G 1T5
	5515	ROSCON INDUSTR DR	1808250 ONTARIO LIMITED	5515 Roscon Industrial Dr., RR 1 Oldcastle, ON N0R 1L0
	5575	ROSCON INDUSTRIAL	MARONTATE ENTERPRISES INC	5575 Roscon Industrial Dr., RR 1 Oldcastle, ON N0R 1L0

EASEMENT#	EASEMENT ADDRESS		OWNER(S)	MAILING ADDRESS
E9	5605	ROSCON INDUSTRIAL	1382229 ONTARIO LIMITED	5605 Roscon Industrial Dr., RR 1 Oldcastle, ON N0R 1L0
	5635	ROSCON INDUSTRIAL	1382229 ONTARIO LIMITED	
	1100	HIGHWAY 3	DESMARAIS, JOSEPH PAUL VICTOR	1100 Highway 3, RR 1 Oldcastle, ON N0R 1L0
E10	1100	HIGHWAY 3	DESMARAIS, JOSEPH PAUL VICTOR	1100 Highway 3, RR 1 Oldcastle, ON N0R 1L0
E11	2005	FASAN DR	1432351 ONTARIO INC	205 Fasan Dr. Oldcastle, ON N0R 1L0
	2015	FASAN DR	DIXON, ALLAN & SUSAN	2015 Fasan Dr. Oldcastle, ON N0R 1L0
E12	2175	SOLAR CRES	EL-HY CO LIMITED	2175 Solar Cres., RR 1 Oldcastle, ON N0R 1L0
	2340	OLYMPIA DR	MICHAEL TOOL & MOLD (WINDSOR) LIMITED	2340 Olympia Dr. Oldcastle, ON N0R 1L0
E13	5385	BRENDAN LANE	990077 ONTARIO LIMITED	5390 Brendan Lane, RR 1 Oldcastle, ON N0R 1L0
	5400	WALKER RD	GORSKI BULK TRANSPORT INC	8801 Trans-Canada Hwy Saint-Laurent, QC N4Z 1Z6
E14	5405	DI COCCO CRT	MOVIN' FREIGHT HOLDINGS LTD	5405 DiCocco Crt Oldcastle, ON N0R 1L0
	5410	DI COCCO CRT	166050 CANADA INC	9615 Chestnut Dr. Windsor, ON N8R 1G9
E15	2800	TRAFALGAR CRT	DOCHERTY, THOMAS JOSEPH KASCHAK, DEBORAH KATHERINE	2880 Trafalgar Crt. Oldcastle, ON N0R 1L0
	2820	TRAFALGAR CRT	BERTRAM, DANE & JENNIFER	2820 Trafalgar Crt. Oldcastle, ON N0R 1L0
E16	4040	COUNTY RD 46	Husky Oil Ltd	PO Box 6525 Stn D Calgary, AB T2P 3G7
	5015	8TH CONCESSION RD	R J CYR CO INC	5015 8th Concession Rd., RR 3 Maidstone, ON N0R 2K0
	4965	8th CONCESSION RD	LAVAL TOOL & MOULD LTD	4965 8th Concession Rd., RR 3 Maidstone, ON N0R 1K0
	4975	8TH CONCESSION RD	679637 ONTARIO LTD	4975 8th Concession Rd., RR 3 Maidstone, ON N0R 1K0

EASEMENT#	EASEMENT ADDRESS		OWNER(S)	MAILING ADDRESS
E17	5041	8TH CONCESSION RD	PRODART ENTERPRISES INC	4590 Rhodes Dr. Windsor, ON N8W 5C2
	4150	DELDUCA DR	360 MANUFACTURING	4150 Delduca Dr. RR1 Oldcastle, ON N0R 1L0
	4200	DELDUCA DR	FILIPPO LIBURDI CONSTRUCTION LIMITED	3380 Parkwood Ave. Windsor, ON N8W 2L1
E18	4201	DELDUCA DR	EAGLE HEATING & COOLING INC	5205 8th Concession Maidstone, ON N0R 1K0
	4300	DELDUCA DR	2030185 ONTARIO LTD	4300 Delduca Dr. Olecastle, ON N0R 1L0
E19	5145	URE ST	2391472 ONTARIO LTD	5170 O'Neil Dr. Oldcastle, ON N0R 1L0
	5155	URE ST	WEST INDUSTRIES INC	380 Crystal Bay Dr. Amherstburg, ON N9V 4A7
	N/A	O'NEIL DR	WEST INDUSTRIES INC	380 Crystal Bay Dr. Amherstburg, ON N9V 4A7
	5170	O'NEIL DR	EAGLE PRESS & EQUIPMENT CO	5170 O'Neil Dr. Oldcastle, ON N0R 1L0
E20	5105	8TH CONCESSION RD	DELICATA, GIUSEPPE	5105 8th Concession Rd., RR 3 Maidstone, ON N0R 1K0
	5175	8TH CONCESSION RD	WEST INDUSTRIES INC	3786 North Talbot Rd., RR1 Oldcastle, ON N0R 1L0
	5100	URE ST	ROM-EX INVESTMENT LTD NEWENG INVESTMENT LTD	5100 Ure St., RR 1 Oldcastle, ON N0R 1L0
	5130	URE ST	N TALBOT HOLDINGS LTD	14 Catalina Crt. Kingsville, ON N9Y 4E7
E21	5100	8TH CONCESSION RD	UNION GAS LIMITED	50 Keil Dr. N Chatham, ON N7M 3V9
PA1	5400	OUTER DR	470698 ONTARIO LTD TRUSTEE	5590 Outer Drive Oldcastle, ON N9A 6J3
PA2		TALBOT RD	WESTCO WINDSOR INC.	Lease Admin 6149 Fedex Ground Packaging Systems Ltd Moon Township, PA 15108
PA3		N TALBOT RD	838073ONTARIO INC.	5680 Hwy #3, RR 3 Maidstone, ON N0R 1K0
PA4	5100	8TH CONCESSION RD	UNION GAS LIMITED	50 Keil Dr. N Chatham, ON N7M 3V9
PA5		9TH CONCESSION RD	HAYES, JORDAN AND JUSTIN	4799 9th Concession Maidstone, ON N0R 1K0