



Prepared for:
City of Brantford

North Brantford and Tutela Heights Subwatershed Study Update

Phase 1 Update Report

Prepared by:
Aquafor Beech Ltd.

2600 Skymark Avenue
Building 6, Suite 202
Mississauga, ON
Reference #: 66955
November 2024
Final Report

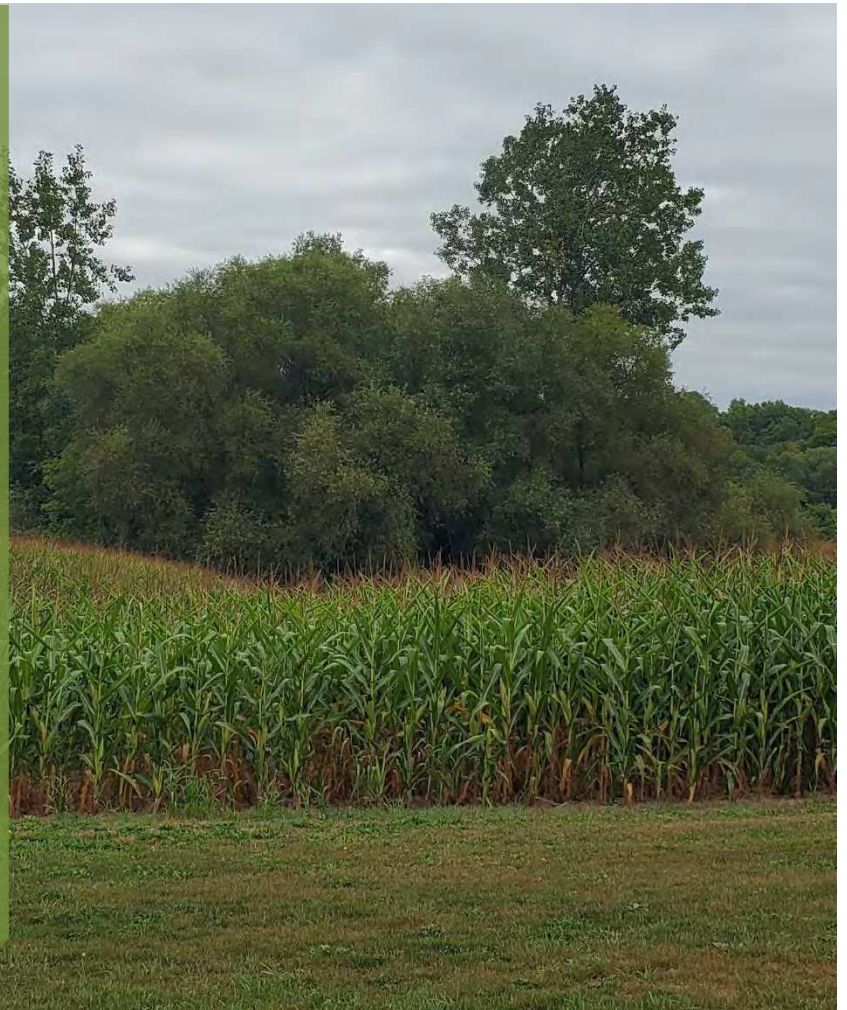


Table of Contents

List of Tables	ii
List of Figures	iii
Appendices	vii
1 Introduction	1
1.1 Study Area and Land Uses	2
1.1.1 Subwatershed Study Area	2
1.1.2 North Brantford.....	2
1.1.3 Tutela Heights.....	2
1.2 Existing Policy Framework	6
1.2.1 Provincial Policy Statement.....	6
1.2.2 Growth Plan for the Greater Golden Horseshoe.....	7
1.2.3 Consolidated Linear Infrastructure Environmental Compliance Approval	8
1.2.4 City of Brantford Official Plan - Envisioning Our City: 2051 (September, 2022).....	9
1.2.5 Grand River Conservation Authority	12
1.2.6 Endangered Species Act	14
1.3 Subwatershed Study Goals, Objectives, and Phasing.....	15
1.4 Class Environmental Assessment (EA) Process	16
1.5 Block Plan Process within North Brantford and Tutela Heights.....	17
2 Background Information	20
3 Existing Subwatershed Conditions	22
3.1 Field Assessment Approach.....	23
3.2 Groundwater Resources	27
3.2.1 Study Area	27
3.2.2 Previous Studies	27
3.2.3 Physical Setting.....	31
3.2.4 Quaternary Geology	39
3.2.5 Field Program	43
3.2.6 Hydrostratigraphy	75
3.2.7 Groundwater Flow.....	79
3.2.8 Recharge and Evapotranspiration	89
3.3 Surface Water Resources.....	105
3.3.1 Headwater Drainage Feature Assessment	105
3.3.2 Fluvial Geomorphologic Resources	116
3.3.3 Hydrology & Hydraulics	142
3.3.4 Sediment Quality	161
3.3.5 Water Quality	165
3.4 Ecological Resources.....	177
3.4.1 Background Information Sources.....	178
3.4.2 Overview of Ecological Field Studies	178
3.4.3 Aquatic Resources	180
3.4.4 Terrestrial Resources.....	207
3.4.5 Species at Risk	242
3.4.6 Significant Wildlife Habitat.....	255

3.4.7 Summary of Ecological Resources.....	258
4 Opportunities and Constraints	259
4.1 Natural Hazards	259
4.1.1 Flood Hazards	260
4.1.2 Erosion Hazards	265
4.2 Natural Heritage	273
4.2.1 Municipal Natural Heritage System	273
4.2.2 Summary of Natural Heritage Considerations.....	283
4.3 Other Considerations.....	283
4.3.1 Groundwater Resource Opportunities.....	283
4.3.2 Headwater Drainage Features.....	288
4.4 Summary of Constraints	290
5 Recommendations for Further Study	294
5.1 Groundwater Recommendations	296
5.2 Surface Water Recommendations.....	296
5.2.1 Hydrology and Hydraulic Modeling.....	296
5.2.2 Erosion Hazard.....	296
5.3 Natural Heritage System Recommendations	297
5.3.1 Site-Specific Studies to Confirm Constraints.....	297
6 References.....	299

List of Tables

Table 3.1: Summary of Property Access	23
Table 3.2: Well construction details.....	45
Table 3.3: Summary of hydraulic conductivity testing.....	50
Table 3.4: Results of Guelph permeameter testing.....	56
Table 3.5: Geotechnical borehole location details	58
Table 3.6: Geotechnical Log Details	74
Table 3.7: Hydrostratigraphic units.....	76
Table 3.8: Summary of water takings in the study area.	86
Table 3.9: AES Climate stations used for historical climate analysis.	89
Table 3.10: Definitions of Management Recommendations (CVC & TRCA, 2014)	113
Table 3.11: Guidelines for the Interpretation of RGA Results and SI Values.....	120
Table 3.12: Dominant Geomorphic Adjustment Processes (based on RGA Results).....	121
Table 3.13: Tributary K Comparison of Channel Profiles	126
Table 3.14: Tributary K Comparison of Channel Cross-sections	127
Table 3.15: Jones 2 Comparison of Channel Profile.....	130
Table 3.16: Jones 2 Comparison for Channel Planform	130
Table 3.17: Jones 2 Comparison of Channel Cross-sections	131
Table 3.18: MNRF Erosion Allowance Guidelines for Watercourses in Valley Settings	135
Table 3.19: Erosion Rates	136
Table 3.20: Summary of Estimated Flood Flows.....	149
Table 3.21: Manning’s Values Used in HEC-RAS Model.....	153

Table 3.22 Hydraulic Model Calibration Results	155
Table 3.23: Sediment Quality Sampling Results (mg/kg)	164
Table 3.24: Water Quality Parameters and Sampling Procedures	172
Table 3.25: Water Quality Sampling Results for June 7, 2022	175
Table 3.26: Summary of Ecological Field Surveys	178
Table 3.27: Channel Morphology Diagnostic Indicators	182
Table 3.28: OSAP Channel Structure Summaries	183
Table 3.29: FBI Value Interpretation	196
Table 3.30: Benthic Invertebrate Habitat Summary	198
Table 3.31: Benthic Invertebrate Monitoring Results	200
Table 3.32: Fish Community Survey Results	203
Table 3.33: Provincially Rare ELC communities	208
Table 3.34: Summary of Vegetation Communities Delineated in 2022.	210
Table 3.35: Wetland Communities.....	217
Table 3.36 Study Area Flora – Coefficient of Conservatism by Category	223
Table 3.37 Study Area Flora – Regionally Rare and Uncommon Vascular Plants	224
Table 3.38: Hedgerow Assessment	227
Table 3.39: Bird Species List – Aquafor Beech 2022	233
Table 3.40: Conditions During Amphibian Calling Surveys	237
Table 3.41: Anuran Calling Survey Results – Aquafor Beech 2022	238
Table 3.42: Additional Wildlife Observations from 2022 Field Surveys.....	242
Table 4.1: Erosion Thresholds by Study Reaches	268
Table 4.2: Core Natural Areas Components for the North Brantford & Tutela Heights Study Area	274
Table 4.3: Summary of HDF Management Implications	289
Table 4.4: Summary of Constraints	291
Table 5.1: Summary of Deferred Studies	294

List of Figures

Figure 1.1: Study Area: North Brantford Study Area	4
Figure 1.2: Study Area: Tutela Heights Study Area	5
Figure 1.3: Subwatershed Study & Environmental Assessment Study Process	17
Figure 1.4 Land Uses and Block Plan Areas in the North Brantford and Tutela Heights Subwatersheds (based on the City of Brantford Official Plan – Envisioning Our City: 2051)	18
Figure 3.1: Property Access Status.....	25
Figure 3.2: North Brantford and Tutela Heights subwatershed study area.	29
Figure 3.3: Fairchild Creek and Whitemans Creek model areas.	30
Figure 3.4: Study area topography, in metres above sea level (masl).....	33
Figure 3.5: Physiographic features within the study area (after Chapman and Putnam, 1984).	34
Figure 3.6: Generalized schematic showing the bedrock and overburden geologic units (after Earthfx, 2018).....	35
Figure 3.7: Paleozoic bedrock geology of the study area (data from OGS, 2010).....	36
Figure 3.8: Bedrock surface topography (after Earthfx, 2018).	38

Figure 3.9: Late Wisconsin (Michigan Subepisode) till relative time-distance diagram (Karrow, 2005).....39

Figure 3.10: Surficial geology of the study area (after OGS, 2010).....41

Figure 3.11: Overburden thickness in the study area.42

Figure 3.12: Well drilling at MW-1 (left) and well completion at MW-4 (right).44

Figure 3.13: Location of new boreholes and other boreholes with geologic information.46

Figure 3.14: Location of MW3 (Clarke Rd. south of German School Rd.).....47

Figure 3.15: Location of MW4 (Westlake Rd. at Moore Rd.).....47

Figure 3.16: Location of MW5 (Park Road N. north of Powerline Rd.).....48

Figure 3.17: Location of MW6 (East end of Lynden Rd. at Garden Ave.).....48

Figure 3.18: Location of MW7 (Tutela Heights Rd. east of Rue Chateaux Terrace).49

Figure 3.19: Residual drawdowns versus time for single well response tests.....51

Figure 3.20: Fractures in silt/silt clay matrix filled with fine sand at MW-1 (left) and coarse sand encountered at MW2-D (right).51

Figure 3.21: Observed groundwater levels at MW1-S (blue) and MW1-D (red) along with CASPAR rainfall data (green) for the same period.....53

Figure 3.22: Observed groundwater levels at MW2-S (blue) and MW2-D (red).....53

Figure 3.23: Observed groundwater levels at MW3-S.....53

Figure 3.24: Observed groundwater levels at MW5-D.54

Figure 3.25: Observed groundwater levels at MW6-D.54

Figure 3.26: Observed groundwater levels at MW4-S (blue) and MW4-D (red).....54

Figure 3.27: Observed groundwater levels at MW7-D.55

Figure 3.28: Long-term hydrograph for PGMN Well W0000065-4 in the Burford area and wells MW-4S and MW4-D (on the secondary y-axis).....55

Figure 3.29: Locations of Guelph permeameter testing and minipiezometer installations.57

Figure 3.30: Location of geotechnical boreholes installed in the riparian areas and locations of other geotechnical boreholes in the study area.59

Figure 3.31: Location of GT-1 (Google Maps, top) and Lidar imagery (bottom)60

Figure 3.32: Google Street View in the vicinity of GT-1.....61

Figure 3.33: Location of GT-2 (Google Maps, top) and Lidar imagery (bottom)62

Figure 3.34: Google Street View in the vicinity of GT-2.....63

Figure 3.35: Location of GT-3 (Google Maps, top) and Lidar imagery (bottom).64

Figure 3.36: Google Street View in the vicinity of GT-3.....65

Figure 3.37: Location of GT-4 (Google Maps, top) and Lidar imagery (bottom)66

Figure 3.38: Google Street View in the vicinity of GT-4.....67

Figure 3.39: Location of GT-5 (Google Maps, top) and Lidar imagery (bottom).68

Figure 3.40: Google Street View in the vicinity of GT-5.....69

Figure 3.41: Location of GT-6 (Google Maps, top) and Lidar imagery (bottom).70

Figure 3.42: Google Street View in the vicinity of GT-6.....71

Figure 3.43: Location of GT-7 (Google Maps, top) and Lidar imagery (bottom).72

Figure 3.44: Google Street View in the vicinity of GT-7.....73

Figure 3.45: West-East section through the North Brantford study area.77

Figure 3.46: West-East section through the Tutela Heights study area.78

Figure 3.47: Observed groundwater levels (masl) in overburden wells.81

Figure 3.48: Observed groundwater levels (masl) in bedrock wells.....	82
Figure 3.49: Interpolated groundwater levels (masl) in the overburden.	83
Figure 3.50: Interpolated groundwater levels (masl) in the bedrock.	84
Figure 3.51: Vertical head (potential) difference between the overburden and bedrock aquifers. .	85
Figure 3.52: Location and purpose of permits to take water (PTTW) in the study area.	88
Figure 3.53: Active and inactive AES climate stations in the study area (with data after 2011).	91
Figure 3.54: Daily precipitation for Brantford MOE (6140954) and Brantford Airport (6140942), WY1961 to WY2022.	92
Figure 3.55: Annual average precipitation in the study area (Brantford stations, WY1961 – WY2022) and number of missing days per year.	92
Figure 3.56: Monthly average precipitation, in mm/mon, for WY1961 to WY2022 and range in the data.....	93
Figure 3.57: Monthly percentage of daily precipitation events above specified size relative to total number of precipitation events for WY1961 to WY2022.	94
Figure 3.58: Monthly average mean, maximum, and minimum temperatures, in °C, for WY1961 to WY2022.	94
Figure 3.59: Topographic slope classes in the study area.....	96
Figure 3.60: Portion of the cascade overland flow network in North Brantford.....	97
Figure 3.61: Distribution of land use classes in North Brantford (left) and Tutela Heights (right). ..	97
Figure 3.62: Land use classes in the study area.	98
Figure 3.63: Percent imperviousness as assigned based on SOLRIS v3 land use classes.	100
Figure 3.64: Soils mapping based on A Horizon texture.	101
Figure 3.65: Estimated annual average evapotranspiration (ET) (mm/yr).	102
Figure 3.66: Estimated annual average surplus (Precipitation - ET) (mm/yr)	103
Figure 3.67: Estimated annual average groundwater recharge (mm/yr).	104
Figure 3.68: Arc Hydro Desktop Analysis and Potential HDFs to be Confirmed During First Site Visit	109
Figure 3.69: HDF Management Criteria Flow Chart.....	112
Figure 3.70: Reaches Assessed by the 2020 Phase 1 SWS Study and the 2022 Phase 1 Update SWS Study (this study) in North Bantford.....	118
Figure 3.71: Reaches Assessed by the 2020 Phase 1 SWS Study and the 2022 Phase 1 Update SWS Study (this study) in Tutela Heights.	118
Figure 3.72: Geomorphic stability of all assessed reaches in North Brantford.	123
Figure 3.73: Geomorphic stability of all assessed reached in Tutela Heights.	123
Figure 3.74 Dominant processes of adjustment by reach in North Brantford.	124
Figure 3.75: Dominant processes of adjustment by reach in Tutela Heights.	125
Figure 3.76: Plan and Profile of Monitoring Site Tributary K.....	128
Figure 3.77: Cross Sections of Monitoring Site Tributary K.....	129
Figure 3.78: Plan and Profile of Monitoring Site Jones 2.....	132
Figure 3.79: Cross Sections of Monitoring Site Jones 2.....	133
Figure 3.80: Erosion hazard limit in confined system (left) where toe of valley slope is less than 15m from watercourse (MNR, 2002); compared to erosion hazard limit for unconfined system (right).....	138
Figure 3.81: Channel Incision at Reach JC-H Tributary.....	139

Figure 3.82: Valley slope in Reach LF Trib A.....	140
Figure 3.83: Valley slope in Reach LF Trib A-H.....	140
Figure 3.84: Channel Incision at Reach LF Trib B	141
Figure 3.85: May 17, 2020 Calibration Result with Flow Record on Jones Creek at Park Road	146
Figure 3.86: March 25, 2021 Calibration Result with Flow Record on Jones Creek at Park Road...	147
Figure 3.87: July 29, 2023 Calibration Result with Flow Record on Jones Creek at Park Road	147
Figure 3.88: June 18, 2018 Validation Result with Flow Record on Jones Creek at Park Road	148
Figure 3.89: July 16, 2024 Validation Result with Flow Record on Jones Creek at Park Road	148
Figure 3.90: Subcatchment Delineation.....	151
Figure 3.91: Existing Conditions 100-Year Floodplain.....	157
Figure 3.92: Existing Conditions Regional Floodplain	159
Figure 3.93: Sediment Sample at Phelps Creek Upstream	161
Figure 3.94: Sediment Sampling Locations	162
Figure 3.95: Water Quality Monitoring Locations	170
Figure 3.96: TM2(North Branch) Thermal Regime.....	176
Figure 3.97: TM3 (Lower Jones) Thermal Regime.....	177
Figure 3.98: Aquatic Monitoring Locations.....	186
Figure 3.99: Jones Creek South Branch: Downstream Looking Upstream	187
Figure 3.100: Jones Creek North Branch: Downstream Looking Upstream	187
Figure 3.101: Lower Jones Creek: Downstream Looking Upstream	187
Figure 3.102: Tributary K: Downstream Looking Upstream	187
Figure 3.103: Silver Creek: Downstream Looking Upstream	188
Figure 3.104: Ditching and Sediment Fencing Adjacent to Watercourse.....	190
Figure 3.105: Aquatic Resource Summary	206
Figure 3.106: Aquafor Beech 2022 ELC Overview (refer also to Appendix J)	213
Figure 3.107: Provincially Significant Wetland Complex Considerations	219
Figure 3.108 : Corridors/Linkages	228
Figure 3.109: Amphibian Calling Survey Stations and Habitat Locations	239
Figure 3.110: Species at Risk and Significant Wildlife Habitat	251
Figure 4.1: Existing Conditions 100-Year Floodplain.....	261
Figure 4.2: Existing Conditions Regional Floodplain	263
Figure 4.3: Profile for Reach UJT2-6-H0L (Jones Trib9 W1-1) for all flow events.....	267
Figure 4.4: Development Constraints, Stable Slope Offsets and Meander Belt Requirements for North Brantford.....	271
Figure 4.5: Development Constraints, Stable Slope Offsets and Meander Belt Requirements for Tutela Heights.	272
Figure 4.6: Restoration/Enhancement Opportunities	279
Figure 4.7: Depth to water table (m)	285
Figure 4.8: Areas of shallow depth to water table (<3m).	286
Figure 4.9: Areas of significant groundwater recharge.....	287
Figure 4.10: Constraints to Development.....	292

Appendices

- Appendix A: CLI ECA Appendix A
- Appendix B: Landowner Access Letter
- Appendix C: Rapid Geomorphic Assessment
- Appendix D: Hydrologic Model Inputs
- Appendix E: Culvert / Crossing Summary
- Appendix F: Hydraulic Model Outputs
- Appendix G: Proof of Certifications for OSAP and Electrofishing
- Appendix H: OSAP Field Sheets
- Appendix I: Flowing Water Information System (FWIS) Data Summary
- Appendix J: ELC Mapping, Summary Table and Field Sheets
- Appendix K: Botanical Species List
- Appendix L: Hedgerow Assessment
- Appendix M: Bird Species List
- Appendix N: Species at Risk Screening Results
- Appendix O: Significant Wildlife Habitat Assessment Results
- Appendix P: 2022 Streamflow and Precipitation Monitoring Results
- Appendix Q: Geomorphic Reach Descriptions
- Appendix R: Borehole Logs
- Appendix S: Model Calibration and Validation

Report Authors:

Alison Gingrich Regehr, Aquafor Beech Limited

David Kynaston, Aquafor Beech Limited

Graham Eby, Aquafor Beech Limited

Julie Scott, Aquafor Beech Limited

Kristen Beauchamp, Aquafor Beech Limited

Yun Xia, Aquafor Beech Limited

Asoka Kodippili, Earthfx Inc.

Dirk Kassenaar, Earthfx Inc.

E.J. Wexler, Earthfx Inc.

Report Reviewer:

Dave Maunder, Aquafor Beech Limited

1 Introduction

The City of Brantford is a rapidly growing population center located by the Grand River west of the City of Hamilton. With a 2021 census population of 104,688, it is politically separate with a municipal government of its own that is fully independent of Brant County’s municipal government. The North Brantford and Tutela Heights Subwatersheds are located within the 2,720 hectares annexed from the County of Brant Boundary Adjustment Lands in 2017.

In 2017, the City of Brantford retained PLAN B Natural Heritage to prepare a Comprehensive Environmental Impact Statement (EIS) for the Boundary Adjustment Lands including the North Brantford and Tutela Heights Subwatersheds. The EIS, published in November 2020 by PLAN B Natural Heritage, was completed as part of the Municipal Comprehensive Review (MCR) for the City of Brantford to inform a new Official Plan and the Subwatershed and Master Servicing Plan studies. Meanwhile, the City had also retained GM BluePlan Engineering to complete a Phase 1 Subwatershed Study as part of the MCR and the City of Brantford’s Official Plan review process. Since the preparation of these documents, the City of Brantford was able to define the Expanded Urban Settlement Area, map proposed land uses, define a long-term infrastructure plan, and provide guidelines and policies to frame growth and mitigate impacts.

The new City of Brantford Official Plan – Envisioning Our City: 2051 – expanded the City’s Settlement Area with designating approximately 900 hectares of urban land uses. The settlement area expansion includes almost 400 hectares for new Employment Areas and 500 hectares for Community Areas, which gives a total of 525 hectares of Employment Areas and 730 hectares of Community Areas within the Boundary Adjustment Lands. The North Brantford and Tutela Heights Subwatershed Study is the beginning of a multi-staged approach to fully characterize, evaluate, and implement recommendations for this subwatershed.

This document constitutes the Phase 1 Update of the North Brantford and Tutela Heights Subwatershed Study Update (SWS), which investigates and inventories the natural resources which could potentially be impacted by future urban development. Along with characterization of natural resources this document identifies constraints and opportunities which will be considered for block plans being developed within the Study Area. The findings documented in this report will be used to develop a comprehensive Subwatershed Management Plan, including stormwater management and natural heritage strategies, which will protect, rehabilitate and enhance the environment during the planning process to ensure that any urban development will not negatively impact the natural heritage and water resource systems in the area.

The Subwatershed Study will fulfill the requirements of the City of Brantford Official Plan - Envisioning Our City: 2051 (OP) and also inform future development plans by guiding development in a manner that respects the local natural heritage system, natural hazards and supports long-term environmental sustainability.

1.1 Study Area and Land Uses

1.1.1 Subwatershed Study Area

The Study Area for this subwatershed study encompasses two geographical areas within the City of Brantford; i.e., the North Brantford lands and Tutela Heights subwatershed. Each of these subwatersheds has primary, secondary and tertiary Study Areas, which are described in **Sections 1.1.2** and **1.1.3**, respectively. However, efforts have been focused on the portions of the watersheds that fall within the primary Study Area, shown outlined in red on **Figure 1.1** and **Figure 1.2**.

Existing land use within the North Brantford and Tutela Heights subwatersheds is mainly rural in character and includes existing agriculture, residential, and highway commercial land uses. The Grand River is found at the Northeastern boundary of Tutela Heights subwatershed.

1.1.2 North Brantford

The North Brantford lands, as illustrated in **Figure 1.1**, are located north of Powerline Road and Paris Road along the north side of the city, and east of Garden Avenue to the municipal boundary between the City of Brantford and the County of Brant, with an approximate area of 2,123 hectares. Historically, the land use within the North Brantford Subwatershed was predominately agricultural with some forest and wetlands. Presently, the westernmost and easternmost portions of the subwatershed are designated primarily for Employment purposes with the rest of them for Core Natural Areas. Meanwhile, the central part of the North Brantford Subwatershed is mainly planned for residential purposes, south of Core Natural Areas along Jones Creek and a large portion of rural area within the subwatershed.

The Primary Study Area for the North Brantford Area is roughly 2,123 hectares, including the lands east of Garden Avenue. Approximate 2,100 hectares of municipal Boundary Adjustment Lands obtained from the County of Brant in the North Brantford Area is the Secondary Study Area. The Tertiary Study Areas include lands of great significance to the subwatershed study, which are outside of the municipal boundary, including the catchment areas of Jones Creek and Fairchild Creek and their tributaries.

Jones Creek is a tributary of Fairchild Creek which drains much of the North Brantford Area and flows generally from west to east before discharging to Fairchild Creek.

Fairchild Creek drains an area of approximately 401 km², running north to south and flows into the Grand River downstream of Brantford. A short section of the middle portion of Fairchild Creek is located along the eastern limit of the North Brantford boundary expansion area.

1.1.3 Tutela Heights

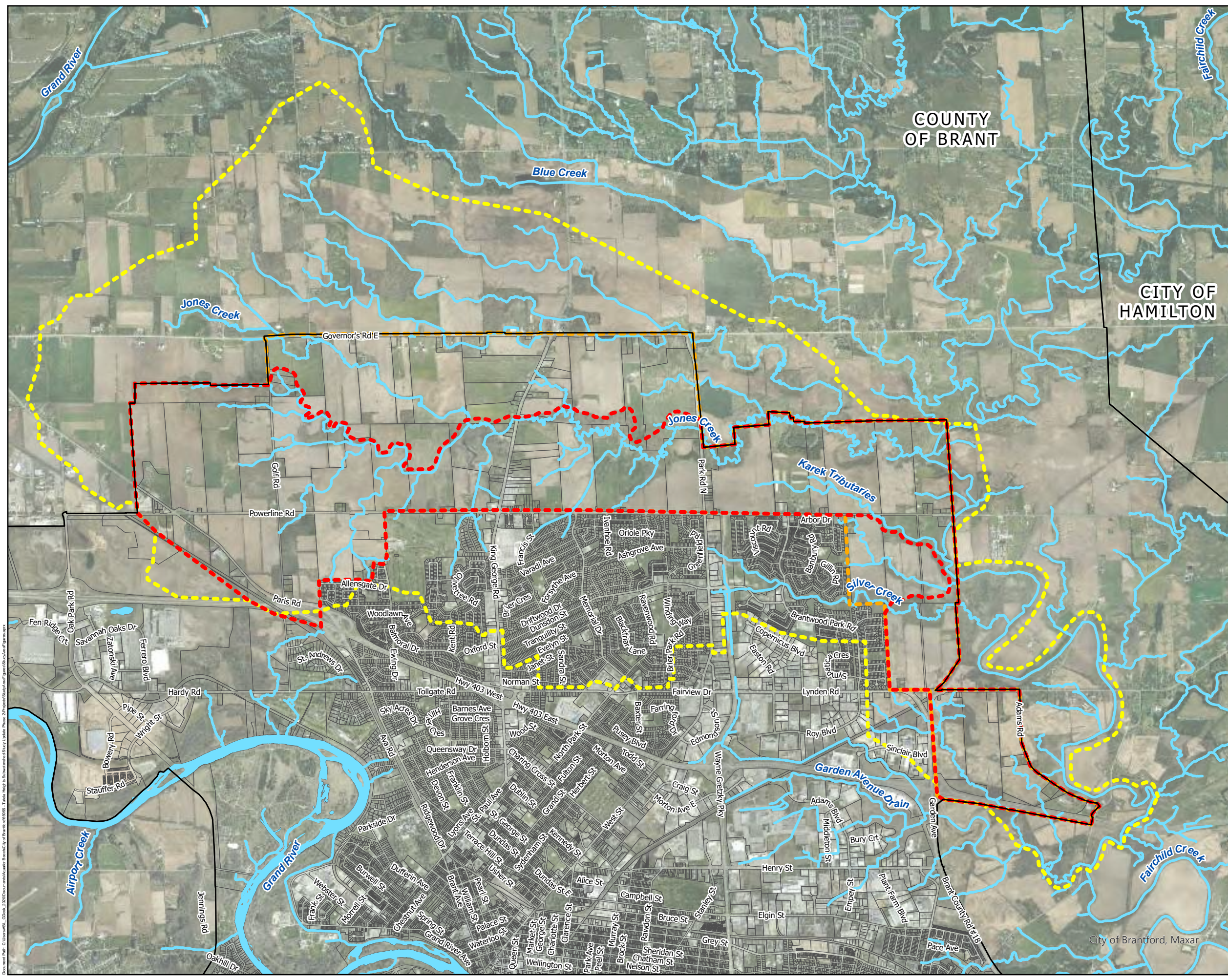
Tutela Heights subwatershed, as displayed in **Figure 1.2**, is bounded generally by Mt. Pleasant Road, Tutela Heights Road, and Phelps Road.

In the Tutela Heights area, the Primary Study Area is roughly 581 hectares, which is also the actual Boundary Adjustment Lands in Tutela Heights, and includes the same lands as the Secondary Study

Area. The Tertiary Study Area is defined as the lands that form catchments of the tributaries to the Grand River, namely Phelps Creek.

Historically, the land use within the Tutela Heights Subwatershed was predominately agricultural with some forest and wetlands. Presently, community areas, rural areas and core natural areas comprise the whole subwatershed. No employment land use is designated within this area.

Phelps Creek is a relatively small third-order channel located in the southeastern portion of the Boundary Expansion Area. The watercourse flows east to discharge to the Grand River.



Legend

- Municipal Boundary
- Property Parcel
- Watercourse
- Waterbodies

Study Area:

- Primary
- Secondary
- Tertiary

LOCATOR MAP

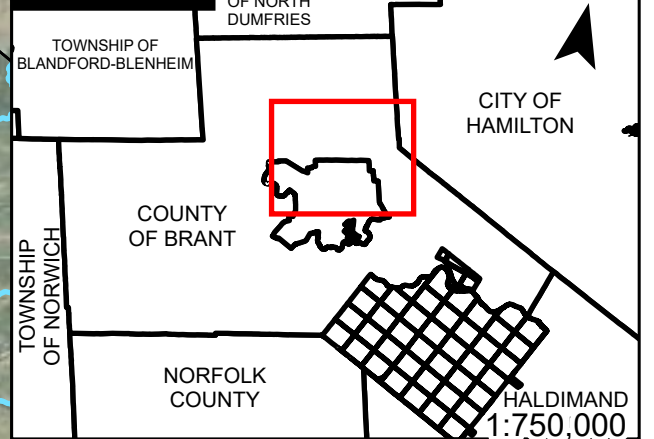
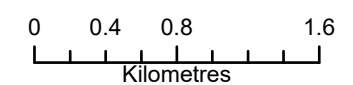


Figure 1.1

North Brantford Study Area

Date: 2022-12-05
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford, GRCA
 Created by: A.V.





Legend

- Municipal Boundary
- Property Parcel
- Watercourse
- Waterbodies
- Study Area:**
- Primary
- Secondary
- Tertiary

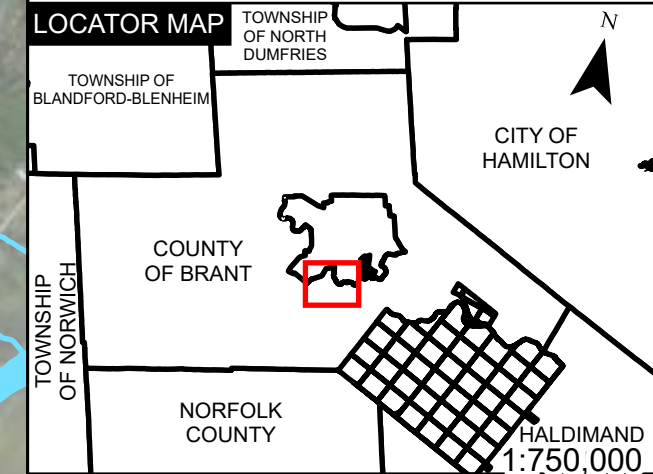
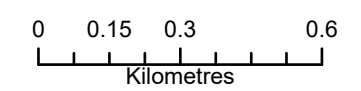


Figure 1.2

Tutela Heights Study Area

Date: 2022-12-05
Projection: NAD83_UTM_Zone_17N
Data Source: City of Brantford, GRCA
Created by: A.V.



1.2 Existing Policy Framework

The following subsections outline the NHS policy framework relevant to **the North Brantford and Tutela Heights subwatersheds**.

1.2.1 Provincial Policy Statement

The 2020 Provincial Policy Statement (PPS), promulgated under the Planning Act, directs municipal land use planning activities related to matters of provincial interest. Section 2.1.2 of the PPS states that:

The diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features (Ministry of Municipal Affairs and Housing, 2020).

The PPS supports not only the protection of individual natural heritage features (woodlands, wetlands, watercourses, valleylands, wildlife habitat, etc.) but also the linkages that connect them into a broader Natural Heritage System (NHS). The NHS approach is effective because it acknowledges that natural heritage features have strong functional ties to one another, and that this functionality may be compromised when individual features become isolated within a predominately agricultural or urban matrix.

A NHS is defined by the Province of Ontario as:

A system made up of natural heritage features and areas, and linkages intended to provide connectivity (at the regional or site level) and support natural processes which are necessary to maintain biological and geological diversity, natural functions, viable populations of indigenous species and ecosystems. These systems can include natural heritage features and areas, federal and provincial parks and conservation reserves, other natural heritage features, lands that have been restored or have the potential to be restored to a natural state, areas that support hydrologic functions, and working landscapes that enable ecological functions to continue. The Province has a recommended approach for identifying natural heritage systems, but municipal approaches that achieve or exceed the same objectives may also be used” (Provincial Policy Statement, MMAH 2020).

The NHS approach is a useful method for the protection of natural heritage features and areas because it reinforces an understanding that the elements of the system have strong ecological ties to each other, as well as to other physical features and areas in the overall landscape. The NHS approach also addresses a number of important land use planning concerns, including biodiversity decline, landscape fragmentation and the maintenance of ecosystem health. The Natural Heritage Reference Manual (NHRM) describes these planning concerns in greater detail and outlines the potential benefits of a NHS (MNR 2010).

Section 2.1 of the PPS provides specific requirements for the protection of natural features and the restrictions that apply to development and site alteration in association with those features. For example, Section 2.1.5 of the PPS states that development and site alteration shall not be permitted in significant woodlands, significant valleylands, and significant wildlife habitat unless it has been demonstrated that the proposed activities will not result in negative impacts to these features and their functions. The clauses in Section 2.1 of the PPS support the detailed NHS policies and constraints to development that are present in the municipal Official Plan, which is discussed in **Section 1.2.4**.

1.2.2 Growth Plan for the Greater Golden Horseshoe

The portion of Ontario termed the Greater Golden Horseshoe includes most municipalities in a broad band around the shore of Lake Ontario from Peterborough to Niagara. This region contains many of Ontario's most significant ecological features and scenic landscapes, as well as productive farmland and a large proportion of the inhabitants of the province. Maintaining a balance between the demand for space and resources and the preservation of natural heritage features and functions presents a challenge that must be addressed through careful planning. This plan is issued under the *Places to Grow Act, 2005* and is proposed to be merged with the PPS in the near future.

The 2020 Growth Plan for the Greater Golden Horseshoe, prepared under the *Places to Grow Act (2005)*, is intended to “plan for growth and development in a way that supports economic prosperity, protects the environment, and helps communities achieve a high quality of life” (Ministry of Municipal Affairs and Housing, 2020). One of the key components of the Growth Plan is the development and implementation of an NHS and establishment of related policies such as those within Clause 3 of Section 4.2.2 of the Growth Plan (applicable to lands outside of settlement areas):

3. Within the Natural Heritage System:
 - a. new development or site alteration will demonstrate that:
 - i. there are no negative impacts on key natural heritage features or key hydrologic features or their functions;
 - ii. connectivity along the system and between key natural heritage features and key hydrologic features located within 240 meters of each other will be maintained or, where possible, enhanced for the movement of native plants and animals across the landscape;
 - iii. the removal of other natural features not identified as key natural heritage features and key hydrologic features is avoided, where possible. Such features should be incorporated into the planning and design of the proposed use wherever possible;
 - iv. except for uses described in and governed by the policies in subsection 4.2.8 [pertaining to Mineral Aggregate Resources], the disturbed area,

including any buildings and structures, will not exceed 25 per cent of the total developable area, and the impervious surface will not exceed 10 per cent of the total developable area;

- v. with respect to golf courses, the disturbed area will not exceed 40 per cent of the total developable area; and
- vi. at least 30 per cent of the total developable area will remain or be returned to natural self-sustaining vegetation, except where specified in accordance with the policies in subsection 4.2.8.

Section 4.2.4 of the Growth Plan further discusses lands adjacent to the NHS.

1. Outside settlement areas, a proposal for new development or site alteration within 120 metres of a key natural heritage feature within the Natural Heritage System or a key hydrologic feature will require a natural heritage evaluation or hydrologic evaluation that identifies a vegetation protection zone, which:
 - a) is of sufficient width to protect the key natural heritage feature or key hydrologic feature and its functions from the impacts of the proposed change;
 - b) is established to achieve and be maintained as natural self-sustaining vegetation; and
 - c) for key hydrologic features, fish habitat, and significant woodlands, is no less than 30 metres measured from the outside boundary of the key natural heritage feature or key hydrologic feature.
2. Evaluations undertaken in accordance with policy 4.2.4.1 will identify any additional restrictions to be applied before, during, and after development to protect the hydrologic functions and ecological functions of the feature.
3. Development or site alteration is not permitted in the vegetation protection zone, with the exception of that described in policy 4.2.3.1 or shoreline development as permitted in accordance with policy 4.2.4.5.
4. The new City of Brantford Official Plan was adopted by Brantford City Council on March 23, 2021 and approved with modifications by the Minister of Municipal Affairs and Housing, taking effect on August 5, 2021, consistent with the Provincial Policy Statement (2020) and in conformity with the Growth Plan for the Greater Golden Horseshoe (2020).

1.2.3 Consolidated Linear Infrastructure Environmental Compliance Approval

In order to comply with the Consolidated Linear Infrastructure Environmental Compliance Approval (CLI ECA), the proposed stormwater treatment train must comply with the

requirements outlined in Appendix A of the CLI ECA application. These requirements arose from the pending LID Planning and Design Guide. The City of Brantford has received its CLI ECA.

A key component of the CLI ECA (provided in **Appendix A**) is the control of stormwater, as described below:

Stormwater volumes generated from the geographically specific 90th percentile rainfall event on an annual average basis from all surfaces on the entire site are targeted for control. Control is in the following hierarchical order, with each step exhausted before proceeding to the next:

- 1) retention (infiltration, reuse or evapotranspiration),
- 2) LID filtration, and
- 3) conventional stormwater management.

Step 3, conventional stormwater management, should proceed only once Maximum Extent Possible has been attained for Steps 1 and 2 for retention and filtration.

While the CLI ECA allows for site-specific studies to achieve water balance, erosion control, water quantity, and flood control criteria, water quality treatment of suspended solids requires control (as outlined above) of the 90th percentile storm event; and if conventional methods are necessary, then 80%, 70% or 60% suspended solids removal (based on the receiver) as per the full ETV Canada particle size distribution.

1.2.4 City of Brantford Official Plan - Envisioning Our City: 2051 (September, 2022)

The City of Brantford Official Plan 2022 (the OP) states that “it is the intent of this Plan to ensure that the biodiversity, ecological function and connectivity of the Natural Heritage System is protected, maintained, restored or, where possible, enhanced for the long-term, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features” (Section 5.6).

According to Section 5.6 of the OP, the Natural Heritage System identified on Schedule 6 is comprised of the following components:

- i. The Core Natural Areas Designation, which comprises the environmental features and an associated 30 metre buffer, as well as portions of the Natural Heritage System for the Growth Plan for the Greater Golden Horseshoe located within Brantford, that the City shall protect and conserve; and
- ii. The Adjacent Lands Overlay, which is based on an approximate 90 metre setback from the boundary of the Core Natural Areas Designation and is intended to act as a trigger for the completion of an Environmental Impact Study when required by the City.

- iii. A Natural Heritage System for the Growth Plan has been mapped by the Province to support a comprehensive, integrated, and long-term approach to planning for the protection of the region’s natural heritage and biodiversity.

Core Natural Areas are comprised of the following components:

- a) Provincially significant wetlands;
- b) Provincially significant woodlands;
- c) Provincially significant valleylands;
- d) Significant wildlife habitat attributes and functions, including habitat for species-at-risk and rare plant communities such as prairie, savannah and oak woodland;
- e) Significant areas of natural and scientific interest;
- f) Hazard lands;
- g) Other natural heritage features (i.e., woodlands that are less than 4 hectares, locally significant wetlands, treed slopes, and cultural habitat features); and,
- h) Enhancement/restoration areas.

This SWS has therefore taken the approach of identifying and evaluating all natural heritage features on the landscape and evaluating their significant/sensitivity, not necessarily limited to the features identified as part of the NHS.

In addition to those defined categories, the OP also documented the Growth plan policies for the Natural Heritage System, Key Hydrologic Features and Key Natural Heritage Features in Section 5.6.3.

Natural Heritage

- a) Within the Natural Heritage System for the Growth Plan in areas outside of the Settlement Area Boundary:
 - i. New development or site alteration will demonstrate that:
 - a. There are no negative impacts on key natural heritage features or key hydrologic features or their functions;
 - b. Connectivity along the system and between key natural heritage features and key hydrologic features located within 240 metres of each other will be maintained or, where possible, enhanced for the movement of native plants and animals across the landscape;
 - c. The removal of other natural features not identified as key natural heritage features and key hydrologic features is avoided, where possible. Such features should be incorporated into the planning and design of the proposed use wherever possible;
 - d. The disturbed area, including any buildings and structures, will not exceed 25 percent of the total developable area, and the impervious surface will not exceed 10 percent of the total developable area;
 - e. With respect to golf courses, the disturbed area will not exceed 40 percent of the total developable area; and,

- f. At least 30 percent of the total developable area will remain or be returned to natural self-sustaining vegetation; and,
- ii. The full range of existing and new agricultural uses, agriculture-related uses, on-farm diversified uses, and normal farm practices are permitted. However, new buildings or structures for agricultural uses, agriculture related uses, or on-farm diversified uses are not subject to policy 5.6.3.a.i. but are subject to the policies in subsections 5.6.3.b and 5.6.3.c

Key Hydrologic Features and Key Natural Heritage Features

- b) Outside of settlement areas, development or site alteration is not permitted in key natural heritage features that are part of the Natural Heritage System for the Growth Plan or in key hydrologic features, except for:
 - i. Forest, fish and wildlife management;
 - ii. Conservation and flood or erosion control projects, but only if they have been demonstrated to be necessary in the public interest and after all alternatives have been considered;
 - iii. Mineral aggregate operations and wayside pits and quarries;
 - iv. Activities that create or maintain infrastructure authorized under an Environmental Assessment process;
 - v. Expansions to existing buildings and structures, accessory structures and uses, and conversions of legally existing uses which bring the use more into conformity with this Plan, subject to demonstration that the use does not expand into the key hydrologic feature or key natural heritage feature or vegetative protection zone unless there is no other alternative, in which case any expansion will be limited in scope and kept within close geographical proximity to the existing structure;
 - vi. Expansions or alterations to existing buildings and structures for agricultural uses, agriculture-related uses, or on-farm diversified uses and expansions to existing residential dwellings if it is demonstrated that:
 - a. There is no alternative, and the expansion or alteration in the feature is minimized and, in the vegetation protection zone, is directed away from the feature to the maximum extent possible; and,
 - b. The impact of the expansion or alteration on the feature and its functions is minimized and mitigated to the maximum extent possible; and,
 - vii. Small-scale structures for recreational uses, including boardwalks, footbridges, fences, docks, and picnic facilities, if measures are taken to minimize the number of such structures and their negative impacts.

Lands Adjacent to Key Hydrologic Features and Key Natural Heritage Features

- c) Outside of settlement areas, a proposal for new development or site alteration within 120 metres of a key natural heritage feature within the Natural Heritage System for the Growth Plan or a key hydrologic feature will require a natural heritage evaluation or hydrologic evaluation that identifies a vegetation protection zone, which:

- i. Is of sufficient width to protect the key natural heritage feature or key hydrologic feature and its functions from the impacts of the proposed change;
 - ii. Is established to achieve and be maintained as natural self-sustaining vegetation; and
 - iii. For key hydrologic features, fish habitat, and significant woodlands, is no less than 30 metres measured from the outside boundary of the key natural heritage feature or key hydrologic feature.
- d) Evaluations undertaken in accordance with policy 5.6.3.c will identify any additional restrictions to be applied before, during, and after development to protect the hydrologic functions and ecological functions of the feature.
- e) Development or site alteration is not permitted in the vegetation protection zone, with exception of that described in policy 5.6.3.b.
- f) Notwithstanding policies 5.6.3.c-e:
- i. A natural heritage or hydrologic evaluation will not be required for a proposal for development or site alteration on a site where the only key natural heritage feature is the habitat of endangered species and threatened species;
 - ii. New buildings and structures for agricultural uses, agriculture-related uses, or on-farm diversified uses will not be required to undertake a natural heritage or hydrologic evaluation if a minimum 30 metre vegetation protection zone is provided from a key natural heritage feature or key hydrologic feature; and,
 - iii. Uses permitted in accordance with policy 5.6.3.f.ii:
 - a. Are exempt from the requirement of establishing a condition of natural self-sustaining vegetation if the land is, and will continue to be, used for agricultural purposes; and
 - b. Will pursue best management practices to protect and restore key natural heritage features, key hydrologic features, and their functions.

Other policies in Section 5.6 of the OP note, through the preparation of an Environmental Impact Study (EIS), the limits of the previously-established Core Natural Areas Designation within the NHS (as depicted on Schedule 6 of the OP) may be refined, and linkages and restoration opportunities will be identified for further evaluation during the following Block Plan stage and Development Application stages. This SWS will therefore evaluate the existing natural heritage features in the Study Area (building upon but not necessarily limited to the existing NHS as depicted in the OP), identify linkages and restoration opportunities, and provide guidance regarding developmental constraints that may be further evaluated and developed through the preparation of Block Plans, in keeping with the policies of Section 5.6 of the OP.

1.2.5 Grand River Conservation Authority

1.2.5.1 Ontario Regulation 150/06

Along with the policy in City of Brantford Official Plan, relevant natural hazards policy includes Ontario Regulation 150/06 Regulation of Development, Interference with Wetlands and Alteration to Shorelines and Watercourses which is administered and enforced by the Grand River Conservation Authority (GRCA).

Ontario Regulation (O.Reg.) 150/06 was approved under the Authority of Section 28 of the CA Act to cover the area under GRCA's jurisdiction. A principal mandate of GRCA is to prevent the loss of life and property due to flooding and erosion and to conserve and enhance natural resources. O.Reg. 150/06 is a key tool in fulfilling this mandate because it prevents or restricts development in areas where the control of flooding, erosion, dynamic beaches, pollution or the conservation of land may be affected by development.

Sections of O.Reg. 150/06 that specifically apply to this study include development prohibitions with respect to:

Section [2.(1)]

(b) River or stream valleys that have depressional features associated with a river or stream, whether or not they contain a watercourse, the limits of which are determined in accordance with the following rules:

- (i) where the river or stream valley is apparent and has stable slopes, the valley extends from the stable top of bank, plus 15 metres, to a similar point on the opposite side,
- (ii) where the river or stream valley is apparent and has unstable slopes, the valley extends from the predicted long term stable slope projected from the existing stable slope or, if the toe of the slope is unstable, from the predicted location of the toe of the slope as a result of stream erosion over a projected 100-year period, plus 15 metres, to a similar point on the opposite side,

(iii) where the river or stream valley is not apparent, the valley extends the greater of,

- (A) the distance from a point outside the edge of the maximum extent of the flood plain under the applicable flood event standard, plus an allowance not to exceed 15 metres, to a similar point on the opposite side, and
- (B) the distance from a watercourse or the predicted meander belt of a watercourse, expanded as required to convey the flood flows under the applicable flood event standard, plus 15 metres, to a similar point on the opposite side;

(c) Hazardous lands;

(d) Wetlands; or

(e) Other areas where development could interfere with the hydrologic function of a wetland, including areas within 120 metres of all provincially significant wetlands and wetlands greater than or equal to 2.0 hectares in size, and areas within 30 metres of wetlands less than 2.0 hectares in size.

Section [2.(2)]

All areas within the jurisdiction of the Authority that are described in subsection (1) are delineated as the “Regulation Limit” shown on a series of maps filed at the head office of the Authority under the map title “Ontario Regulation 97/04: Regulation for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses”.

1.2.5.2 GRCA Natural Heritage System

GRCA highlights that a natural heritage system is a way of observing, and understanding, an area’s natural features like wetlands, forests, creek valleys and rivers, as well as plants and animals that share those areas. The North Brantford lands lies within Fairchild Creek Subwatershed and the Tutela Heights lands lies in the Lower Middle Grand River Subwatershed. Fairchild Creek is predominantly agricultural and contains City of Brantford, the town of St. George, and several rural communities. It has 22% natural cover, of which most are large swamp complexes and the remainder are fragmented patches along watercourses and steep slopes (MacVeigh *et al.* 2016). Lower Middle Grand River Subwatershed includes portions of the City of Hamilton, City of Brantford, Brant and Haldimand Counties. The dominant landform is agricultural and contains 4% wetlands and 14% woodlands. Similar to the City of Brantford Official Plan that guides this SWS study, GRCA’s NHS emphasizes how these natural features are connected to each other and how they work together, by which environmentally critical and habitat restoration areas could be properly recognized.

GRCA utilizes map and characterization reports to help identify the network of natural heritage features and functions, which also shows the linkage of natural corridors. It is acknowledged by GRCA the significance of maintaining biological and geological diversity, natural functions, viable populations of indigenous species, and ecosystem within the Natural Heritage System.

1.2.5.3 Bill 23 Implications

Passing of Bill 23, the *More Homes Built Faster Act*, required updates to the *Conservation Authorities Act*. These updates have modified the roles and responsibilities of conservation authorities. Municipalities can no longer requires the conservation authority to comment on conservation and environmental matters in the development review process, except for flooding and erosion. GRCA permits are still required for any development or site alteration within GRCA regulated areas.

1.2.6 Endangered Species Act

The protection of Species at Risk (SAR) in Ontario is dictated primarily by the *Endangered Species Act* (ESA). The stated purposes of the ESA are:

1. To identify SAR based on the best available scientific information, including information obtained from community knowledge and aboriginal traditional knowledge;
2. To protect species that are at risk and their habitats, and to promote the recovery of species that are at risk; and

3. To promote stewardship activities to assist in the protection and recovery of species that are at risk.

A scientific body known as the Committee on the Status of Species at Risk in Ontario (COSSARO) is tasked with identifying threats to species in Ontario and classifying those deemed at risk as Extirpated, Endangered, Threatened, or Special Concern. For Endangered and Threatened species, the preparation of a recovery strategy is required; these offer science-based recommendations that aid in their protection and future recovery. These species are also protected from being killed, harmed or harassed (ESA s. 9) and receive habitat protection (s. 10). Special Concern species receive management plans rather than recovery strategies and are not subject to species or habitat protection under the Act. Rather, their habitat is protected under the Planning Act as it is considered a type of Significant Wildlife Habitat per provincial criteria (MNRF, 2015).

1.3 Subwatershed Study Goals, Objectives, and Phasing

The overall goal of this Subwatershed Study may be defined as follows:

“Development of a management plan that allows sustainable urban growth, while ensuring maximum benefits to the natural and human environments on a watershed basis.” – Watershed Planning in Ontario

The Subwatershed Study is undertaken in three phases (**Figure 1.3**). The objectives of this study are summarized below, according to the three study phases. This report has been prepared to present the results for the updated Phase 1 of the process.

Phase 1: Subwatershed Characterization

- identify and evaluate the location, extent, significance and sensitivity of the existing natural features of the Study Area, together with their potential interrelationship with other natural features;
- identify sensitive areas and natural hazard lands, together with recommended buffers and select preliminary management practices for these lands; and
- develop constraints and opportunities mapping to identify developable and non-developable lands which will inform the development and updating of Block Plans within the Study Area.

Phase 2: Subwatershed Management Strategies

- identify potential land use impacts to natural features and functions (Impact Assessment);
- identify protective measures (best management practices, or BMP's) that, when implemented, will protect, enhance or restore the environmental features and functions;

- formulate alternative subwatershed management strategies;
- evaluate each Strategy, based on a range of environmental, social and cost considerations, together with stakeholder input; and
- select, among the alternatives, a recommended subwatershed strategy (or plan).

Phase 3: Implementation and Monitoring Plans

- develop an Implementation Plan to ensure the long-term integrity of the Recommended Plan, including the identification of issues and areas where further detailed studies may be required at the draft plan of subdivision stage of the planning process, including the identification of issues and areas where further detailed studies may be required at the block plan or draft plan of subdivision stage of the planning process;
- identify any future recommended monitoring studies or contingency plans; and
- integrate the Subwatershed Study findings with Municipal Official Plan Policy and ongoing Block Plans.

1.4 Class Environmental Assessment (EA) Process

This Subwatershed Study is being conducted as a Municipal Class Environmental Assessment (Class EA). The study will satisfy Stage 1 and 2 of the Class EA process:

- Phase 1 – identification of the problem (deficiency) or opportunity; and
- Phase 2 – identification of alternative solutions to address the problem or opportunity by taking into consideration the existing environment, and establish the preferred solution taking into account public and review agency input.

The relationship between the components of the Subwatershed Study process and the Class EA process is depicted in **Figure 1.3**.

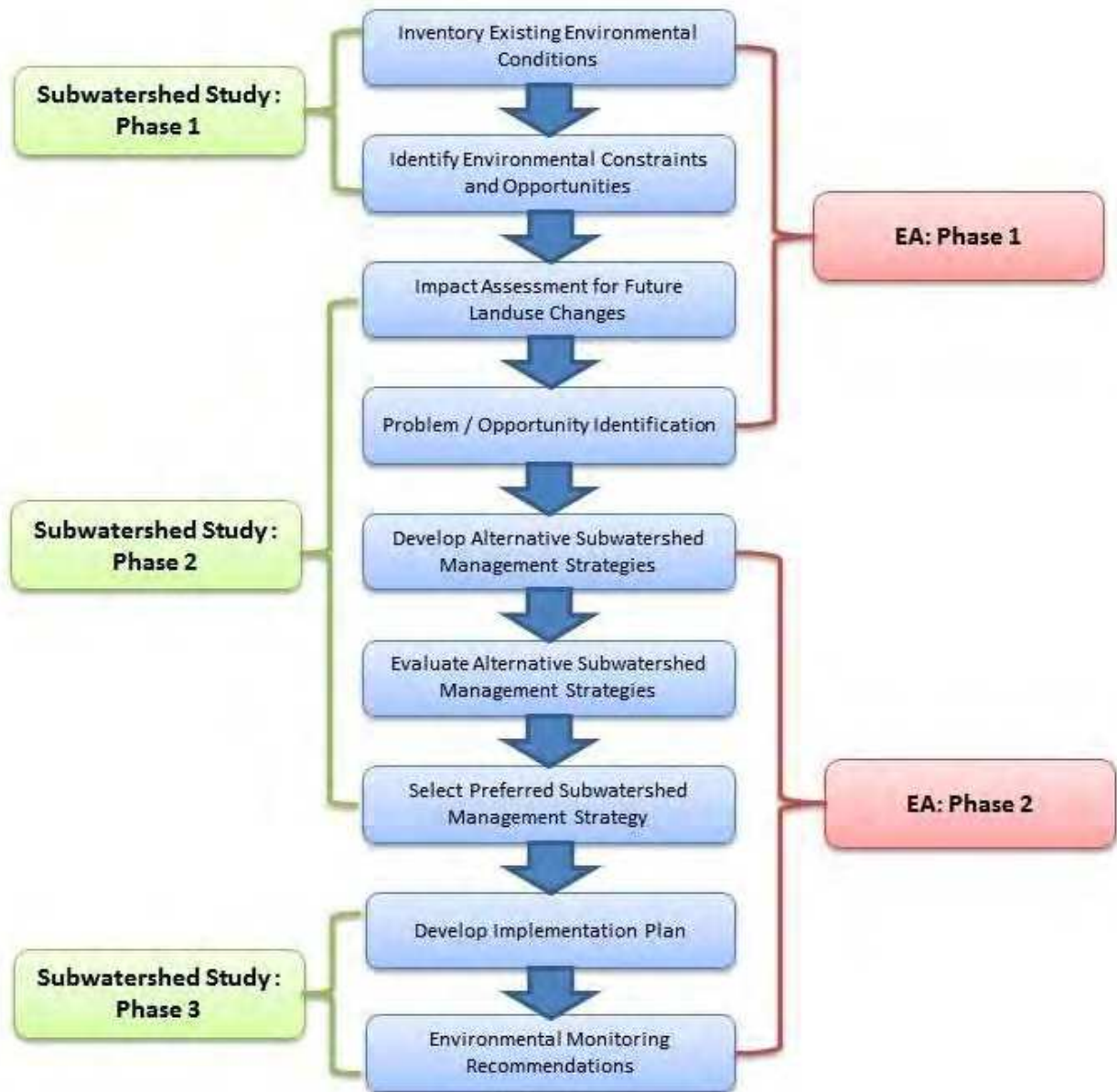


Figure 1.3: Subwatershed Study & Environmental Assessment Study Process

1.5 Block Plan Process within North Brantford and Tutela Heights

The City of Brantford Official Plan – Envisioning Our City: 2051 expanded the City’s Settlement Area by approximately 900 hectares for urban land uses, in which nearly 400 hectares are designated as new Employment Areas and up to 500 hectares of the expansion lands are planned for community/ residential areas. The land uses and Block Plan areas for the North Brantford and Tutela Heights are shown in **Figure 1.4**.

Brantford Expansion Lands

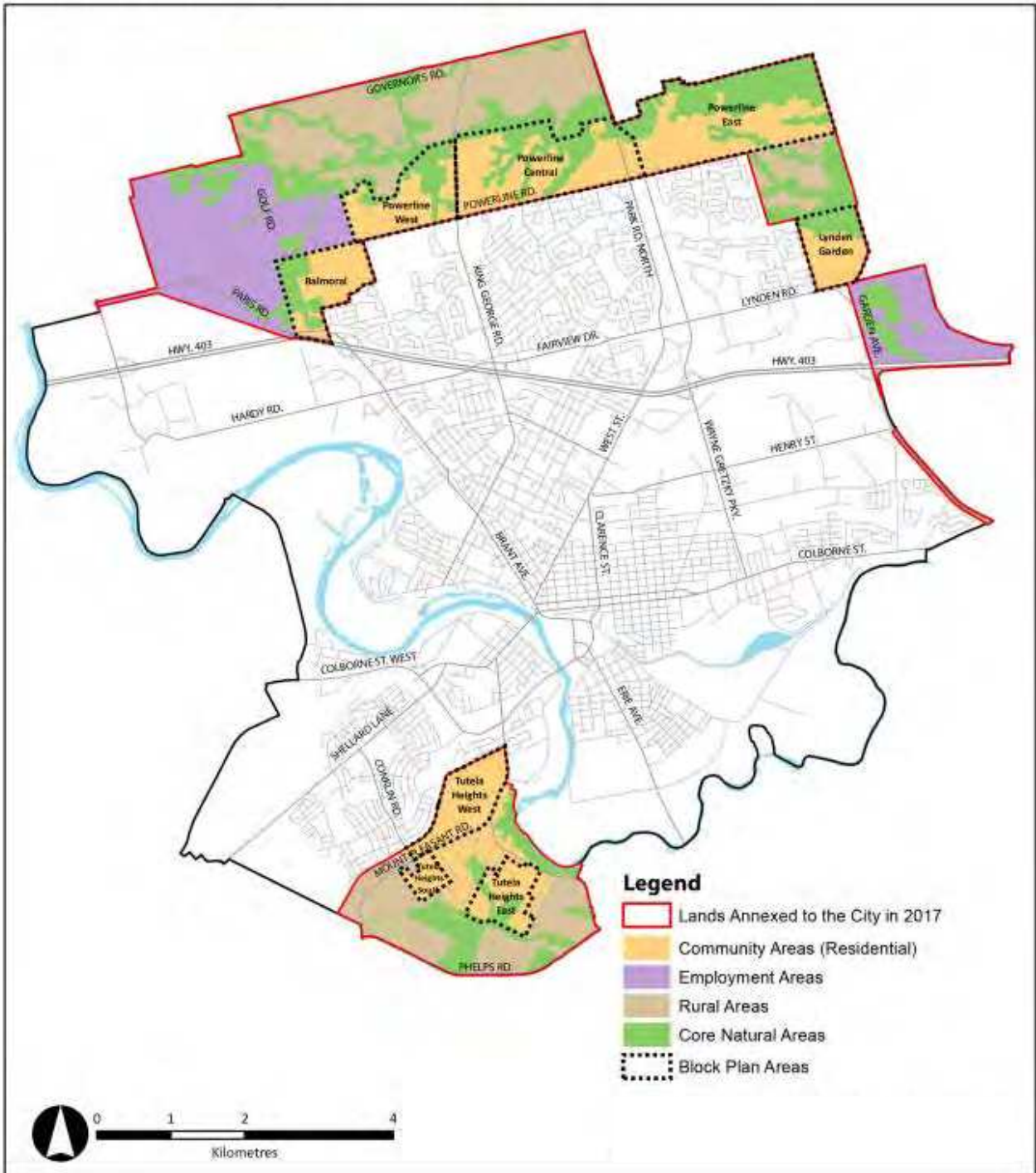


Figure 1.4 Land Uses and Block Plan Areas in the North Brantford and Tutela Heights Subwatersheds (based on the City of Brantford Official Plan – Envisioning Our City: 2051)

The City of Brantford envisions to achieve a population of 165,000 residents and 80,000 jobs by the year 2051. To ensure the comprehensive and balanced growth of the City, the OP also requires the preparation of Block Plans for Community Areas in the lands annexed from the County of Brant. There are five (5) block plan areas within the North Brantford Subwatershed, i.e., Powerline West, Powerline Central, Powerline East, Balmoral and Lynden Garden. Similarly, three (3) residential areas were delineated in Tutela Heights Subwatershed. These Block Plans are to be prepared prior to the submission of development applications: Tutela Heights West, Tutela Heights South and Tutela Heights East. Lastly, the industrial lands will not be required to follow a comprehensive block planning process, but will still be required to follow the Subwatershed Study.

The outcomes of the North Brantford and Tutela Heights Subwatershed Study will include, but not be limited to, constraints mapping and a Stormwater Management Strategy. All Block Plans must comply with the outcomes of this Subwatershed Study.

2 Background Information

A series of historical study reports and background information was provided by the City of Brantford, Grand River Conservation Authority (GRCA), and the County of Brant, for background review and consideration during the North Brantford and Tutela Heights Subwatershed Study. Key documents are summarized below.

Comprehensive Environmental Impact Statement North Brantford and Tutela Heights, City of Brantford (Plan B Natural Heritage, November 2020)

This statement documents and summarizes the natural environment of North Brantford and Tutela Heights subwatersheds. This report is an assessment of the existing conditions including policy and land use, surface and groundwater features, aquatic habitat conditions and water quality, vegetation and wildlife, and terrestrial natural heritage. The purpose of the report was intended to inform the Subwatershed and Master Servicing Plan Studies that were completed as part of the MCR and the City of Brantford’s Official Plan update.



The report established that the Study Area is dominated by agricultural land use, followed by existing residential development. The report identifies key components of the natural heritage system for the Study Area as follows:

- Growth Plan NHS;
- PSWs;
- Unevaluated (naturally occurring) wetlands 0.5 ha in area or larger;
- Anthropogenic wetlands 2.0 ha in area or larger;
- Woodlands 4.0 ha in area or larger;
- Watercourses - Jones Creek, Fairchild Creek, and Phelps Creek – defined valleylands and riparian corridors, including bottomland/floodplain and valley slope vegetation, fish/wildlife habitat, and corridor/linkage functions;
- Headwater drainage features to be “conserved”, as defined by ERI (2019);
- Grand River – Significant Valleyland, critical habitat for Species at Risk, species dispersal corridor;
- Floodplains and valley slope/erosion hazards;
- Habitat for species at risk protected under the *Endangered Species Act* (2007); and,
- A 30 m protective buffer from all NHS components.

Environmental management and mitigation recommendations to protect, restore and enhance the natural heritage system for the long-term have been provided for implementation through subsequent stages in the planning process.

The recommended natural heritage system framework described above was used in the development of land use concept plans for the Study Area, and the subsequent evaluation of alternatives, and selection of a preferred option. The land use concept plans were prepared to

assist the evaluation of Settlement Area expansion options through the MCR process and Official Plan review. An analysis of potential impacts associated with the preferred land use concept for North Brantford and Tutela Heights has been provided.

North Brantford and Tutela Heights Subwatershed Study (GM BluePlan Engineering, November 2020)

The purpose of this report was to provide objectives and recommendations to mitigate natural hazards, protect natural waterways and mitigate potential risks, as well as conserve the natural heritage systems and biodiversity. This report was the beginning of a multi-staged approach working towards the completion of a fully comprehensive subwatershed plan for the area.

The Subwatershed Plan included the following:

- Preliminary Baseline Characterization of the Study Area utilizing the best available information, supplemented with any additional information gained in the interim.
- Preliminary analysis to review the impact of development. Modelling of impacts will be completed utilizing the best available information and the use of sensitivity analysis to test the assumptions being made and to test the general resiliency of the proposed mitigation measures.
- Baseline desktop analysis, utilizing the best available information, including key hydrologic and hydrogeological impacts and mitigations, streamflow and temperature regime, groundwater recharge, and total water cycle mass balance.
- Draft recommendations for the management of the Urban Boundary Expansion Lands, including specific objectives, thresholds, targets, and best management practices for development, water/wastewater servicing, stormwater management, and to support ecological needs.
- An outline for the Phase Two Field Investigations.

Grand River Watershed Water Management Plan (GRCA, 2014)

The Water Management Plan addresses the management of surface and ground water resources in the Grand River watershed to 2031. The Watershed Plan pulls together plans such as forestry, fisheries, natural heritage, drinking water source protection, recreation and other planning processes so that linkages can be made for larger scale watershed planning. Section 5.2.1.3.2 of the Grand River Watershed Water Management Plan references Urban Stormwater. MOE's 2003 Stormwater Management Planning and Design Manual states that municipalities within the GRCA jurisdiction are collaborating to compose a list of best practices for stormwater control for both new and existing developments. This was released as the *Best Practice Guide for Reducing Urban Non-point Source Pollution in the Grand and Speed Rivers*. This guide includes thirteen recommendations that fall under three categories, including: improved stormwater management governance; sustainable funding; and enhanced stormwater management education.

Grand River Source Protection Plan (LERSPC, 2021)

Drinking water source protection plans identify the risks to municipal water quality and water supplies, and the policies and programs that will reduce the risks. Volume II of the Grand River Source Protection Plan covers the City of Brantford. Specific policies relating to Stormwater Management within Intake Protection Zones (IPZ) can be found in policy **CB-MC-3.4** and **CB-MC-3.5**.

CB-MC-3.4: To ensure any existing or new discharge from a stormwater management facility within an Intake Protection Zone where such activity is or would be a significant drinking water threat, the Ministry of the Environment, Conservation and Parks shall review or prepare Environmental Compliance Approvals to ensure that terms and conditions are incorporated that, when implemented, cease to be and/or never become a significant drinking water threat.

CB-MC-3.5: To ensure any future discharge from a stormwater management facility, where such an activity would be a significant drinking water threat, never becomes a significant drinking water threat, and in consideration of applications received under the Planning Act or Condominium Act the City of Brantford shall locate future stormwater management facilities outside of the Intake Protection Zone, wherever possible.

3 Existing Subwatershed Conditions

Environmental features within the North Brantford and Tutela Heights subwatersheds Study Areas that were explored through this study include:

- Groundwater resources, including the quantity of water which is recharged and discharged from the groundwater table;
- Surface water resources, including assessment of headwater drainage features, the quantity and quality of water in the watercourses and floodplains, and stream morphologic features, including areas subject to erosion;
- Aquatic features, including aquatic habitat, benthic macroinvertebrate communities, fish communities, fish barriers, crossings, and online ponds; and
- Terrestrial features, including vegetation communities, flora, and wildlife.

It is important to recognize that these environmental features are highly inter-related because of their ecological functions and environmental pathways or linkages. For example, a vegetated floodplain feature may provide conveyance for floods and spring meltwater, provide habitat for plants and animals, and provide shade for the watercourse, thereby maintaining cool water temperatures for fish. Maintaining the function of one feature may require maintaining the form of all inter-related or overlapping features and the linkages to adjacent areas.

The following sections provide an overview of the environmental features and functions within the Study Area. The natural ecosystem that existed prior to human settlement has been altered. Activities that have resulted in change include agricultural practices and the construction of roads, highways, and buildings. Defining the current state of the environment,

as well as the relationship between each environmental feature that is present, is necessary in order to characterize key environmental functions, define opportunities and constraints associated with future development, and to ultimately establish strategies to protect, enhance, or restore environmental features over time.

3.1 Field Assessment Approach

The Phase 1 SWS completed by GM BluePlan (2020) completed some field analyses, but was not able to access all properties, nor complete the full range of investigations required. As such, Aquafor reviewed the previously completed work, and developed a scope for the required additional field work to confirm the features present on these properties.

Since the majority of the lands within the Study Area are privately owned, a three-step process was followed to obtain permission for technical staff to access private property to complete the required field assessments. This included:

1. A letter requesting access was sent to all owners with lands in the Study Area registered in the Municipal Property Assessment Corporation (MPAC) database. This resulted in fairly poor responses. A copy of this letter is provided in **Appendix B**.
2. Where houses were present on a property, Aquafor Beech staff knocked on doors to present the access letter and to request the homeowner grant permission through signing the letter.
3. The City subsequently provided a list of properties which had been purchased by developers. A letter was then provided to these developers to request access to public property.

Through this combined approach, access was granted to 110 properties, including 20 properties owned by the City of Brantford (**Table 3.1** and **Figure 3.1**). This accounted for approximately 42% of the properties within the Study Area.






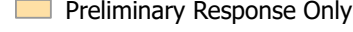

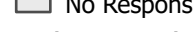
Table 3.1: Summary of Property Access

Property Access Status	Count
Yes	90
City Property	20
Preliminary Response Only	8
No	19
No Response	124
Total	261



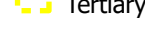
However, the process of receiving permission to access property was delayed due to the poor responses to steps 1 and 2, listed above. While the initial property access letter was sent on November 3, 2021, substantial success in receiving property access was not achieved until May 2022. This delay impacted some of the field investigations, as discussed in **Sections 3.2 – 3.4**.

Where access to private property was not granted, a desktop analysis was attempted to the extent possible. However, since many investigations discussed below require property access for a proper evaluation, these assessments will need to be completed at a later date by the property developer. These assessments must consider the conditions of the subwatershed in which it is located, as documented through this Subwatershed Study, as upstream and downstream conditions will need to be considered as part of the assessment.

Legend

-  Municipal Boundary
-  Road Centreline
-  Watercourse (GRCA)
- Landowner Access:**
-  Yes
-  City Property
-  Preliminary Response Only
-  No
-  No Response

Subwatershed Study Area:

-  Primary
-  Secondary
-  Tertiary

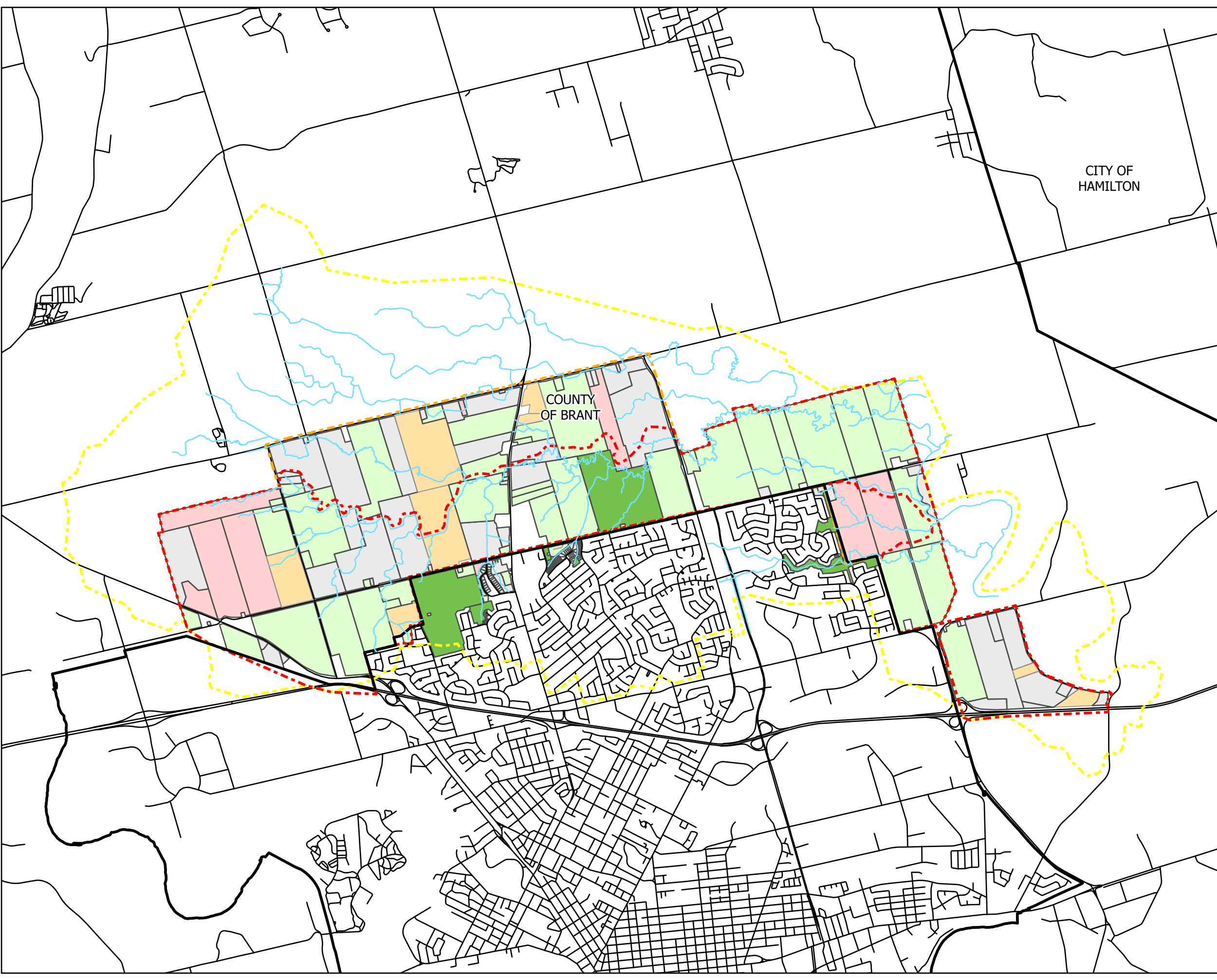
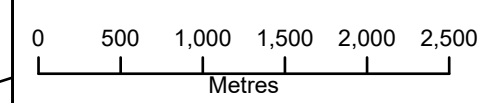


Figure 3.1

Landowner Responses

Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: J.R.



Document Path: D:\Project\City of Brantford\060623_Tools_Highs_Subwatershed_Study\060623\060623_LandownerResponses.mxd

3.2 Groundwater Resources

Groundwater discharge to streams and wetlands provides ecologically significant flows that are generally more consistent in flow rate, water quality and temperature than either surface runoff or shallow interflow. Preserving groundwater recharge is also critical to attenuating storm flows related to urbanization and impervious cover. Maintaining groundwater recharge and discharge is therefore a key aspect of subwatershed protection and management.

North Brantford and Tutela Heights are located in a complex geologic setting. Permeable glacial outwash deposits flank and interleave with upland moraine structures. Low permeability lacustrine deposits are found in the lowland portions of the study area watersheds. This has resulted in a groundwater flow system with highly variable recharge and discharge rates that drive watershed function across many scales.

A key objective of the subwatershed study, specifically related to water resources, is to identify and characterize the hydrogeology of the study area and to develop a conceptual understanding and the tools needed to protect water quality and maintain surface water/groundwater interactions within the study area. A particular area of focus is on quantifying groundwater recharge and discharge and characterizing the connection between surface water and groundwater, which is important in maintaining stream baseflow that supports the local aquatic and terrestrial ecosystems.

The Phase 1 Update work builds on the BluePlan (2020) as well as on recent Source Water Protection studies conducted by Earthfx Incorporated on behalf of the Grand River Conservation Authority (GRCA). These studies and other local studies are summarized below.

3.2.1 Study Area

The North Brantford and Tutela Heights study areas, shown in Figure 3.2, encompasses two separate geographical areas within the city limits. However, to provide a sub-regional context for this study, it was often necessary to examine data and reporting outside the North Brantford and Tutela Heights study areas. The term “study area” is used in this report when discussing the physical setting common to the two subwatershed study areas and, in general, refers to the rectangular area shown in Figure 3.2 bounded by Eastings 557000 to 566500 and Northings 4771000 to 4786500.

3.2.2 Previous Studies

The Phase 1 Update builds on the recent BluePlan (2020) Phase 1 study. The Phase 1 work in 2020 included a preliminary baseline characterization of the study area utilizing best available information. A limited Stage 1 field program was conducted and results from this work, along with visual investigation, identified critical data gaps. No additional hydrogeologic data were collected; however, the findings were used to define the terms of reference for the Phase 1 Update field program.

Earthfx conducted a Tier 3 Water Budget and Risk Assessment study for the Whitemans Creek subwatershed. The study (Earthfx, 2018) characterized the hydrology and hydrogeology of the

Whitemans Creek subwatershed and the surrounding area which included the Tutela Heights study area. The area is mostly agricultural (75% of land use) and includes a number of Provincially Significant Wetlands (PSW's) and sensitive coldwater fisheries. A detailed geologic conceptual model was developed for the study area incorporating recent work by the Ontario Geological Survey (OGS). An integrated groundwater/surface water model of the area surrounding the subwatershed was constructed using the U.S. Geological Survey (USGS) GSFLOW code (model extent shown in Figure 3.3). The hydrologic submodel represents all hydrologic processes including runoff, ET, soil moisture, and snowmelt at a 60-m resolution. All mapped streams, ponds, and wetlands were represented within the integrated model code. The model was calibrated to match transient streamflow, groundwater, evaporation, and snowpack observations at numerous locations. The model was applied to simulate the cumulative effects of pumping, irrigation, drought and groundwater/surface water interaction and was applied to evaluate alternative agricultural water management policies for the subwatershed. The conceptual geologic and numerical models were subsequently refined in the Mt. Pleasant area, located southwest of Tutela Heights, and applied to updated wellhead protection areas (WHPA) for the Mt. Pleasant municipal wells (Earthfx, 2017).

Earthx Incorporated also conducted a Source Water Protection Study on behalf of the GRCA to delineate wellhead protection areas for the St. George and Lynden municipal wellfields (Earthfx, 2018). This study analyzed the hydrology and hydrogeology of the entire Fairchild Creek subwatershed, which includes the North Brantford area (Figure 3.2). A hydrologic model, based on the USGS PRMS code, was developed to estimate groundwater recharge over the Fairchild Creek subwatershed. A steady-state groundwater flow model, based on the USGS MODFLOW-NWT code (Niswonger *et al.*, 2011) was developed to simulate groundwater flow in the bedrock and overburden aquifer systems. The models were calibrated to match observed streamflow at long-term surface water gauges and to match observed groundwater levels.

The work done in developing and calibrating the Fairchild Creek and Whitemans Creek numerical models provided a valuable starting point for extending the local understanding of the North Brantford and Tutela Heights area and their highly variable hydrogeologic setting. Insights obtained from the studies were used to identify locations for new boreholes and other field investigations and provided a regional framework for the interpretation of the data collected.

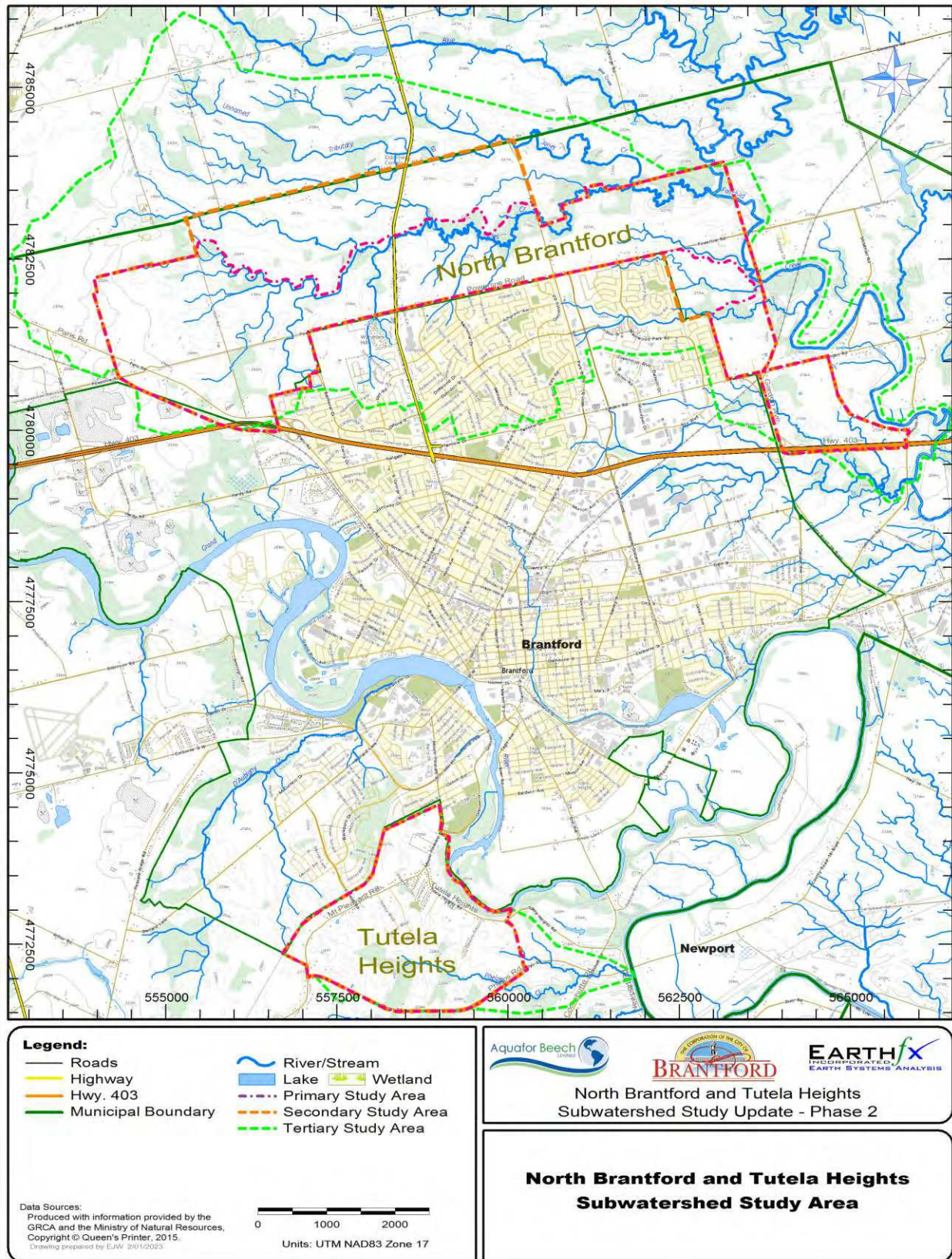


Figure 3.2: North Brantford and Tutela Heights subwatershed study area.

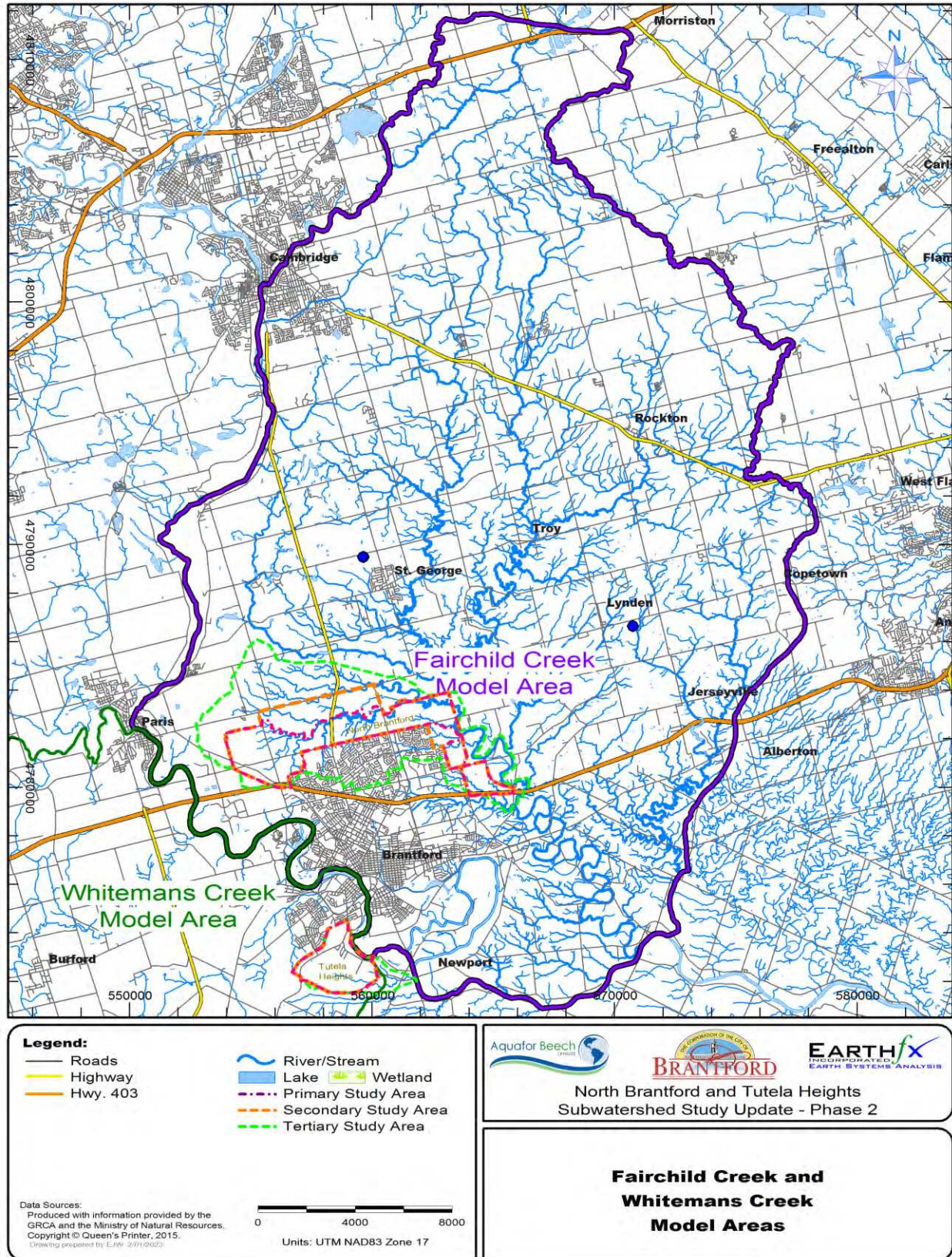


Figure 3.3: Fairchild Creek and Whitemans Creek model areas.

3.2.3 Physical Setting

3.2.3.1 Topography and Physiography

Earthfx compiled a 5-m digital elevation model based on the latest LiDar data for the area. Topography within the North Brantford study area, shown in Figure 3.4, slopes primarily from west to east and ranges from 195 metres above sea level (masl) in the Fairchild Creek valley to 276 masl along the ridge of the Galt Moraine. Topography within the Galt Moraine is characterized as hummocky. A second height of land, about 258 masl, occurs along the western part of the secondary study area boundary and is associated with the Moffat Moraine. East of the Galt Moraine are east-west ridges of shallow-lake glaciolacustrine deposits that are drained by tributaries to Fairchild Creek. A broader area of shallow-lake glaciolacustrine deposits is located south of the primary study area and represents much of the developed portions of North Brantford. The remaining area is gently sloping and is associated with deep lake glaciolacustrine deposits. The streams have carved steeper valleys through these more easily eroded sediments.

The Tutela Heights study area is almost entirely located on the deep water glaciolacustrine deposits. The heights of land follow Tutela Heights Road in the northeast, Mt. Pleasant Road to the northwest, and Phelps Rd. in the south. The height of land, about 235 masl, occurs at the intersection of Mt. Pleasant Rd. and Phelps Rd. Topography generally slopes from these ridges toward Phelps Creek and then towards the east. The lowest elevations, about 188 masl, occur at the confluence of Phelps Creek and the Grand River at the eastern end of the study area. In the north, steep slopes occur in the area between Tutela Heights Road and the Grand River valley. Tutela Heights Road follows a west-east trending ridge of shallow lake glaciolacustrine deposits. Areas of higher relief, associated with the Moffat Moraine, occur 2 km west of the study area.

The physiography of the area surrounding North Brantford and Tutela Heights is very diverse, with portions of several physiographic regions, as defined in Chapman and Putnam (1984), present. These include the Horseshoe Moraines, Norfolk Sand Plain, and Haldimand Clay Plain (Figure 3.5). The till moraines and spillways in the western part of the study area are part of the Horseshoe Moraines, a long moraine system that locally includes the Paris, Galt, and Moffat Moraines. The deposits are mixed till, kame, and sand and gravel terrace deposits. Portions of the moraines are hummocky with significant local depressions and ponds. The depressions can retain water during the spring and serve as areas of focussed groundwater recharge.

The Norfolk Sand Plain is one of two major deltas of glacial Lake Whittlesey and Lake Warren. Typical of deltaic deposits, the soil within the Norfolk Sand Plain is composed predominantly of medium to coarse sand. Deposition of these sands proceeded from west to east, resulting in the partial burial of the Paris, Galt and Moffat moraines. The Haldimand Clay Plain is shown to lie south and east of the study area. Glacial lakes Whittlesey and Warren covered this area and, as a result, there are thick sequences of stratified clay overlying clay till. This physiographic regions map (Figure 3.5) paints an oversimplified picture of the boundaries between the Norfolk Sand Plain and Haldimand Clay Plain. The maps of quaternary geology of

the study area, discussed further on, shows that the deeper lacustrine deposits cover most of the North Brantford area and all of the Tutela Heights area.

3.2.3.2 Bedrock Geology

The study area is underlain by clastic and carbonate sedimentary rocks of Late Ordovician to Middle Silurian age that make up parts of three major depositional sequences (Johnson *et al.*, 1992). A generalized schematic showing the bedrock and overburden geologic units beneath and to the west of the study area is presented in Figure 3.6. The bedrock subcrops become younger from northeast to southwest. On a regional scale, the strata also dip gently to the southwest.

The youngest geologic unit that subcrops in the western portion of the study area is the Salina Group, as shown in Figure 3.7) a thick, complex package of shales, carbonate rocks, and evaporites (anhydrite, gypsum and halite). Within the Salina Group, eight units of formational rank have been recognized in the subsurface in Ontario (Armstrong and Carter, 2010), with the lower two members, occurring beneath the City of Brantford, exhibiting a relative increase in shale content. BluePlan (2020) indicated the Salina Fm. was karstic southwest of the North Brantford study area. The Salina is likely to be thin and discontinuous in the study area with only the uppermost (A sub-member) present. The A sub-member consists of a tan dolomite and grey mudstone (GRCA, 2008). Two boreholes along Cockshutt Road in the Tutela Heights study area identified shale at the bedrock surface, the remaining boreholes and all boreholes in the North Brantford study area indicated limestone at the top of bedrock.

The Middle to Late Silurian Guelph Formation, which comprises thinly- to thickly-bedded fossiliferous dolostones, typically fine- to medium-crystalline in texture, deposited in both open marine and lagoonal environments (Brunton, 2009), subcrops in the eastern part of study area (Figure 3.7). The Guelph formation is generally considered a good water-supply aquifer.

The deeper bedrock units underlying the study area have been referred to by different naming conventions. For this study, the new integrated nomenclature by Brunton (2009) was followed. Accordingly, the Eramosa Member of the Eramosa Formation underlies the Guelph Formation. This unit is composed typically of medium to thick irregular beds of buff, fine to medium crystalline, sucrosic dolostone (Telford, 1976; Liberty, *et al.*, 1976). The lower part of the Eramosa Formation includes the Vinemount Shale Beds (Vinemount Member), which act as a regional aquitard restricting the downward movement of groundwater. The Vinemount Shale Beds effectively isolate the shallow bedrock aquifer system from the lower bedrock units.

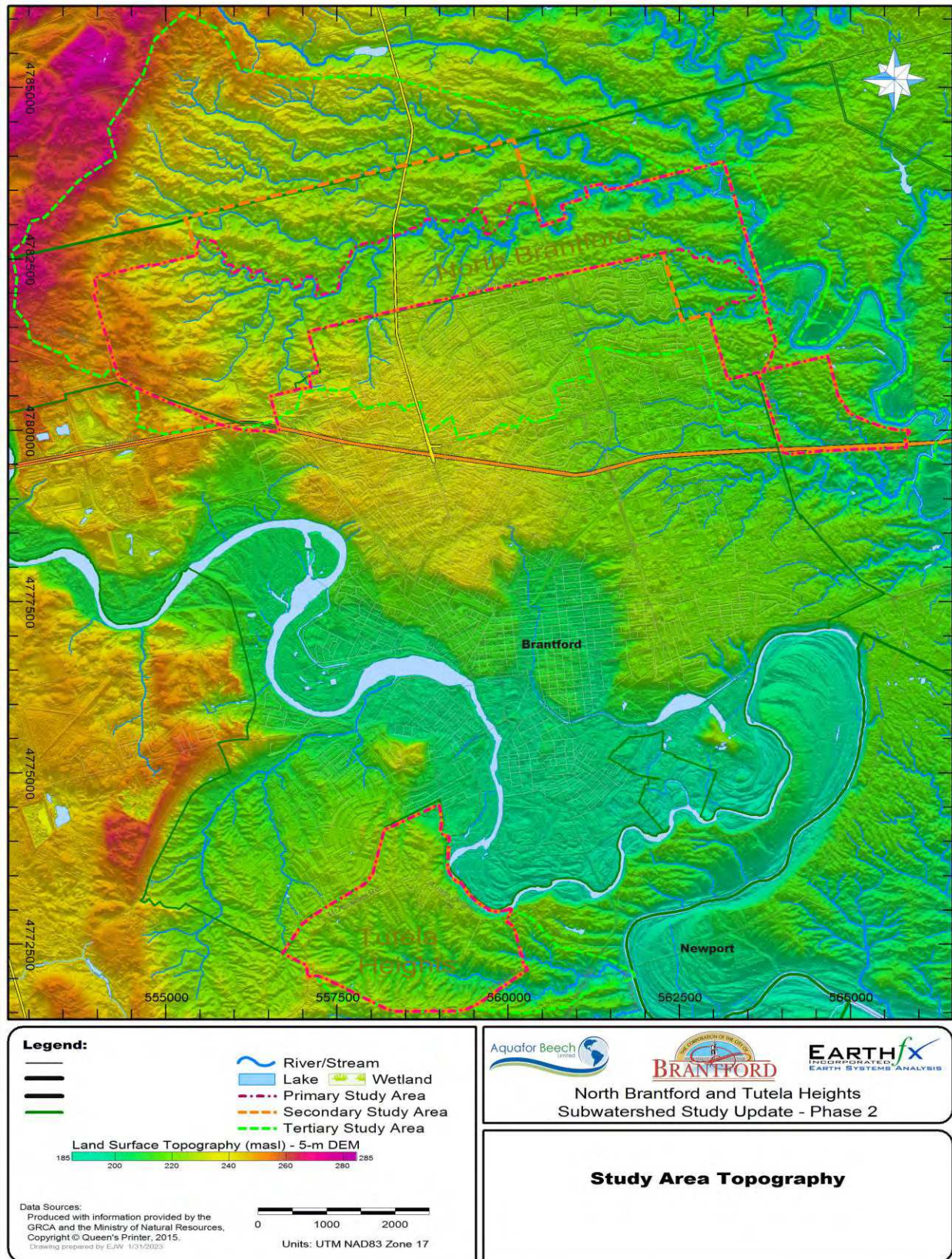


Figure 3.4: Study area topography, in metres above sea level (masl).

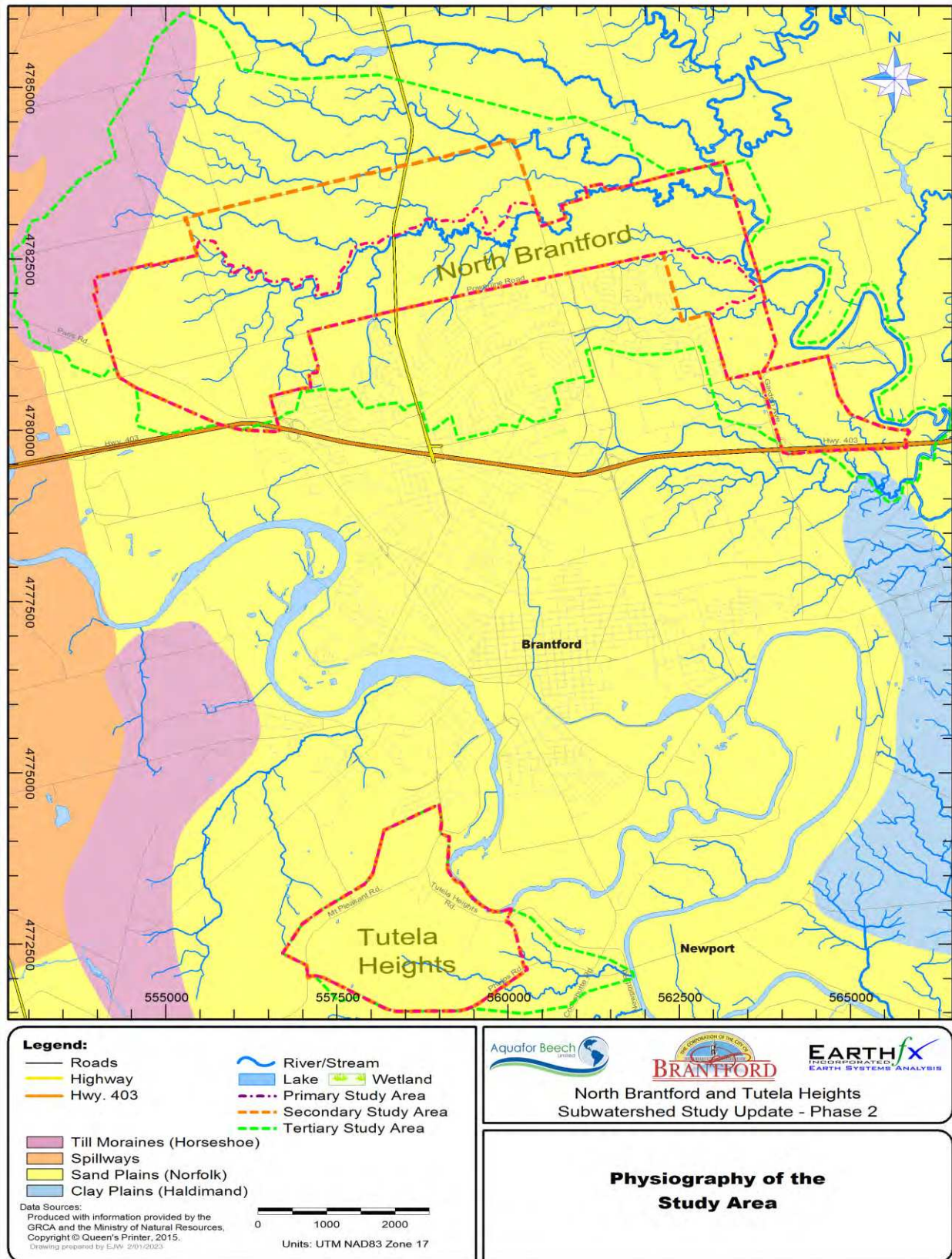


Figure 3.5: Physiographic features within the study area (after Chapman and Putnam, 1984).

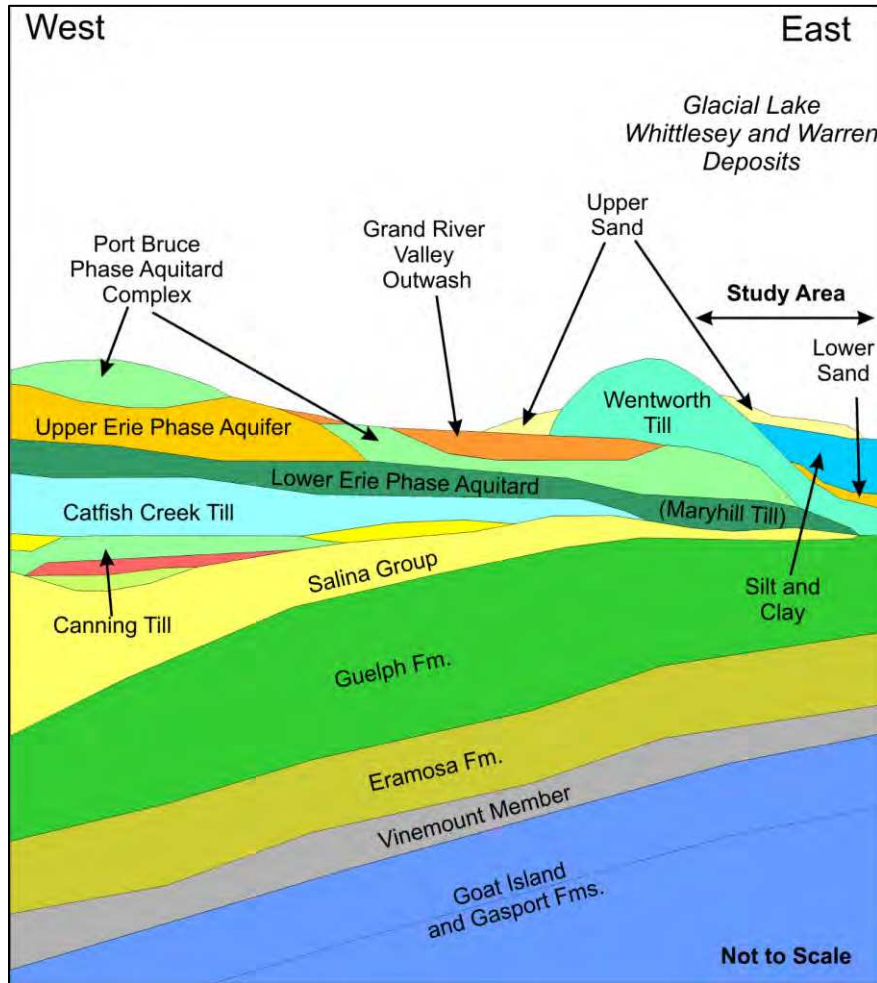


Figure 3.6: Generalized schematic showing the bedrock and overburden geologic units (after Earthfx, 2018).

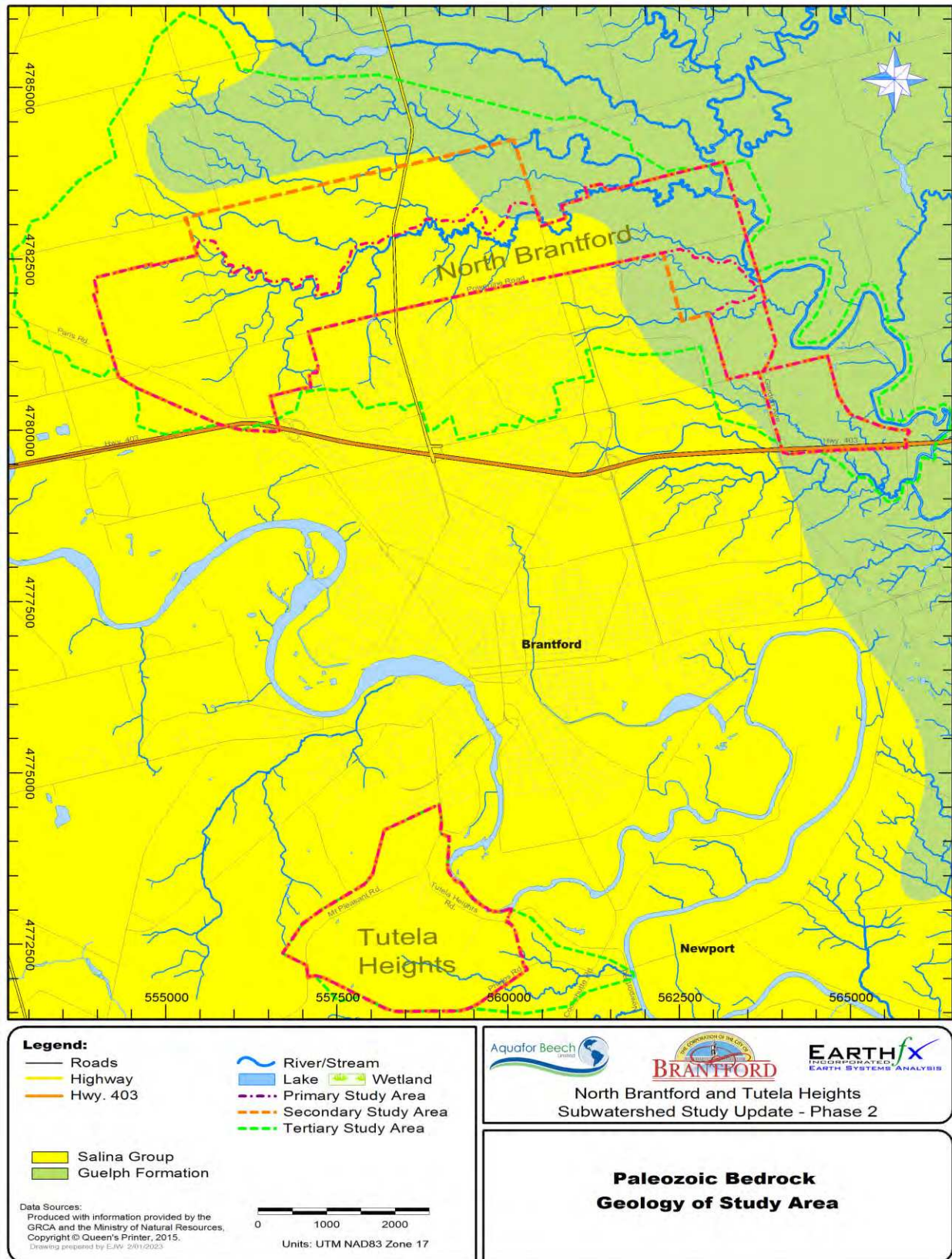


Figure 3.7: Paleozoic bedrock geology of the study area (data from OGS, 2010).

Next in the succession are the thick, medium- to coarse-grained dolostones that form the caprock of the Niagara Escarpment. These rocks are mapped as the Goat Island and Gasport Formations (Liberty *et al.*, 1976a) and were formerly referred to as the Amabel Formation. The Goat Island and Gasport Formations are a regionally-important source of groundwater. Brunton and Brintnell (2011) noted that the variable paleotopography on the Gasport Formation was the main control on the character and presence or absence of the overlying Goat Island and Eramosa Formations. The Goat Island Formation is divided into two members. The Niagara Falls Member is composed of finely-crystalline, crinoidal grainstones and is overlain by the chert-rich finely crystalline Ancaster Member (Brunton, 2009). These deeper bedrock units outcrop to the east at the Niagara Escarpment and within the Dundas Bedrock valley near Copetown. Groundwater levels and flow directions are influenced by regional drainage towards the valley.

3.2.3.2.1 Bedrock Surface

The bedrock surface in the Fairchild Creek subwatershed was interpolated from numerous water well logs in the Ontario Ministry of Conservation and Parks (MECP) Water Well Information System (WWIS) database (Earthfx, 2018). The bedrock surface within the study area is presented in Figure 3.8. As noted earlier, the regional bedrock surface dips gently to the southwest. Locally, the surface slopes to the east towards the Dundas bedrock valley near Copetown. Higher bedrock elevations (greater than 220 masl) occur just south of the North Brantford study area. A local low is (less than 160 masl) is interpreted under the Tutela Heights study area.

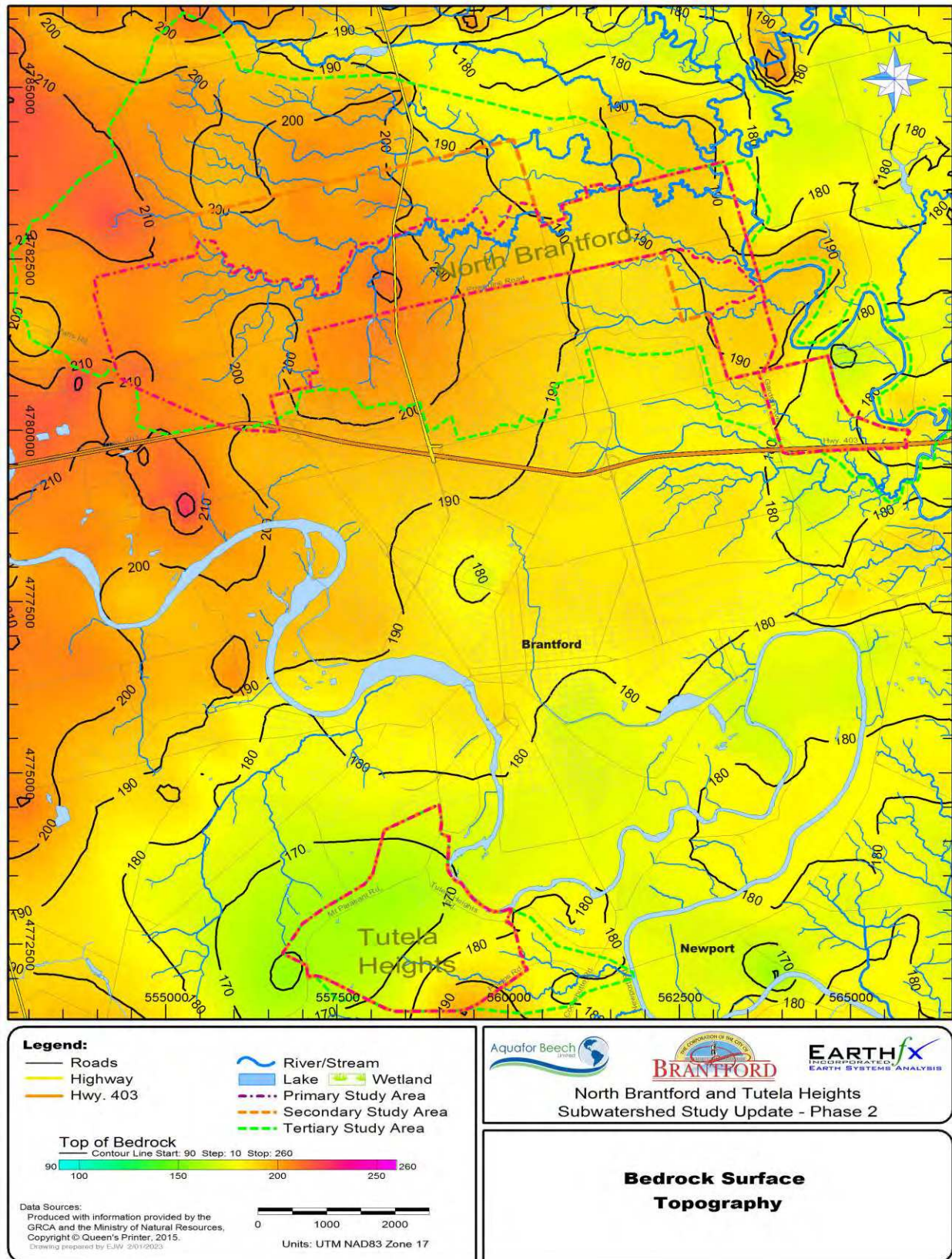


Figure 3.8: Bedrock surface topography (after Earthfx, 2018).

3.2.4 Quaternary Geology

The materials overlying bedrock in the study area are mainly glacial, glaciofluvial, and glaciolacustrine sediments deposited in the latter part of the Wisconsin stage of the Pleistocene Epoch (see Figure 3.6). The tills in the study area are generally associated with the Port Bruce phase of the Late Wisconsin, during which a number of ice advances out of the Lake Ontario basin resulted in the deposition of extensive till sheets as well as the Paris, Galt, and Moffatt end moraines that occur in the western portion of the study area. A relative time-distance diagram of the tills is shown in Figure 3.9.

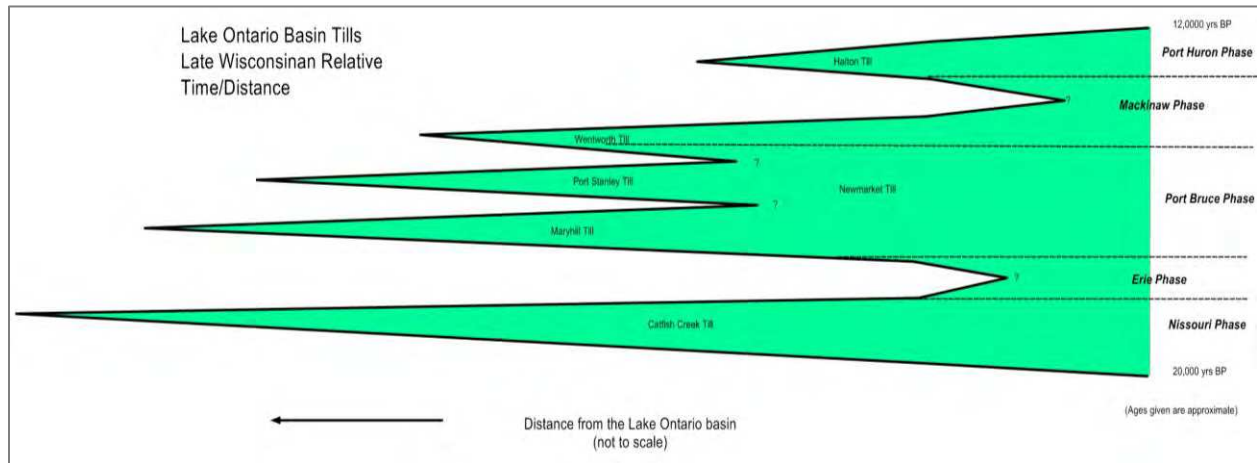


Figure 3.9: Late Wisconsin (Michigan Subepisode) till relative time-distance diagram (Karrow, 2005)

Surficial geology for the study area is shown in Figure 3.10 and is based on a digital compilation by the Ontario Geological Survey (OGS, 2010) of earlier maps. There are only five significant units that are exposed in the area. The Wentworth Till is the youngest of the till units underlying the surface area. It was mapped at surface by Karrow (1987) where it outcrops west of the North Brantford study area, making up the Paris, Galt, and Moffat Moraines. The Wentworth Till is generally a sandy-silt to silty-sand till and locally can be very stony. Water well records strongly suggest that there are older tills at depth, likely the Port Stanley and Maryhill tills (Port Bruce Phase) and possibly, the older (Erie Phase) Catfish Creek Till (Figure 3.6). These are tills associated with the phases of ice advancement out of Lake Ontario are readily correlated in boreholes record because the ice advancement processes resulted in a large-scale regional deposition pattern. The sediments separating the tills, if present, are probably mainly glaciolacustrine deposits of silt and fine sand.

The Mackinaw phase followed the Port Bruce phase and was mainly a time of ice recession from the area with active glaciofluvial and glaciolacustrine sedimentation. The extensive sands and gravels of the Grand River outwash were deposited at this time (Bajc and Dodge, 2011) and occur mainly west of the study area. The Erie-Ontario ice lobe later re-advanced through the study area as far as the Paris Moraine, overriding areas of outwash and depositing the Wentworth Till, a very silty, often stony, sand diamicton (Karrow, 1993; Bajc and Dodge, 2011).

Both the advance and retreat of the Wentworth ice were accompanied by deposition of extensive proglacial outwash, along with glaciolacustrine sedimentation where outwash flows reached glacial Lake Whittlesey (Cowan, 1975; Barnett, 1978). The sandy outwash deposits can be seen mainly in the western part of the North Brantford area. Finer-grained materials were deposited to the east and form the thick glaciolacustrine deposits underlying most of the North Brantford and Tutela Heights areas.

The total overburden thickness is highly variable, with areas of thinly-covered bedrock in the river valleys (**Figure 3.11**). Overburden thickness exceeds 70 m under the moraines along the western portion of the North Brantford study area. It also exceeds 70 m in the southern part of the Tutela Heights study area primarily due to the depression in the bedrock surface.

Figure 3.45 shows a west to east section across the North Brantford study area illustrating the sequence of stratigraphic unit in comprising the bedrock and overburden. The section location is shown on the inset map. Lithologic logs for boreholes in the MECP WWIS database having good quality location data and geologic descriptions, located within 250 metres of the section line) are posted on the sections along with logs for the new boreholes drilled for this study. The nomenclature for the geologic units follows that used in the Tier 3 Water Budget Assessment for the Whitemans Creek subwatershed (Earthfx, 2017) and the Fairchild Creek model development (Earthfx, 2018). A west to east section through Tutela Heights is shown in Figure 3.46.

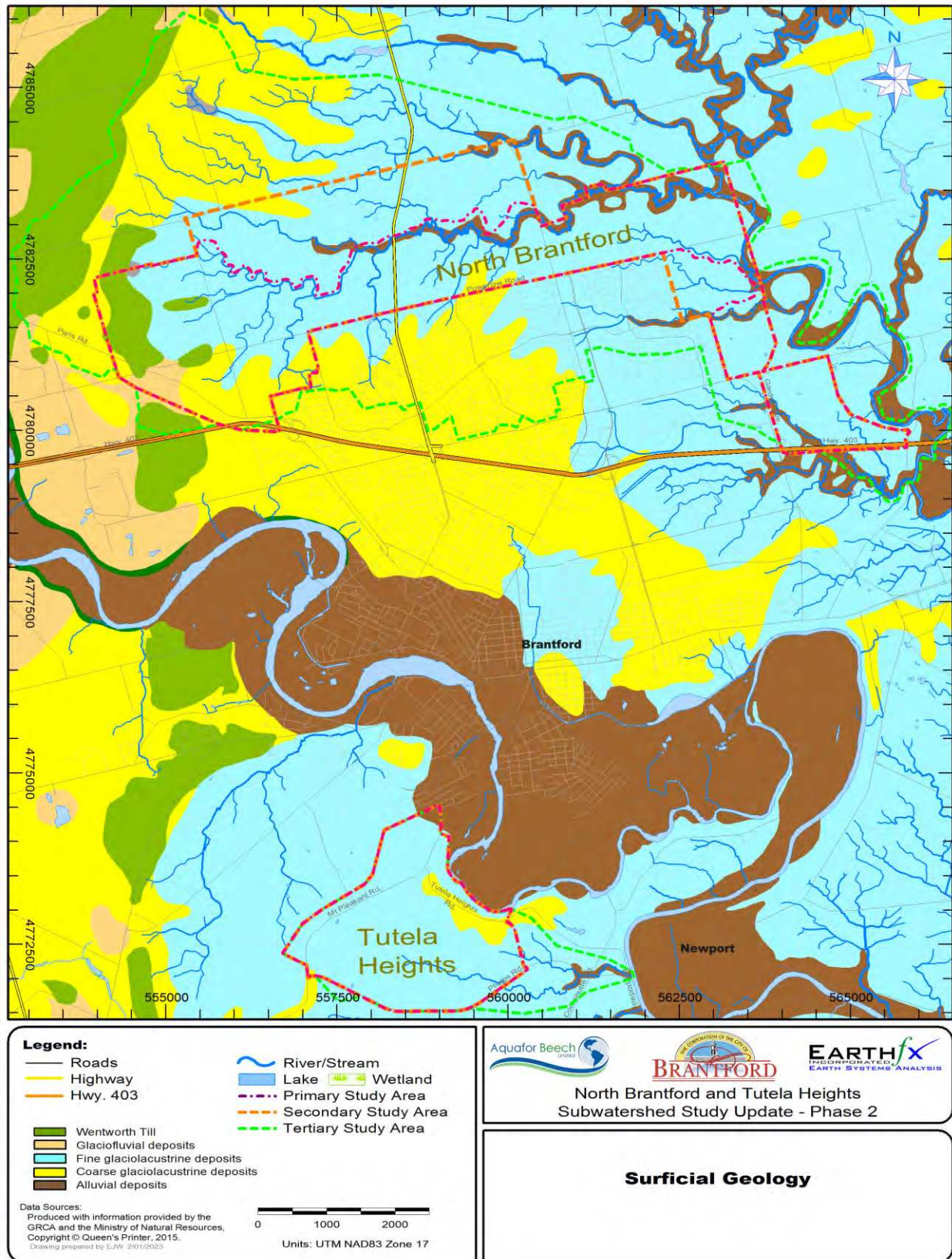


Figure 3.10: Surficial geology of the study area (after OGS, 2010).

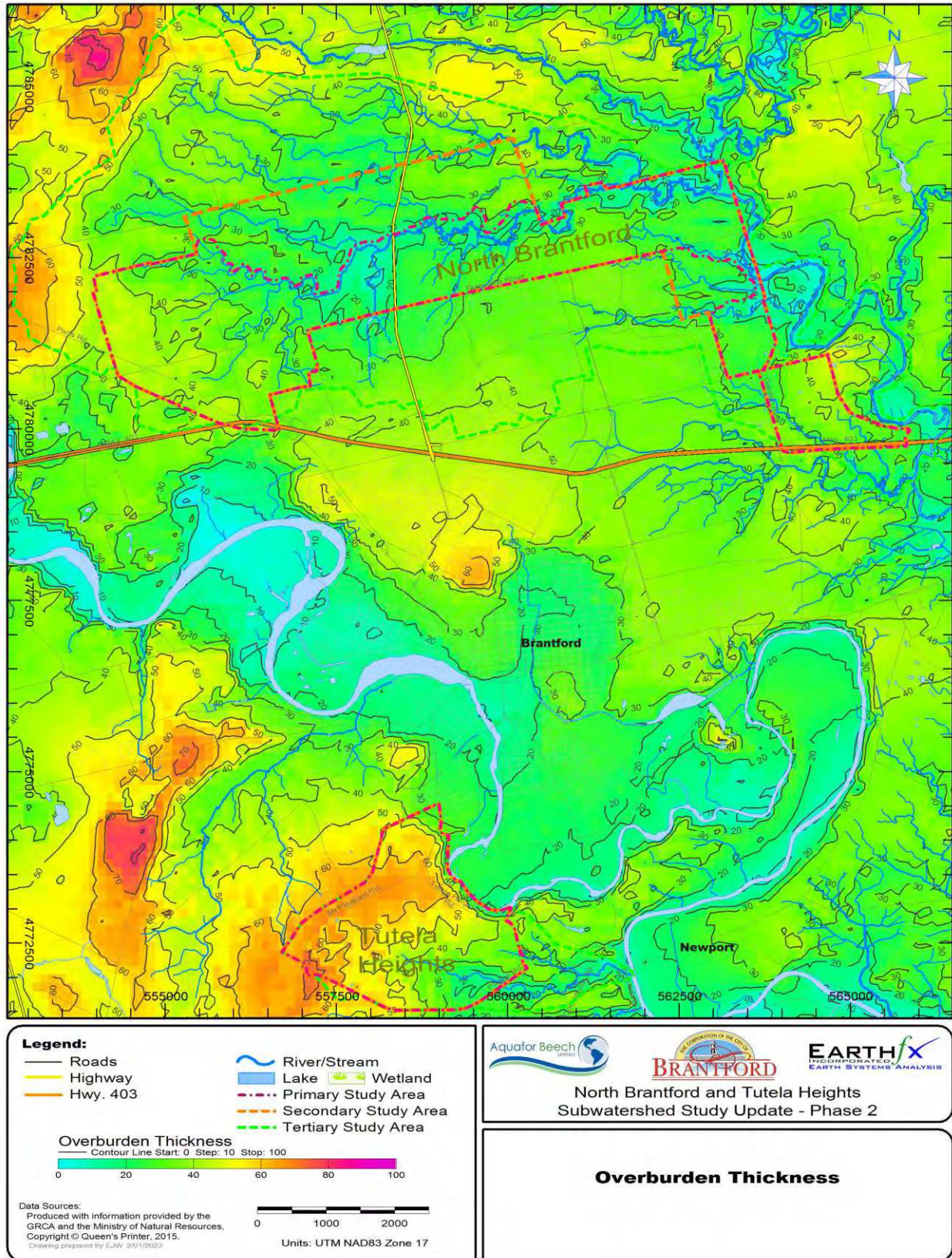


Figure 3.11: Overburden thickness in the study area.

3.2.5 Field Program

3.2.5.1 Drilling and Monitoring Well Installation

Four nested (shallow and deep) monitoring wells clusters were installed at three locations in North Brantford and one cluster in Tutela Heights (two monitors each at MW1-MW4, for a total of 8 monitoring wells). Three supplemental single depth monitoring wells were drilled, two in the eastern part of North Brantford and one in the eastern part of Tutela Heights (MW5-MW7, each with one monitoring interval). The borehole locations are shown in **Figure 3.13**. The locations of other wells with geologic information (of varying quality) are also shown on **Figure 3.13**. The purpose of the drilling program was to supplement existing information and to define local geologic and hydrogeologic conditions. The boreholes were equipped with monitoring wells and loggers to record seasonal fluctuation of groundwater levels. The nested well clusters, with deep and shallow wells, provide additional data on groundwater gradients (vertical differences in groundwater levels with depth).

The number of wells installed was based on recommendations from BluePlan (2020). Initial sites were selected based on insights obtained from the previous work in the area. In some cases, site access constraints required adjustments to the final well locations. Location details are shown in **Figure 3.12** through **Figure 3.18**. All installation, logging, surveying, and testing of the new wells was conducted according to industry standards by Whitewater Hydrogeology.

3.2.5.2 Geologic Logs

Hollow-stem continuous-flight augers were used for the geologic drilling and installation of the monitoring wells (Figure 3.12). No drilling fluids were used and disturbance to the native geologic materials was minimal. The monitoring wells were constructed of 2" diameter PVC to allow for water level monitoring and slug testing, and all met Ontario Regulation 903, as amended. The wells were first developed to improve hydraulic connection with the native material and ensure collection of representative water levels and samples. Construction details are provided in Table 3.2.

The sediments encountered were predominantly low permeability silts and clays, with the exception of MW2, which encountered a 7 m thick sequence of coarse sand at depth. Geologic logs for all wells are provided in **Appendix R**.



Figure 3.12: Well drilling at MW-1 (left) and well completion at MW-4 (right).

Table 3.2: Well construction details.

Name	Easting	Northing	Ground Elv. (masl)	Stick-Up (m)	Depth (m)	Screen Interval (mbgs)		Water Level (mbtoc)	Logger Installed	Slug Test
MW1c-shallow	555845	4781293	231.97	0.0	6.18	4.66	6.18		Y	Y
MW1c-deep	555844	4781295	231.83	0.0	17.06	15.54	17.06		Y	Y
MP-1	555845	4781294	244.71	0.0	1.05	0.15	1.05	dry	Y	Y
MW2c-shallow	554391	4782878	250.25	0.0	6.18	4.88	6.18		Y	Y
MW2c-deep	554387	4782877	250.15	0.0	12.73	11.21	12.73		Y	Y
MP-2	554389	4782878	245.74	1.0	1.05	0.15	1.05	dry	N	
MW3c-shallow	555384	4784637	240.18	1.0	5.65	3.13	4.65	1.88	Y	Y
MW3c-deep	555384	4784637	240.18	1.0	13.29	10.24	13.29	flowing	Y	
MP-3	555384	4784640	237.66	1.0	1.05	0.15	1.05	1.71	N	Y
MW4c-shallow	558623	4772658	224.33	0.7	6.14	4.62	6.14	2.62	Y	Y
MW4c-deep	558621	4772654	223.37	0.7	18.39	15.35	18.39	6.19	Y	Y
MP-4	558622	4772659	227.28	1.0	1.05	0.15	1.05	dry	N	Y
MW5d	560311	4783486	225.03	0.7	14.87	11.83	14.87	4.44	Y	Y
MP-5	560311	4783486	210.01	1.0	1.05	0.15	1.05	dry	Y	Y
MW6d	563666	4780843	216.69	0.76	15.01	11.97	15.01	3.81	Y	
MP-6	563665	4780844	216.23	1.0	1.05	0.15	1.05	dry	N	
MW7d	560350	4772205	212.68	0.85	15.25	12.21	15.25	6.91	Y	Y
MP-7	560351	4772205	219.08	1.0	1.05	0.15	1.05	dry	N	Y

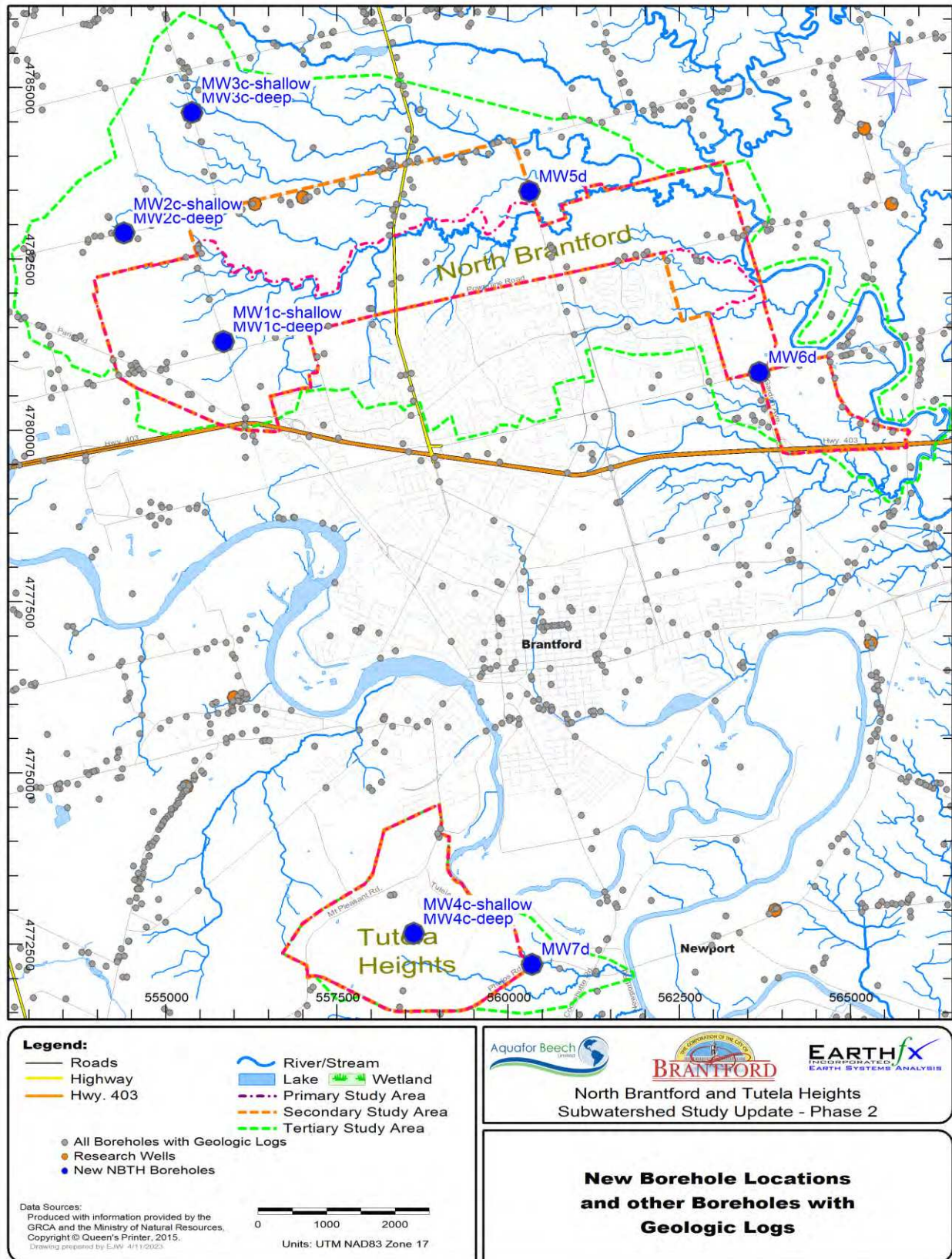


Figure 3.13: Location of new boreholes and other boreholes with geologic information.



Figure 3.14: Location of MW3 (Clarke Rd. south of German School Rd.).

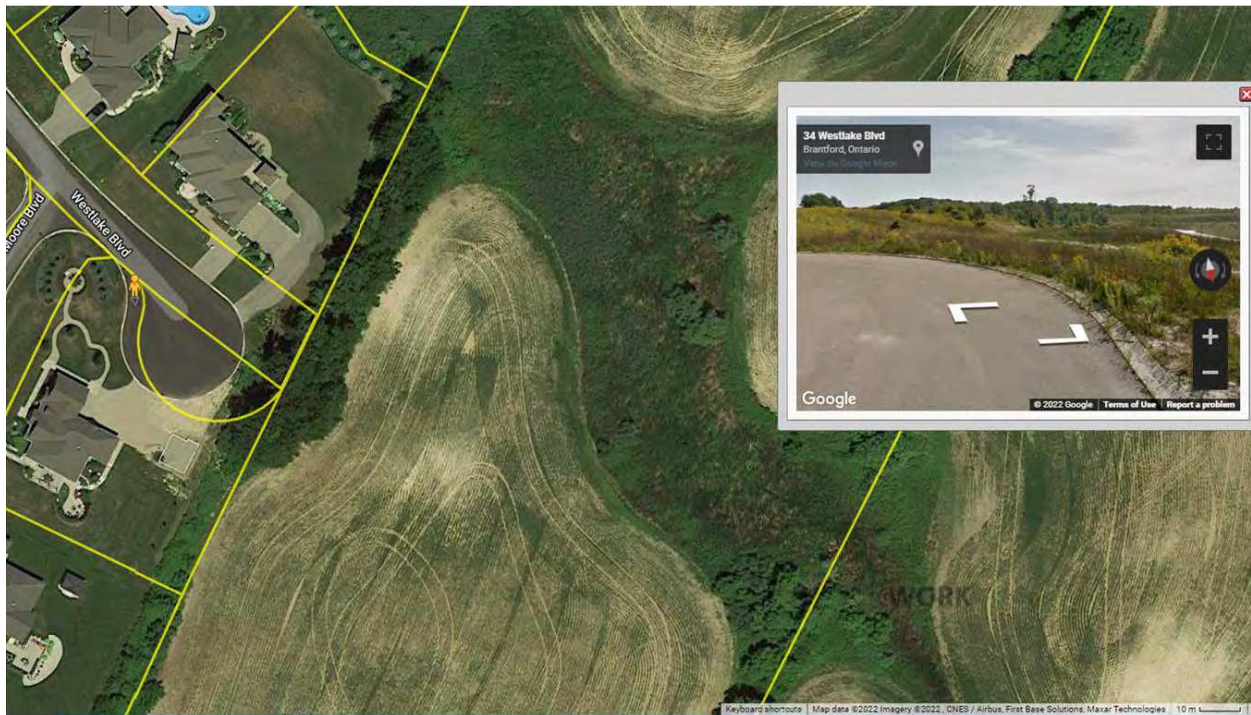


Figure 3.15: Location of MW4 (Westlake Rd. at Moore Rd.).

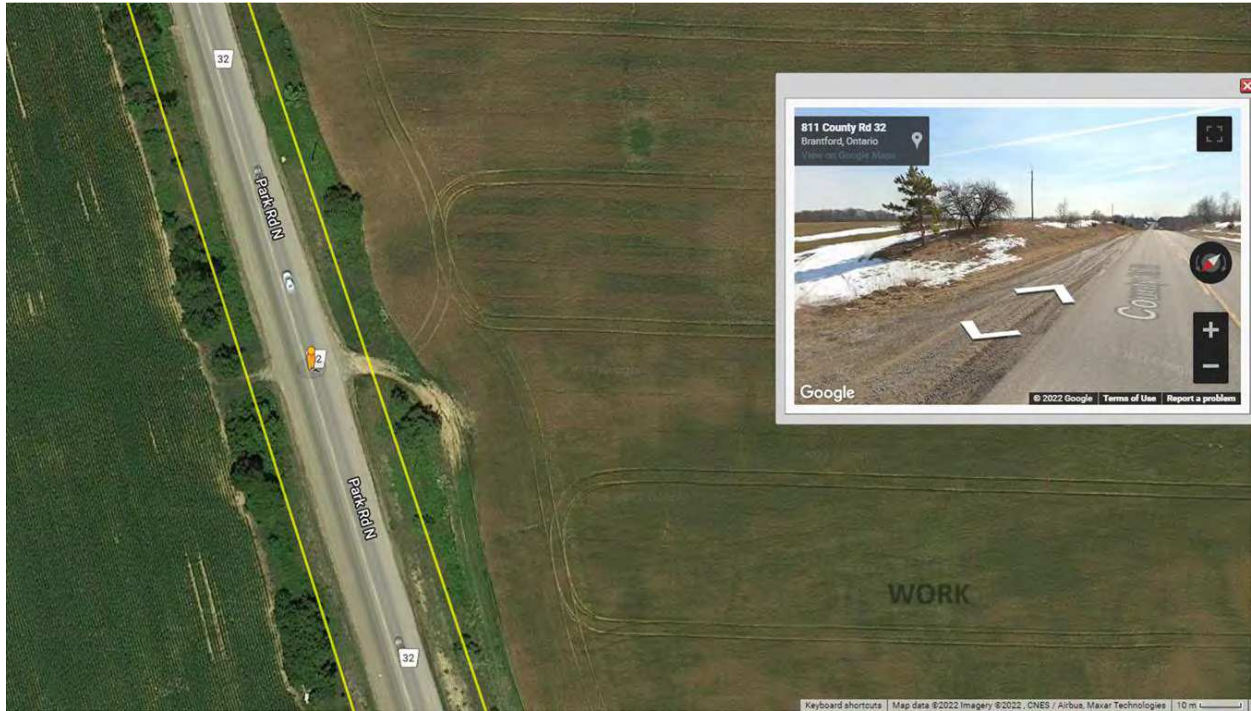


Figure 3.16: Location of MW5 (Park Road N. north of Powerline Rd.).



Figure 3.17: Location of MW6 (East end of Lynden Rd. at Garden Ave.).



Figure 3.18: Location of MW7 (Tutela Heights Rd. east of Rue Chateaux Terrace).

3.2.5.3 Single Well Response Tests

Single well response tests (SWRTs) were conducted at the monitor locations to provide information on the hydraulic conductivity of the formation. Water levels in the wells were raised by injected a measured volume of water and the water levels are monitored over time as they declined. The SWRTs were analyzed using the Hvorslev (1951) method in which the outflow from the well at a selected time is assumed to be proportional to the hydraulic conductivity of the soil and the residual head difference. The well radius (a factor in the Hvorslev relation) includes the well screen and the sand pack. The ratio of horizontal to vertical hydraulic conductivity (anisotropy) was assumed to be equal to 3.0.

Figure 3.19 shows the well response in terms of residual drawdowns for the SWRTs. The response in wells OW2-S and OW2-D were too fast to record and indicate very high hydraulic conductivity for the sands encountered in the boreholes (see Figure 3.20).

Conversely, Well OW1-D shows an extremely slow response, indicative of a very low hydraulic conductivity. The other hydraulic conductivity values ranged between 2.2×10^{-8} and 1.6×10^{-6} m/s, typical for glaciolacustrine materials ranging from clayey silt to silty fine sand.

Table 3.3: Summary of hydraulic conductivity testing.

Well	Well Radius (m)	Effective Well Radius (m)	Screen Length (m)	Hydraulic Conductivity (m/s)
OW1-S	0.0254	0.176	1.524	1.09×10^{-7}
OW1-D			3.038	7.83×10^{-9}
OW3-S			1.524	2.77×10^{-6}
OW3-S (dup)			1.524	1.56×10^{-6}
OW4-S			1.524	2.23×10^{-7}
OW4-D			3.038	3.36×10^{-7}
OW5-D			3.038	2.19×10^{-8}
OW7-D			3.038	3.27×10^{-8}

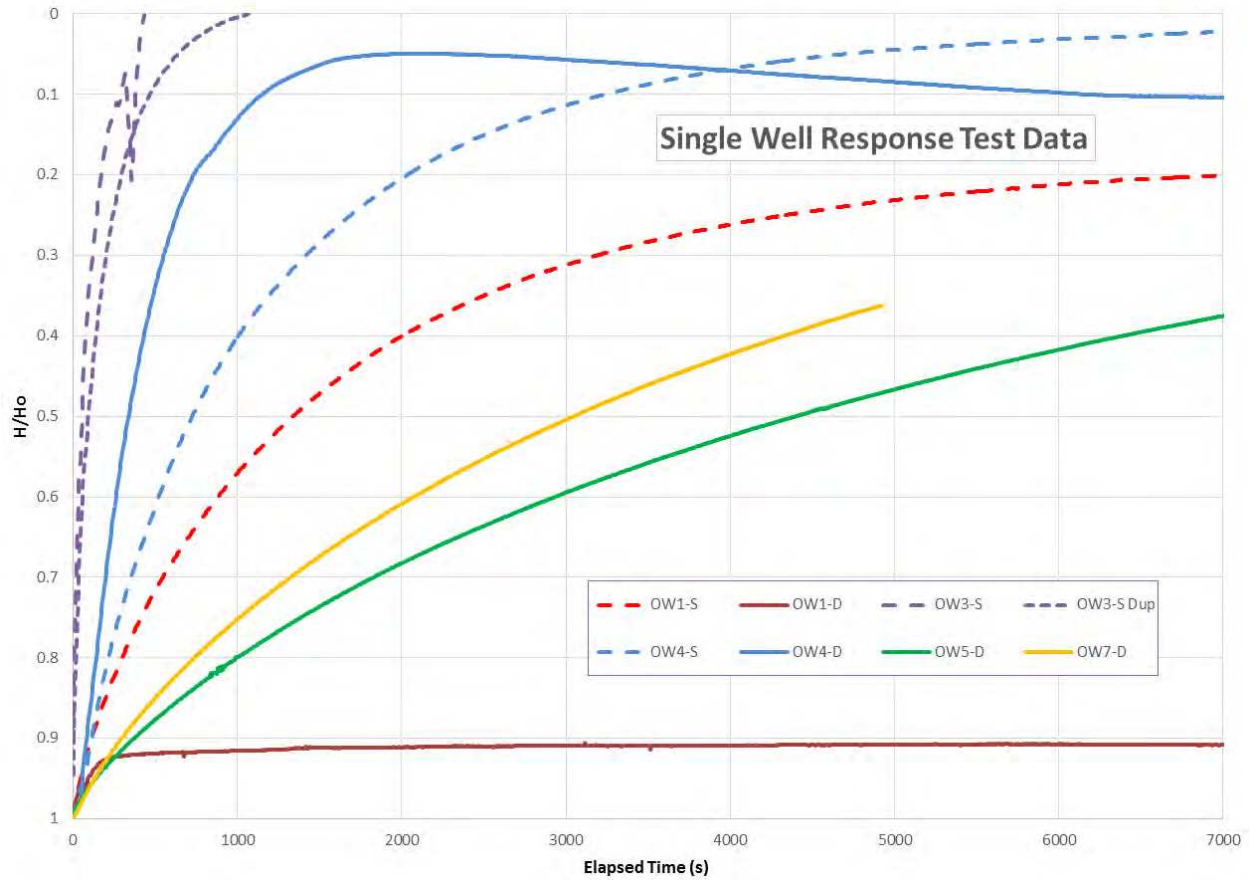


Figure 3.19: Residual drawdowns versus time for single well response tests.



Figure 3.20: Fractures in silt/silt clay matrix filled with fine sand at MW-1 (left) and coarse sand encountered at MW2-D (right).

3.2.5.4 Groundwater Level Monitoring

Groundwater level monitoring using data loggers was conducted for a 6-month period to assess seasonal fluctuations in groundwater levels and to assess response to recharge events. Data from nearby Provincial Groundwater Monitoring Network (PGMN) sites were to be compiled for comparison and assessment against longer-term trends however the groundwater level data have not been updated by MECP since November 2018. The GRCA has recently released current data for their wells and we were able to compile a recent record for a nearby well in Burford, located about 12 km west of the Tutela Heights study area.

Figure 3.21 presents the observed groundwater groundwater levels at MW1-S and MW1-D, located in the western part of North Brantford for May to November 2022. Earthfx also obtained and processed the Canadian Surface Prediction Archive (CaSPAr) rainfall data for the same period. The Canada Precipitation Analysis data set (CaPA_fine) contains hourly precipitation data interpolated to a 2.5 km grid. The data were summed to create a daily coverage that starts on March 3, 2018. The data set is extremely useful because there are few remaining operational Environment Canada rainfall gauges in proximity to the study area. The CaSPAr data are presented with an inverted scale on the secondary y-axis of the hydrograph. The hydrograph shows that groundwater levels are higher at depth within the formation and that the shallow well responds, although in a subdued manner, to larger rainfall events while the deeper well does not. Both wells show the prolonged decline (recession) in water levels during the summer and a small recovery in the fall.

Figure 3.22 presents the observed groundwater groundwater levels at MW2-S and MW2-D for May to November 2022. The hydrograph shows that groundwater levels are higher in the shallow well at this location. The deeper well shows a subdued response to rainfall events while the shallow well only responds to spring rainfall events and then has a level response during the summer, possibly having gone dry. MW3-S (Figure 3.23) shows a little more response than MW1-D, while wells MW5-D (Figure 3.24) and MW6-D (Figure 3.25) show responses typical of the deeper wells.

Figure 3.26 presents the observed groundwater groundwater levels at MW4-S and MW4-D, located in the centre of the Tutela Heights area. The hydrograph shows that groundwater levels are higher at depth within the formation and that the shallow well responds very slightly to larger rainfall events. The deeper wells, MW4-D and MW7-D (Figure 3.27), located to the east, show similar declines and lack of response to rainfall events.

Figure 3.28 shows a long-term (20-yr) hydrograph for PGMN W0000065-4 located in Burford. Water levels at MW4-S and MW4-D are plotted on the secondary y-axis for reference. As can be seen, the hydrograph shows that the PGMN well hit a 20-year low water level in February 2023 and did not show a typical fall recovery. This significant regional scale drought has likely affected all of the new wells, making interpretations of groundwater conditions very difficult at this time.

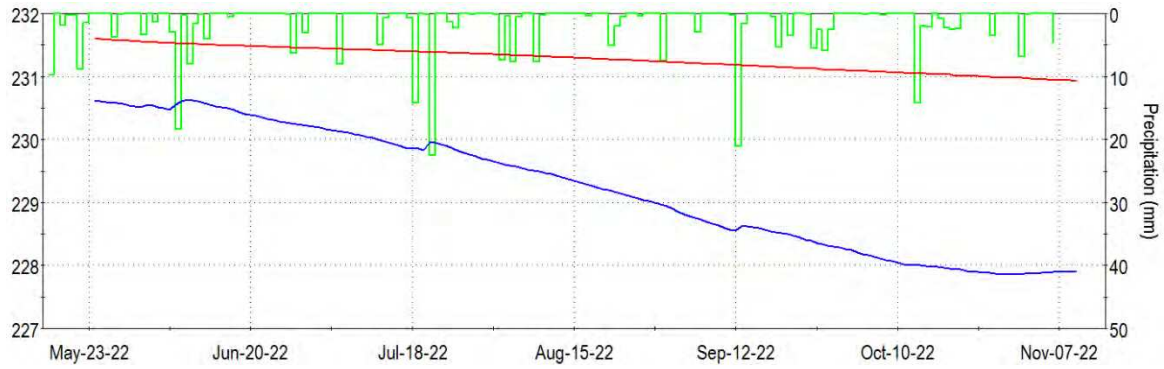


Figure 3.21: Observed groundwater levels at MW1-S (blue) and MW1-D (red) along with CASPAR rainfall data (green) for the same period.

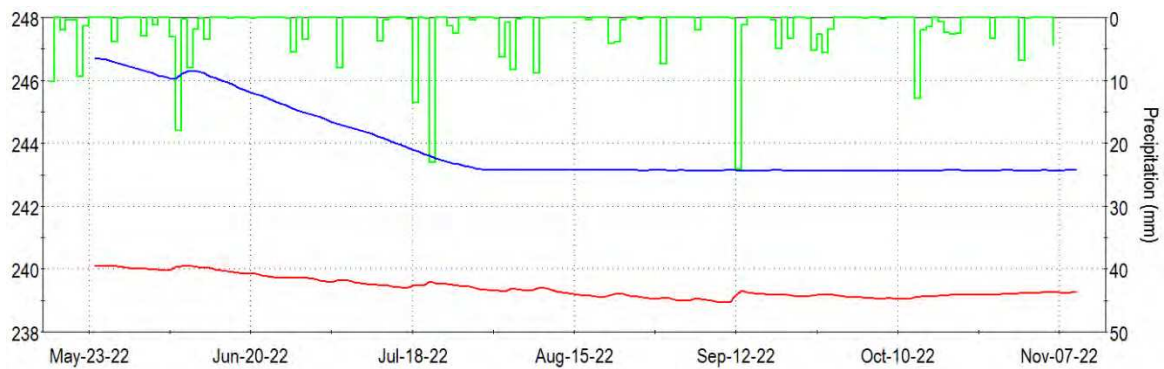


Figure 3.22: Observed groundwater levels at MW2-S (blue) and MW2-D (red).

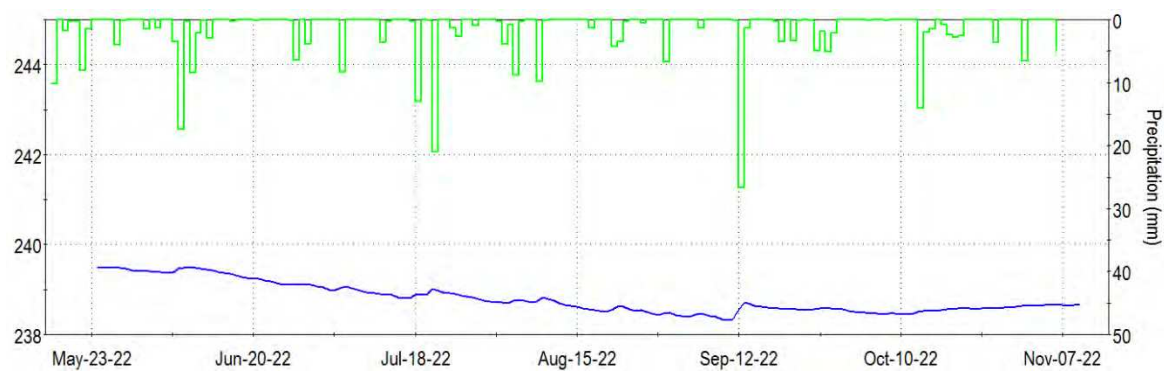


Figure 3.23: Observed groundwater levels at MW3-S.

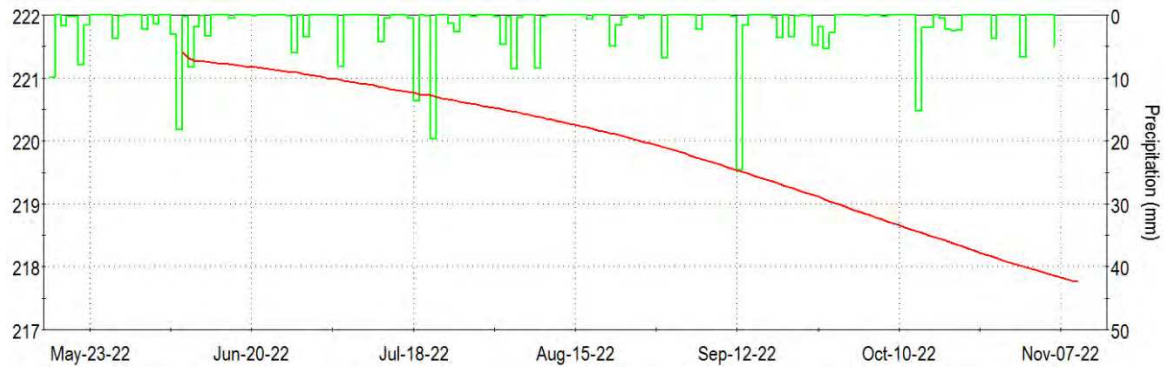


Figure 3.24: Observed groundwater levels at MW5-D.

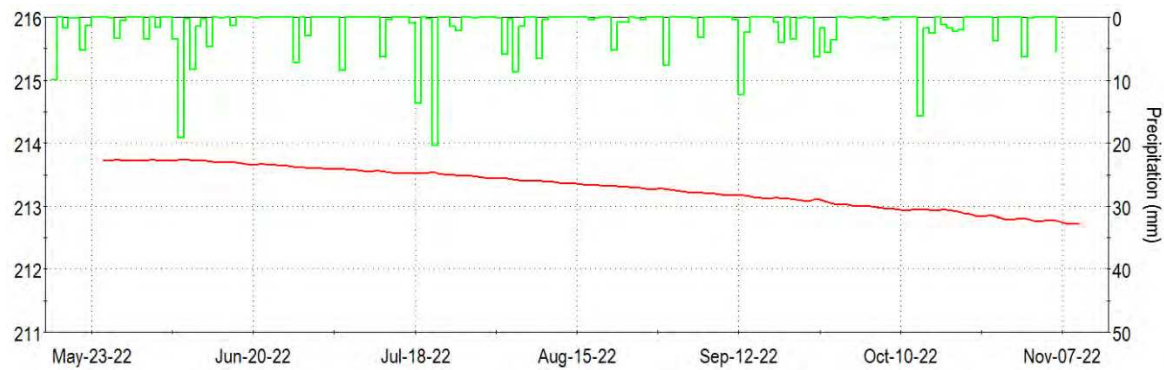


Figure 3.25: Observed groundwater levels at MW6-D.

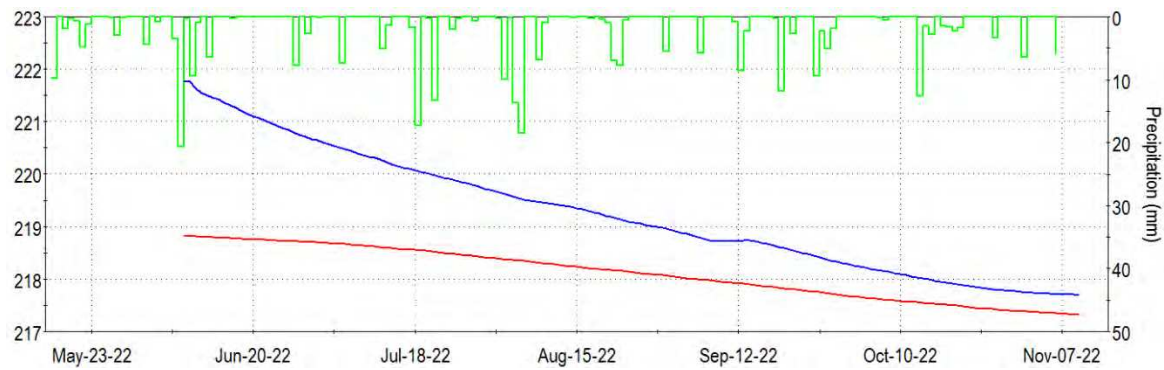


Figure 3.26: Observed groundwater levels at MW4-S (blue) and MW4-D (red).

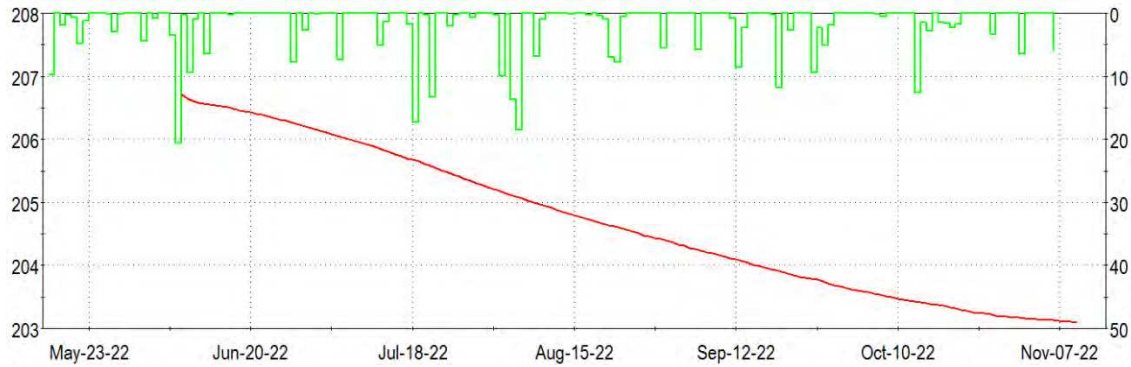


Figure 3.27: Observed groundwater levels at MW7-D.

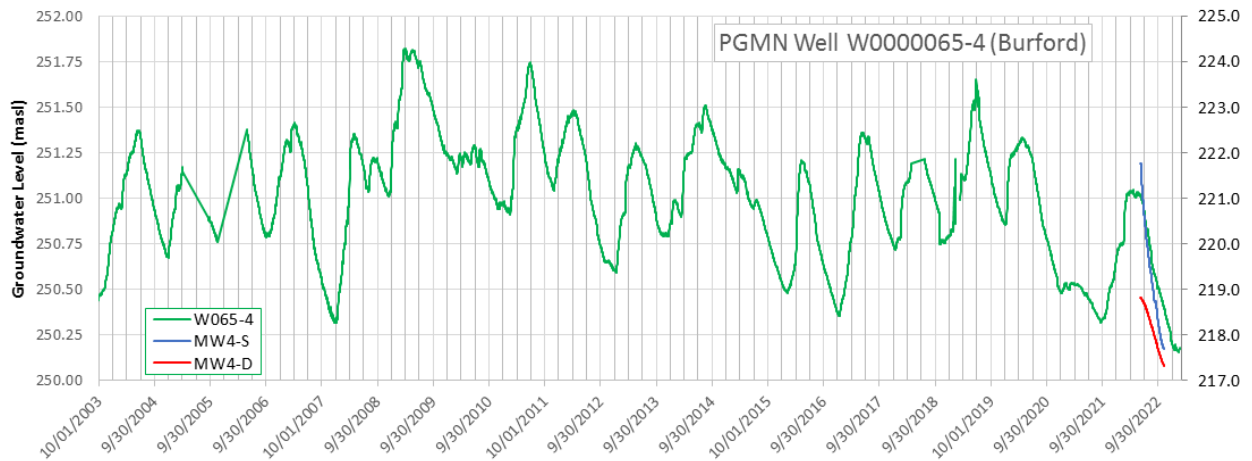


Figure 3.28: Long-term hydrograph for PGMN Well W0000065-4 in the Burford area and wells MW-4S and MW4-D (on the secondary y-axis).

3.2.5.5 Site Recharge Assessment

Earthfx used the same seven monitoring well sites to determine seasonal soil moisture patterns, hydraulic connection, gradients, and overall interaction with shallow groundwater (Figure 3.29). The sites were characterized regarding ground cover, soil type, and other features such as slope. Shallow mini-piezometers were installed at shallow depths after the deeper wells were drilled. Hand augering and digging to expose the soil profile preceded the monitor installation to confirm soil type and assess soil moisture.

Guelph Permeameter (GP) testing was conducted on the shallow native unsaturated soils at these locations to assess infiltration potential (Table 3.4). The GP testing followed ASTM standard D5126. Testing depths ranged from 60 to 85 cm. All surficial soils were characterized as have silty sand with some clay. Two single head and one double head test were conducted at each site. Test values were comparable between sites and estimated hydraulic conductivity values ranged between 1.06×10^{-5} cm/s (1.06×10^{-7} m/s) to 2.22×10^{-5} cm/s (2.22×10^{-7} m/s), which is consistent for a silty sand with clay. These results will be used to provide soil parameters and percolation rates for subsequent analysis.

Table 3.4: Results of Guelph permeameter testing.

Test Location	Soil Type	Depth (cm)	Test Type	Ponded Water Head (cm)	Steady State Flow Rate (cm ³ /s)	Hydraulic Conductivity (cm/s)
GP-1	Silty sand, some clay	NA	GP-1 was located in an area of upwelling. Testing not done			
GP-2	Silty sand, some clay	85	Head #1	7	0.018	1.30×10^{-5}
			Head #2	12	0.0252	1.28×10^{-5}
			Dbl. Head	7/12	Dbl. Head	1.05×10^{-5}
GP-3	Silty sand, some clay	60	Head #1	8	0.0216	1.44×10^{-5}
			Head #2	16	0.0396	1.60×10^{-5}
			Dbl. Head	8/16	Dbl. Head	2.22×10^{-5}
GP-4	Silty sand, some clay	72	Head #1	5	0.0198	1.73×10^{-5}
			Head #2	10	0.0234	1.35×10^{-5}
			Dbl. Head	5/10	Dbl. Head	1.06×10^{-5}
GP-5	Silty sand, some clay	60	Head #1	10	0.0288	1.66×10^{-5}
			Head #2	15	0.0396	1.69×10^{-5}
			Dbl. Head	10/15	Dbl. Head	1.06×10^{-5}
GP-6	Silty sand, some clay	65	Head #1	8	0.0162	1.08×10^{-5}
			Head #2	16	0.0288	1.17×10^{-5}
			Dbl. Head	8/16	Dbl. Head	1.06×10^{-5}
GP-7	Silty sand, some clay	60	Head #1	10	0.0198	1.14×10^{-5}
			Head #2	15	0.0346	1.48×10^{-5}
			Dbl. Head	8/15	Dbl. Head	1.06×10^{-5}

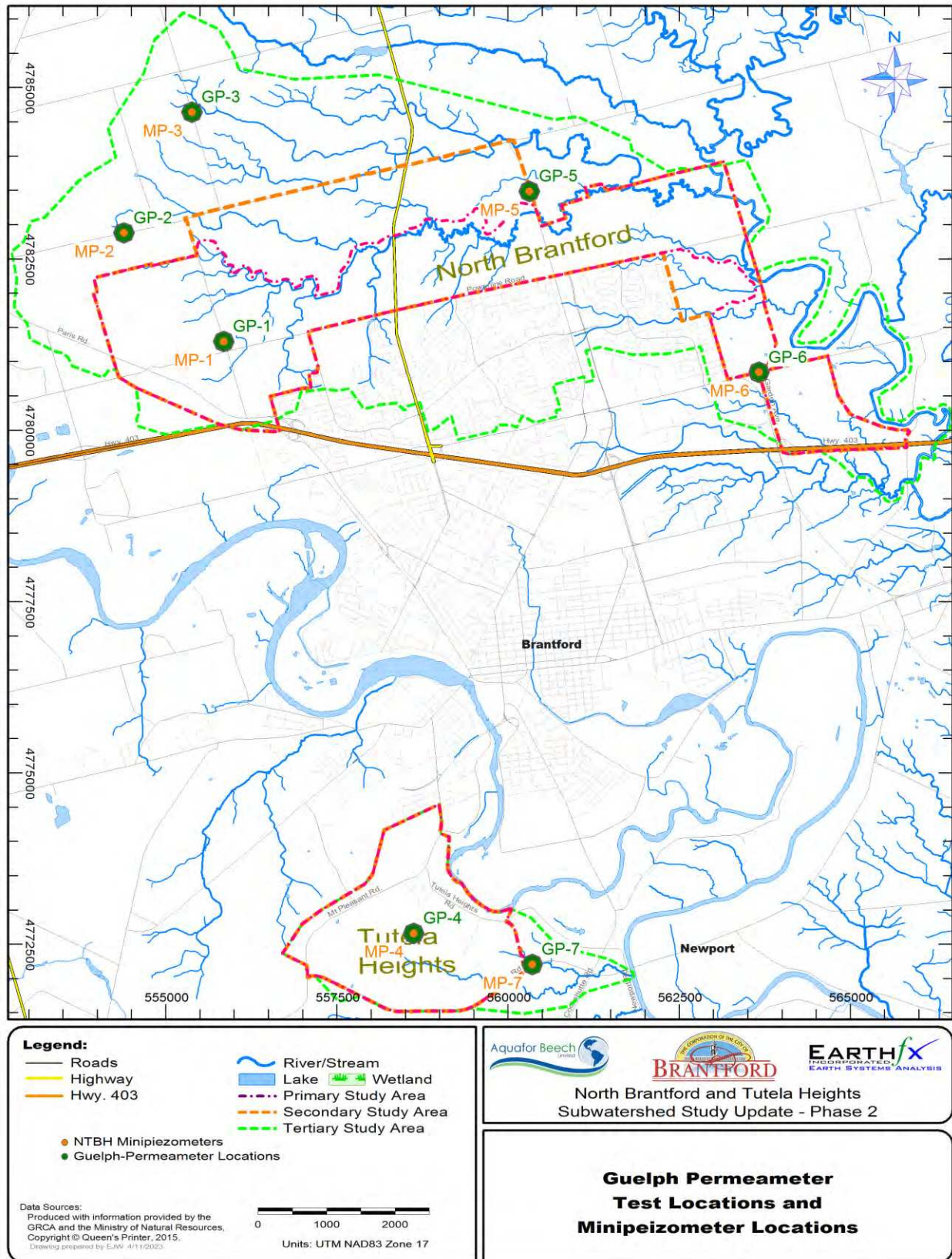


Figure 3.29: Locations of Guelph permeameter testing and minipiezometer installations.

3.2.5.6 Geotechnical Investigation of Riparian Areas

The surficial geologic map for the Brantford study area suggested that there are alluvial deposits in the riparian corridors. A key question to be answered as part of this study was whether these deposits reflect thin alluvial deposits on top of regional lacustrine deposits, or potentially erosional windows exposing deeper groundwater aquifers. If stream erosion has breached the surface aquitard, there could be a much higher potential for groundwater/surface water interaction, higher baseflow, and the potential presence of environmentally-significant cold-water fisheries.

Seven shallow geotechnical boreholes were drilled in the flood plain to investigate this issue. Locations were selected based on existing models, Lidar mapping, and input from other disciplines on the project team. The Lidar data proved very insightful, as it could see through the forest canopy and illustrate fluvial erosion and deposition patterns. Access to the riparian areas was a significant challenge, given the forest coverage near the streams. In some cases, access and safety issues required adjustments to the final borehole locations. Locations of the geotechnical boreholes are shown in Figure 3.30 along with other geotechnical boreholes (i.e. MTO drilling) found in the study area. Figure 3.31 through Figure 3.44 present the local setting of the borehole locations through aerial photographs, Lidar mapping, and Google Street View images. Construction details are provided in Table 3.5.

The plan was to hand auger boreholes to 1.5 m or refusal. The augering proved to be challenging, but the investigations quickly answered the objectives of the program. At most sites, sticky silt and clay or dense, cemented silt were encountered at shallow depth which clogged the augers and limited the ability to go deeper than 0.5 to 1.0 m. As an alternative, the sediment profiles were exposed by digging with a shovel. Geologic descriptions for each of the locations are shown in Table 3.6. Standpipes (minipiezometers) were driven into the ground a short distance away.

All seven locations had a shallow organics layer at or near surface. Some locations had silt or clay on top of this organic layer. Below was a dense silt layer that could not be penetrated. No coarse-grained materials were encountered, and there was no evidence that the stream has eroded through the overlying fine grained (low permeability) materials. Boreholes located adjacent to the streams filled with water, but most remained dry as they were perched above the local water table. No evidence of upward gradients or flowing wells were found.

Table 3.5: Geotechnical borehole location details

Name	Easting	Northing	Ground Elv. (masl)	Depth (m)
GT1	560521	4782840	220.19	0.55
GT2	558348	4782802	216.05	0.5
GT3	563536	4782895	202.13	0.95
GT4	565734	4781305	197.13	0.75
GT5	565932	4780016	210.34	0.45
GT6	560032	4784218	218.06	1.2
GT7	561187	4772012	217.92	1.3

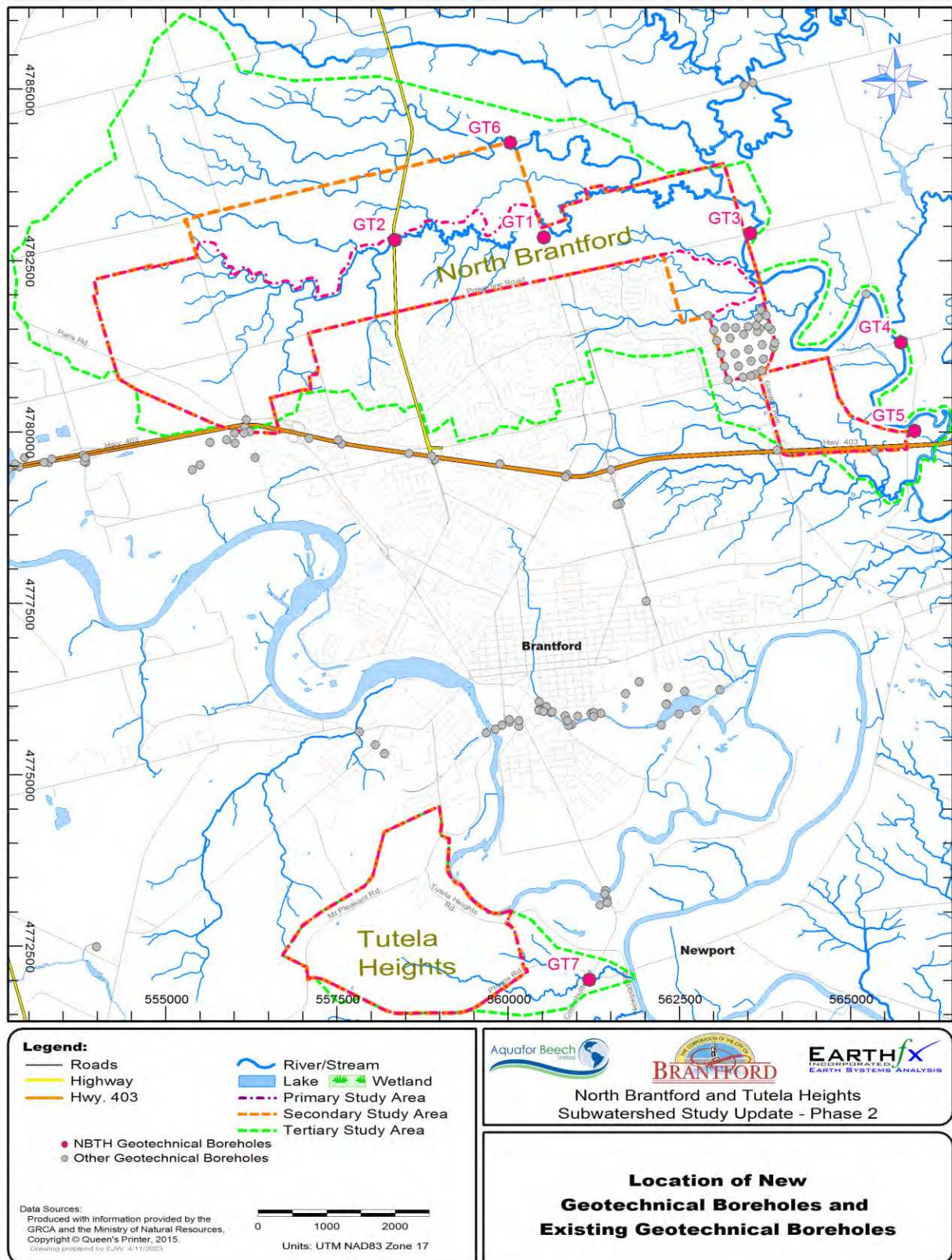


Figure 3.30: Location of geotechnical boreholes installed in the riparian areas and locations of other geotechnical boreholes in the study area.

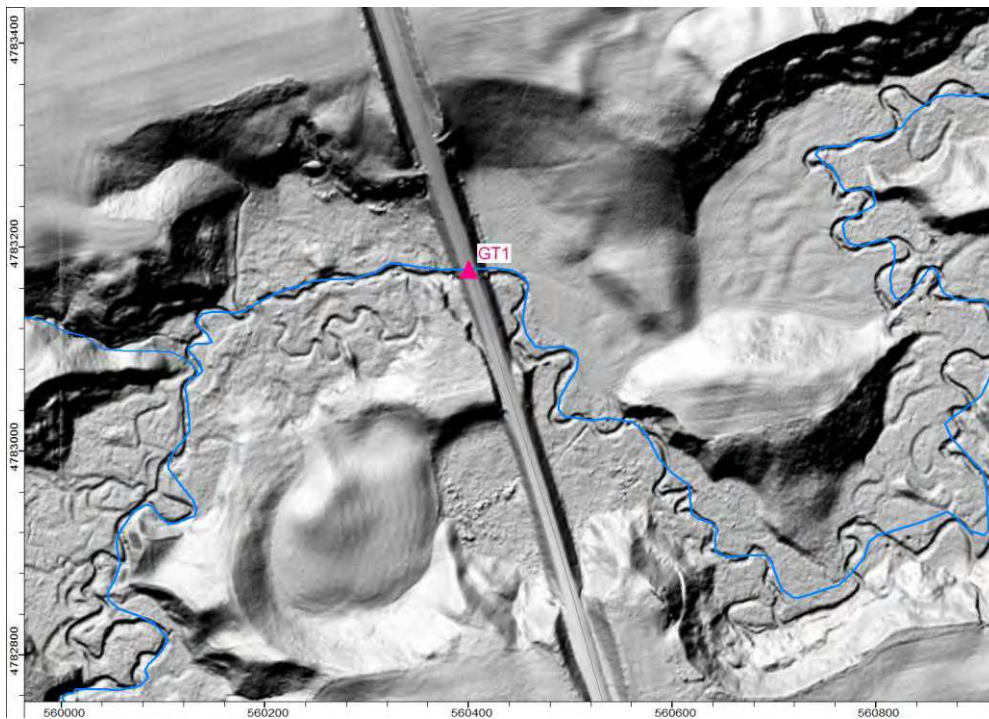
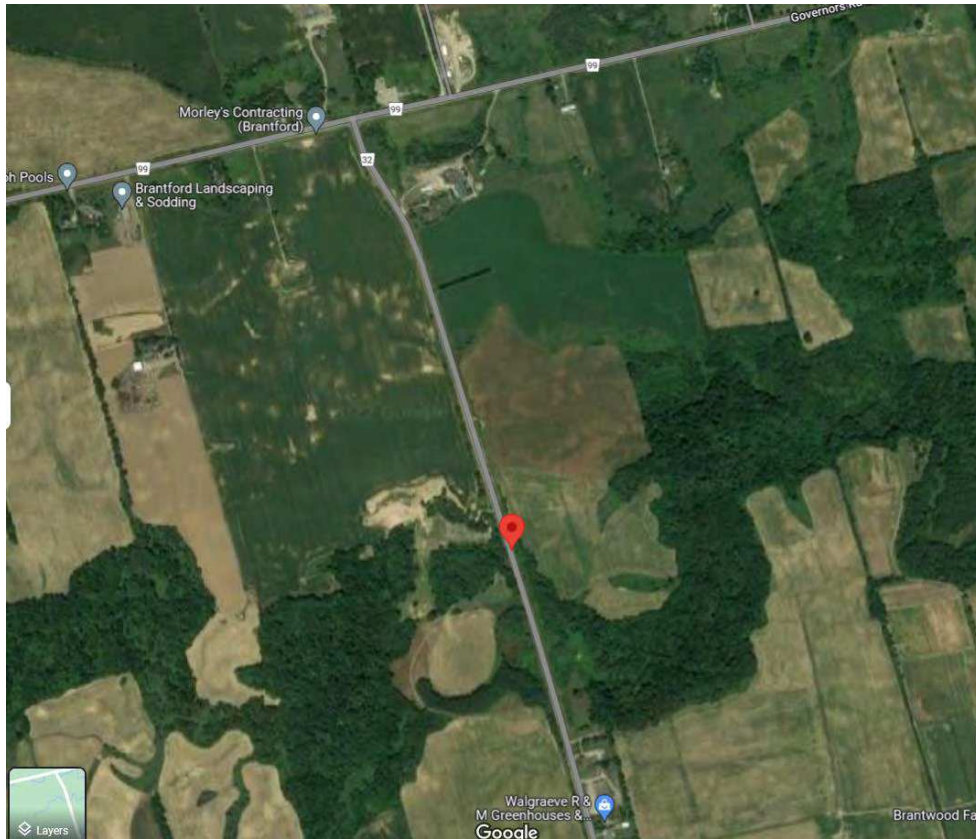


Figure 3.31: Location of GT-1 (Google Maps, top) and Lidar imagery (bottom)



Figure 3.32: Google Street View in the vicinity of GT-1.

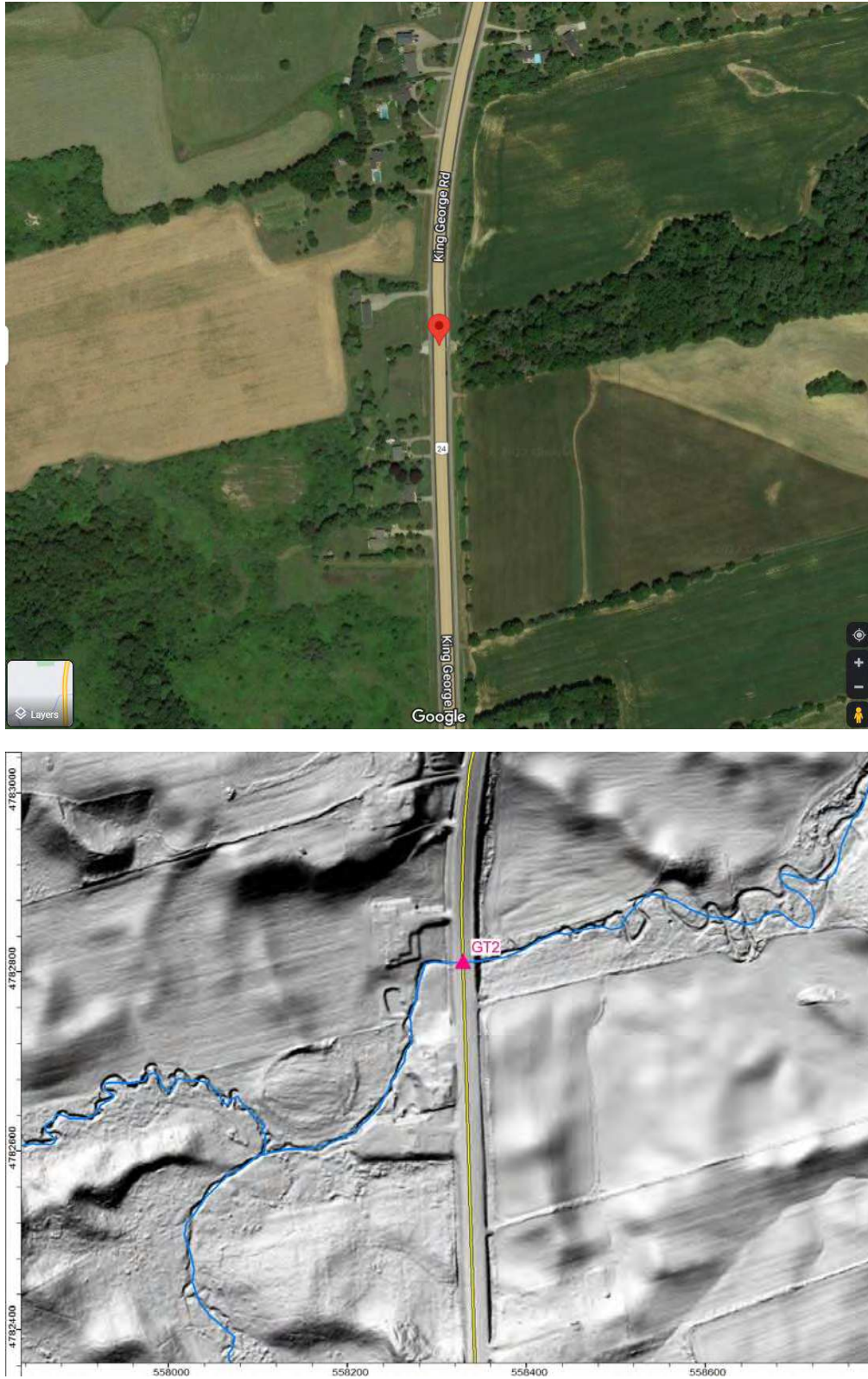


Figure 3.33: Location of GT-2 (Google Maps, top) and Lidar imagery (bottom)



Figure 3.34: Google Street View in the vicinity of GT-2.

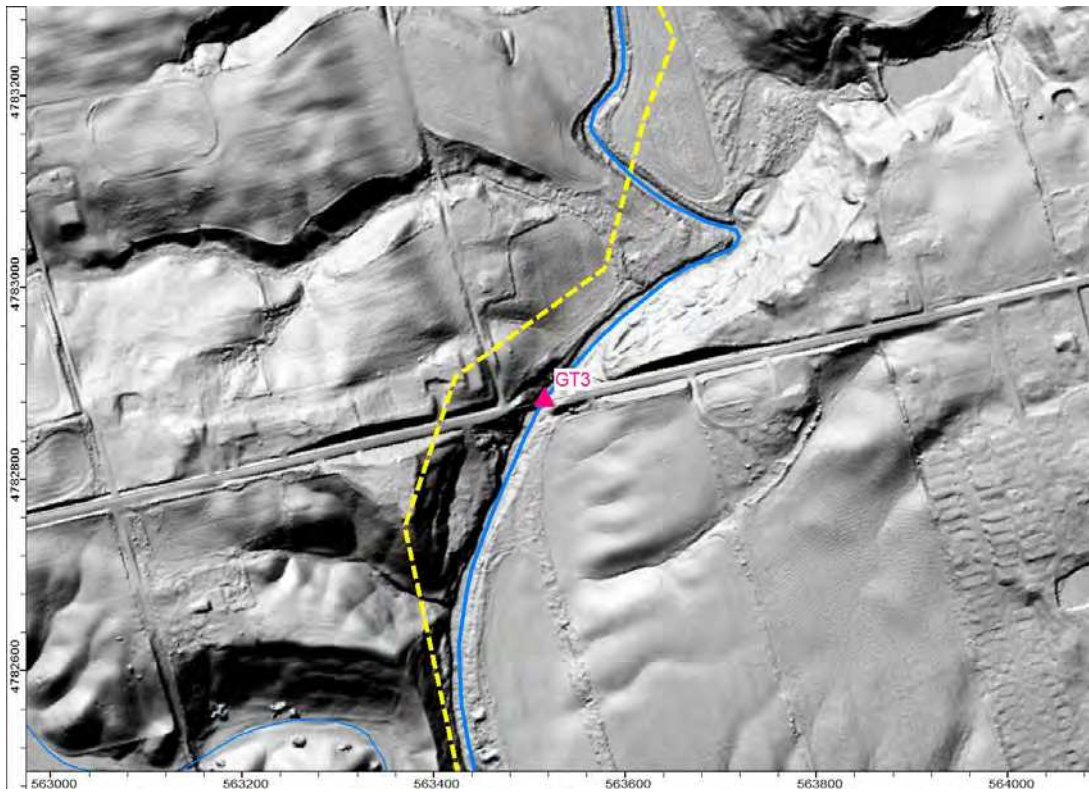
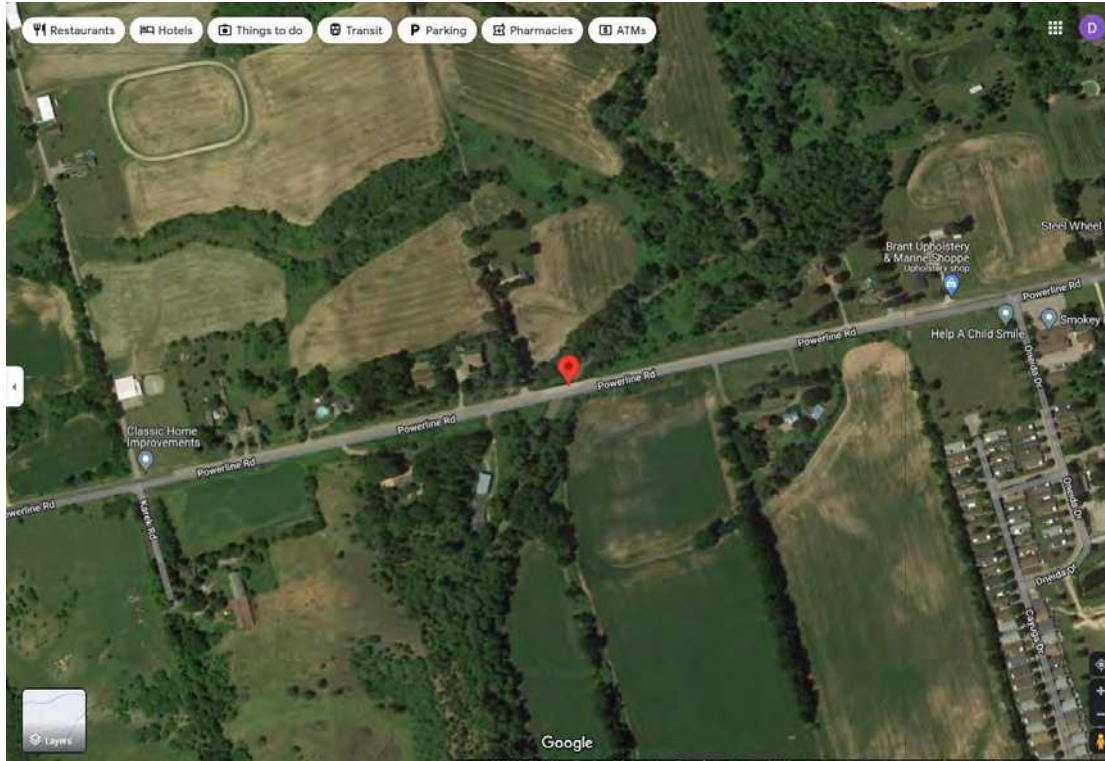


Figure 3.35: Location of GT-3 (Google Maps, top) and Lidar imagery (bottom).



Figure 3.36: Google Street View in the vicinity of GT-3.



Figure 3.37: Location of GT-4 (Google Maps, top) and Lidar imagery (bottom)



Figure 3.38: Google Street View in the vicinity of GT-4.

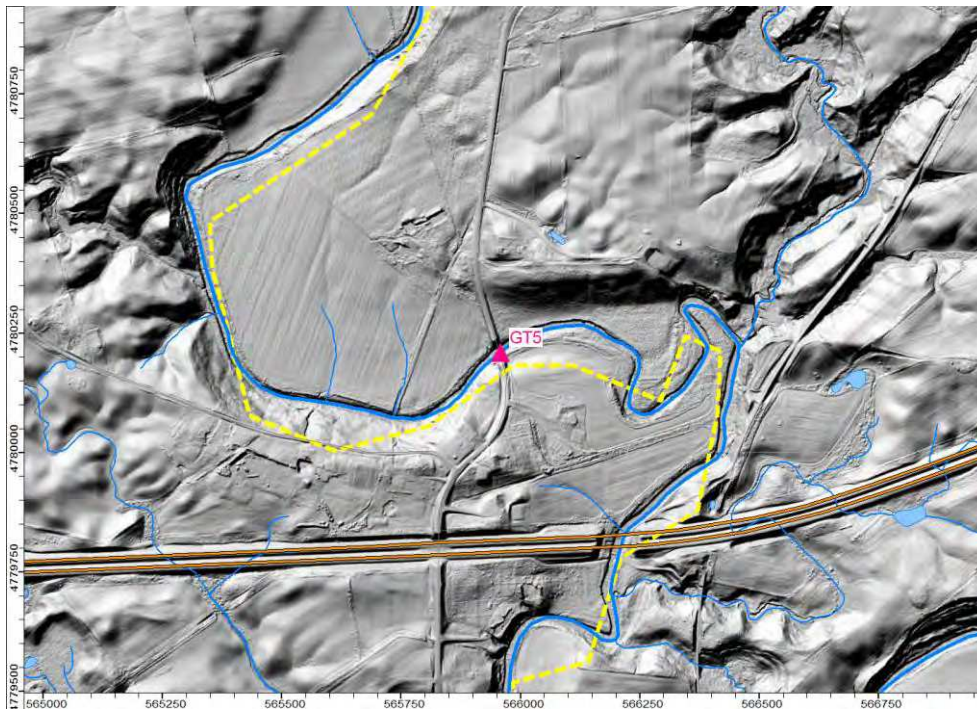
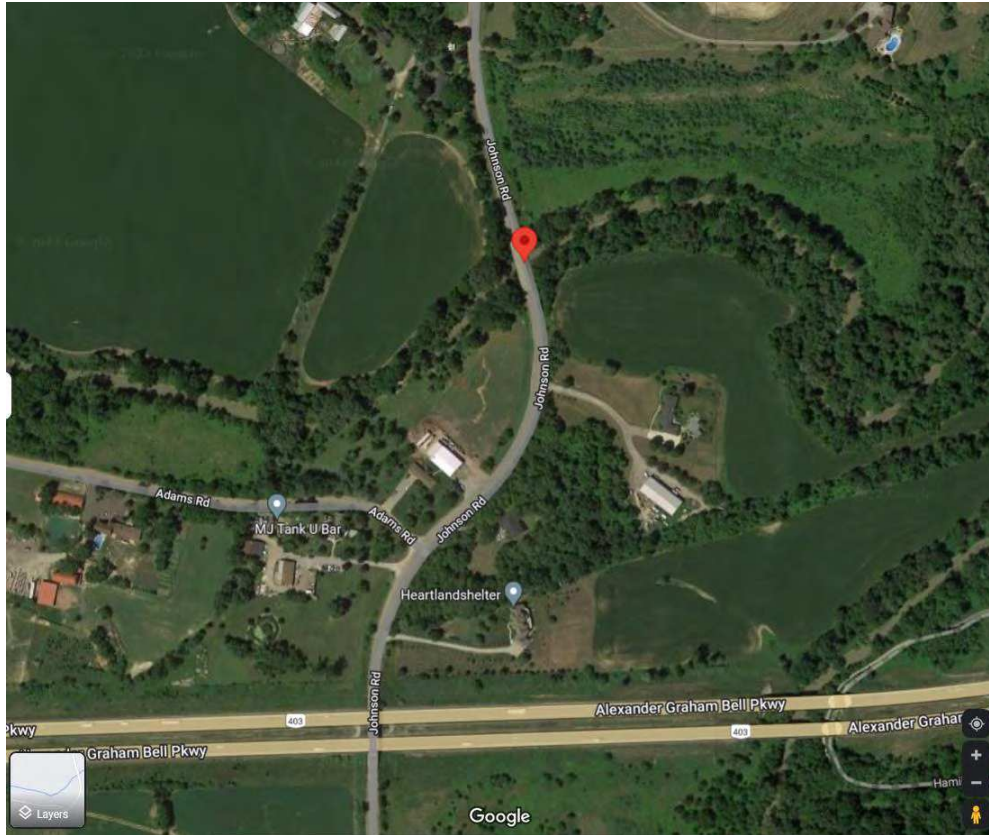


Figure 3.39: Location of GT-5 (Google Maps, top) and Lidar imagery (bottom).



Figure 3.40: Google Street View in the vicinity of GT-5

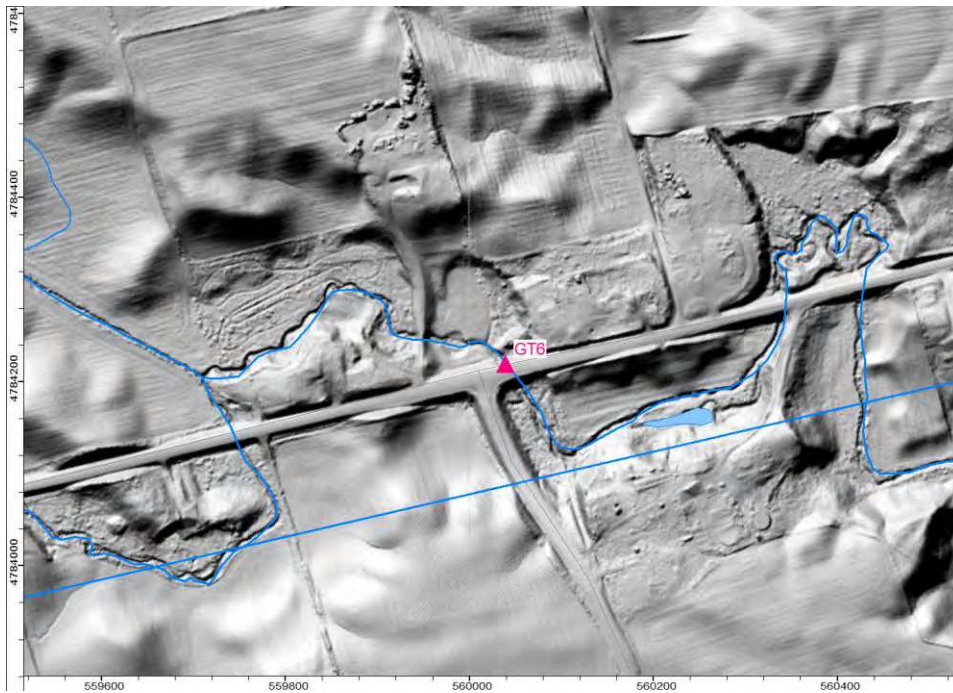
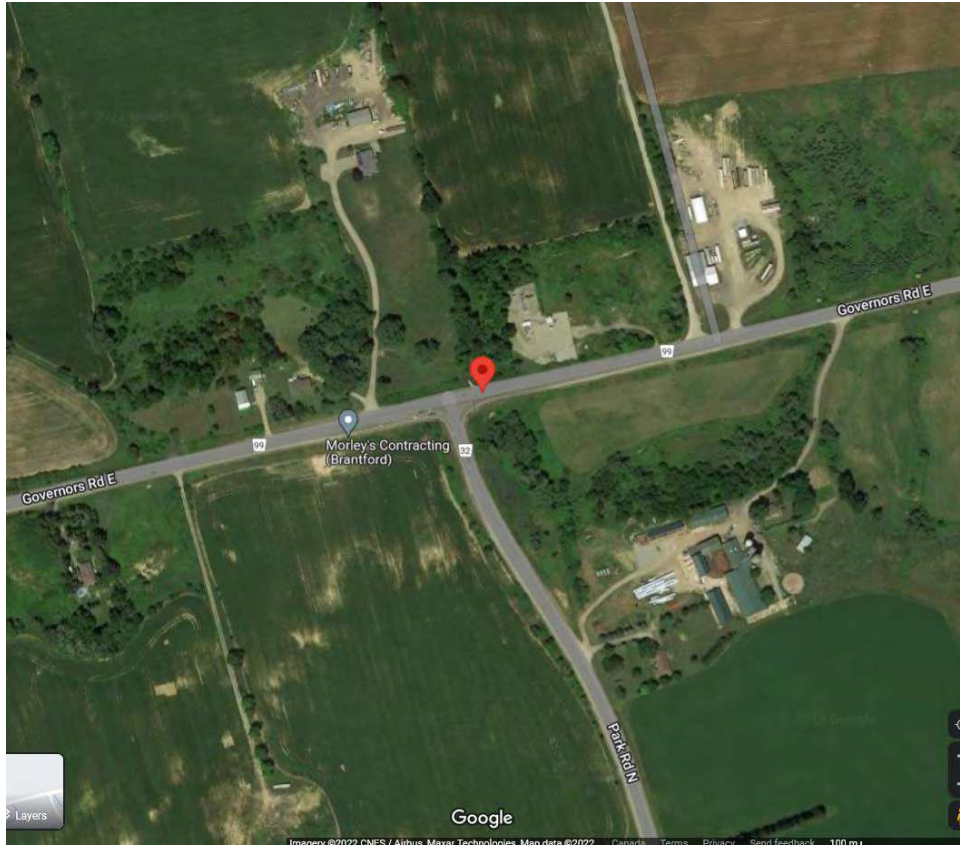


Figure 3.41: Location of GT-6 (Google Maps, top) and Lidar imagery (bottom).



Figure 3.42: Google Street View in the vicinity of GT-6.

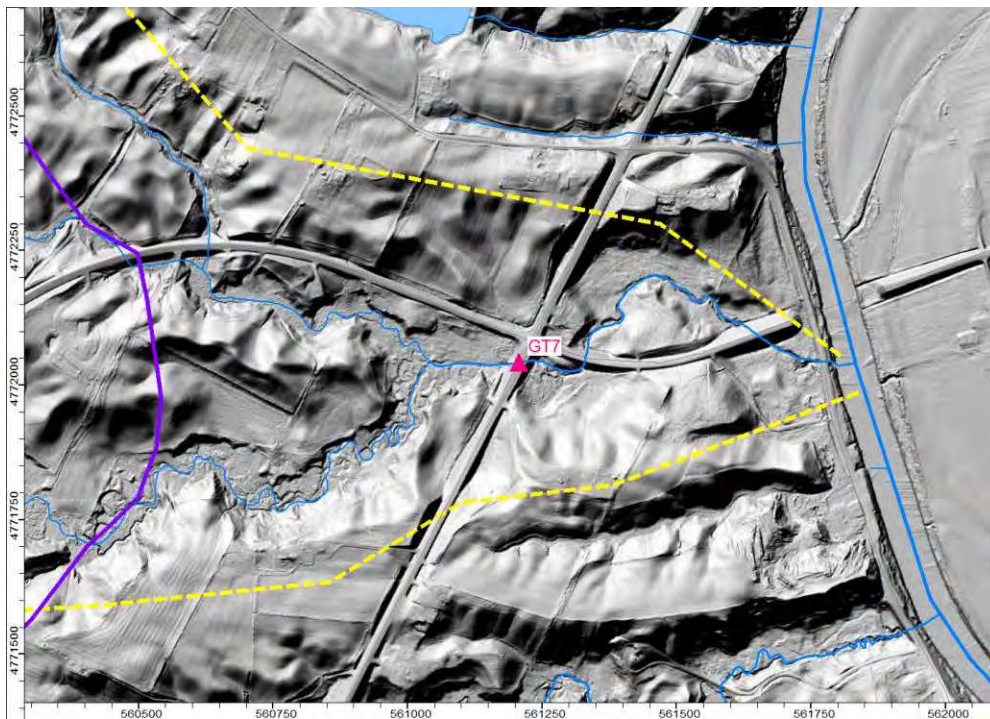
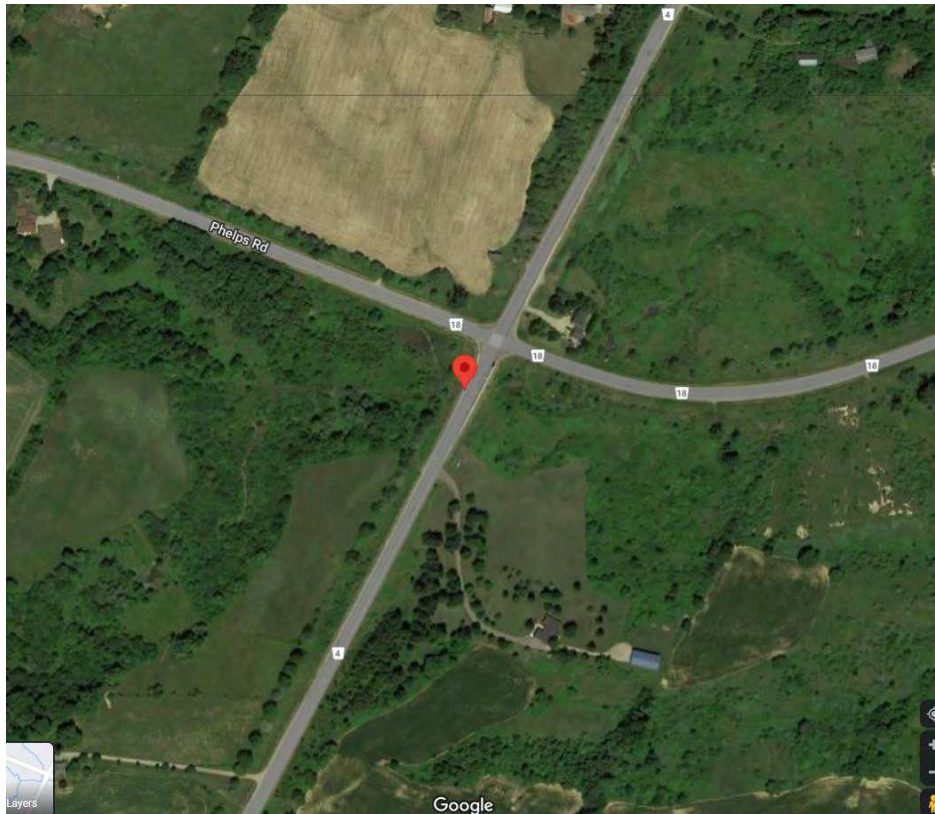


Figure 3.43: Location of GT-7 (Google Maps, top) and Lidar imagery (bottom).



Figure 3.44: Google Street View in the vicinity of GT-7.

Table 3.6: Geotechnical Log Details

Location	Total Depth (m)	Materials	Notes
GT-1	0.55	organic debris at surface to 0.25 m, then brown dense silt, turns grey and wet below 0.3 m	shovel to dig test pit, then installed GT off to side with fence post driver. Refusal at 0.55
GT-2	0.5	0.2 m of silt on top of organic layer (0.2 m thick), then into grey dense silt. Hole was still dry by end of install	root systems made it hard to dig
GT-3	0.95	organic deposits for 0.15 m then soft brown to grey silt, refusal at 0.95 (for GT, but I could only dig to 0.65 m and this was all silt, saturated	soft digging and saturated. GT refusal at 0.95
GT-4	0.75	saturated silt, brown, overlying organic debris, then soft grey silt, refusal at 0.75m	Up on the bank, the material was dense dry silt, light brown, unable to auger it. I was able to get down to the river to install the GT. Dug with a shovel for 0.75m before I hit refusal.
GT-5	0.45	saturated silt, brown, turns grey at 0.3 m, refusal at 0.45	material at bottom of hole could be rolled in hands (more clay)
GT-6	1.2	organics to 0.3 m then brown silt to 0.45 then turns grey, saturated, refusal at 1.2 m	
GT-7	1.1	saturated silt, brown, turns grey at 0.6 m, refusal at 1.1	used shovel to dig for strat description. Auguring wasn't effective

3.2.6 Hydrostratigraphy

A conceptual three-dimensional hydrostratigraphic model was developed for the study area (Earthfx, 2018) and updated as part of this study. The term “stratigraphic model” is used to describe the geologic layers; the term “hydrostratigraphic model” is used to describe the aquifer and aquitard layers contained within that system. While there are often many similarities between the stratigraphic and hydrostratigraphic layers, there are several important differences. Multiple stratigraphic layers can be combined, if the properties are sufficiently similar, into a single hydrostratigraphic unit for the purposes of groundwater model development. Alternatively, a single stratigraphic formation can be split into multiple layers if the properties are significantly different. For example, the upper part of the bedrock units are often weathered and, therefore, more permeable than the rest of the underlying unit, and treated as a separate hydrostratigraphic unit.

The till units serve as regional aquitards within the study area because of their generally fine-grained nature; although, some of the tills can contain significant sandy or silty-sand facies. Where exposed and exhibiting a hummocky upper surface, the Wentworth Till can allow slow but consistent seepage and, therefore, the till moraines can represent significant groundwater recharge areas compared to the low-lying, low-permeability glaciolacustrine deposits.

Aquifers are generally associated with inter-till materials and meltwater deposits that are locally variable in nature and distribution. The aquifers are generally referred to as “inter-till” sediments or with names such as “pre-Wentworth Sediments”. The final aquifer and aquitard layers are listed in Table 3.7. The nomenclature for the hydrostratigraphic units follows that used in the Tier 3 Water Budget Assessment for the Whitemans Creek subwatershed (Earthfx, 2017) and the Fairchild Creek model development (Earthfx, 2018); more detailed discussions of the units can be found there.

Table 3.7: Hydrostratigraphic units.

Group	Conceptual Unit	Hydrogeologic Role
Overburden	Norfolk Sands	Aquifer
	<i>Late Lacustrine Silt and Clay</i>	Aquitard
	<i>Mackinaw Interstadial</i>	Aquifer
	Wentworth Till	Aquitard
	Pre-Wentworth Sediments	Aquifer
	Port Stanley Till	Aquitard
	Inter-till Sediments	Aquifer
	Maryhill Till	Aquitard
	Erie Phase Aquifer	Aquifer
	Catfish Creek Till	Aquitard
	Pre-Catfish Aquifer	Aquifer
Bedrock	Weathered Bedrock Contact Aquifer	Aquifer
	Guelph Formation	Aquifer
	Eramosa	Aquifer
	Goat Island	Aquifer
	Gasport	Aquifer
	Rochester Shale	Base of Model

A few boreholes indicate the presence of sand units within the overburden (Figure 3.45), but the majority indicate continuous clay, sandy clay, or silt deposits, indicating that the lacustrine deposits are not likely to be productive in the North Brantford area. There are few deep wells in the Tutela Heights area and the very limited information indicates that there may be pockets of sand near the bedrock contact, but no continuous overburden aquifer. The Guelph Formation forms the principal aquifer with both study areas but is not widely exploited. The aquifer is mildly productive, especially near the weathered upper zone, where fractures have increased secondary porosity.

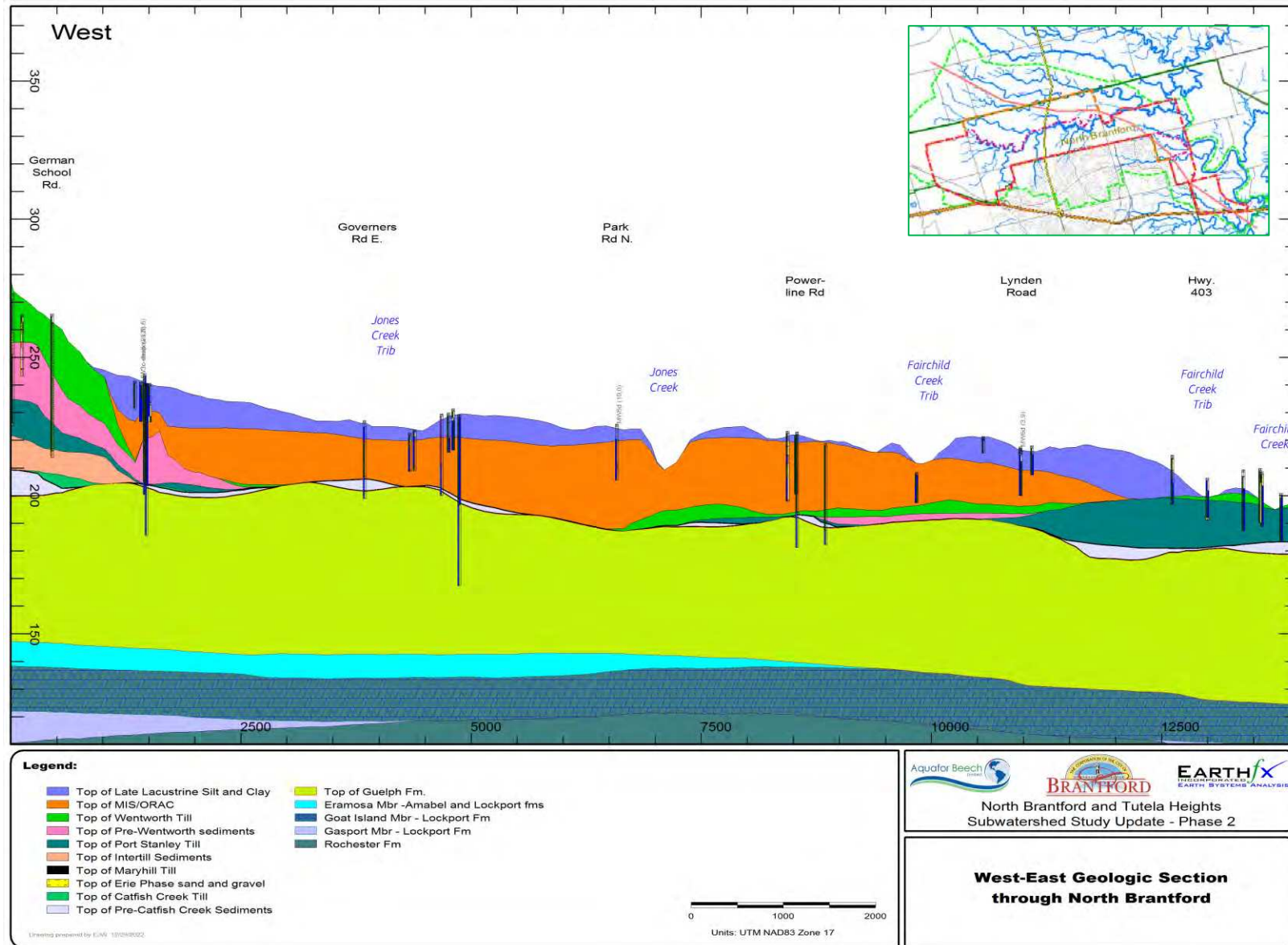


Figure 3.45: West-East section through the North Brantford study area.

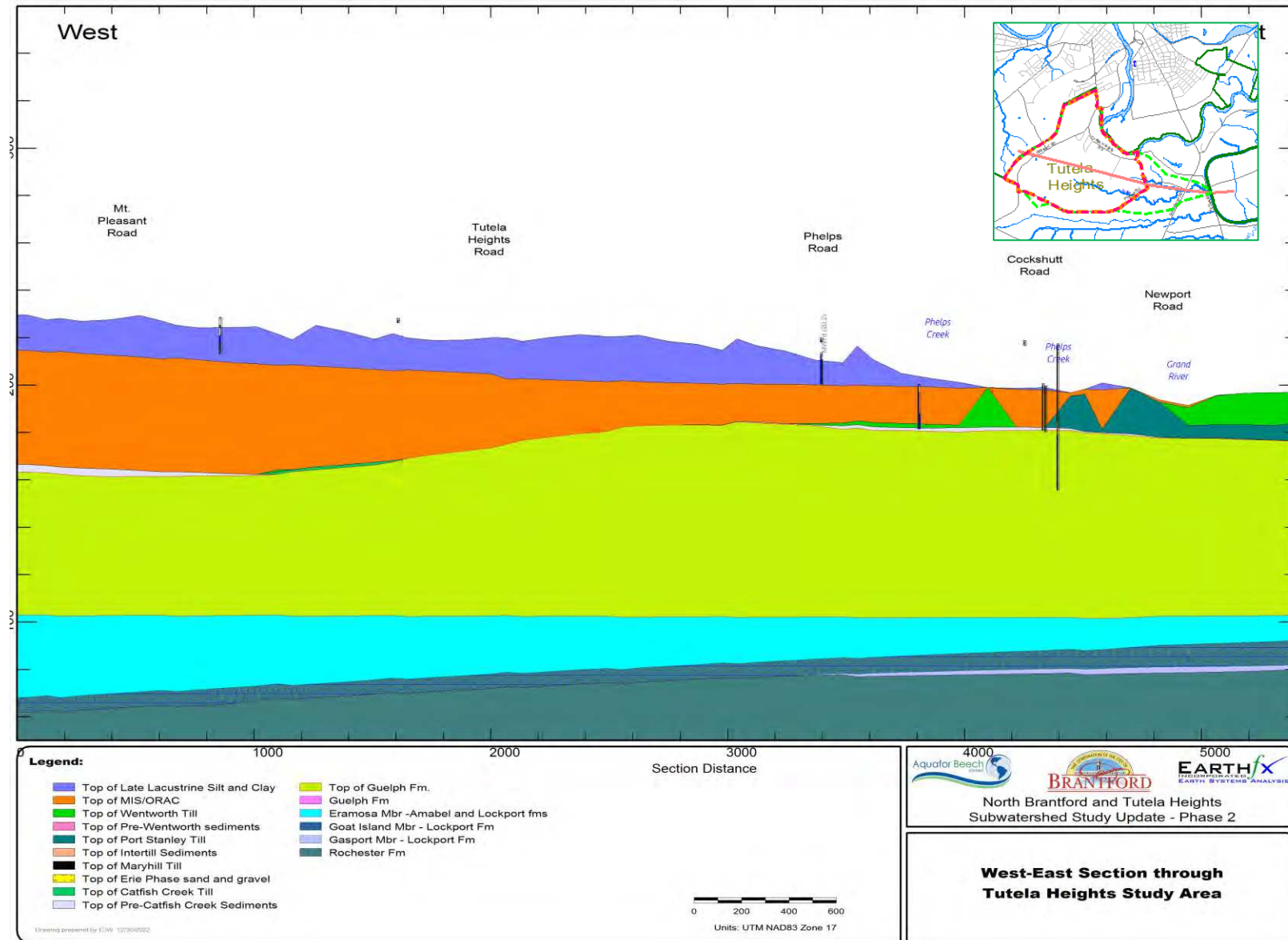


Figure 3.46: West-East section through the Tutela Heights study area.

3.2.7 Groundwater Flow

Static water level data were obtained from the wells in the MOE Water Well Information System (WWIS) database. These water level data represent a one-time measurement taken upon construction of the wells. Numerous biases and errors are known to exist in the water well record data. Significant differences can exist between static water levels in nearby wells and can be due to differences in the time of year the wells were installed, inter-annual differences (i.e., wet and dry years), measurement error, recording error, well location and measuring point elevation errors. Despite these limitations, the WWIS data have good regional coverage and provide important insight into regional trends in aquifer levels and flow patterns. Water levels were examined for obvious outliers, but due to the sparseness of the data, errors in the more isolated wells are harder to identify while at the same time, these measurements take on greater significance.

A total of 1596 overburden and 959 bedrock water level measurements were examined to characterize groundwater flow and included data from wells outside the tertiary study area boundaries. Wells were partitioned into overburden (Figure 3.47) or bedrock (Figure 3.48) wells based on the reported bottom of the monitoring interval.

Water-level data were interpolated using a geostatistical technique known as “kriging” to determine general patterns of groundwater flow. Kriging is a weighted-averaging interpolation method that attempts to minimize variance and bias in the results while honouring the local values at the data points. Figure 3.49 and Figure 3.50 present the interpolated water levels for the overburden and bedrock units. Note that several portions of the overburden water level figure are blanked-out in areas where overburden water level measurements were too sparse to produce a high confidence (low variance) interpolated surface.

Both the shallow and deep groundwater levels show a regional slope from a high of approximately 300 masl in the northwest (beneath the Galt Moraine) to the southern reaches of Fairchild Creek where groundwater levels drop below 200 masl. There is a groundwater divide present across the Galt Moraine indicating groundwater flow to the west, toward the Grand River and to the east and southeast into the Fairchild Creek river valley. Bedrock and overburden water levels do not exhibit a clear trend to the south of Lynden. Some local groundwater mounds and depressions are apparent in the observed overburden water levels, although some of these may be due to poor data quality. Conversely, the bedrock levels in this area are very flat, with a large distance occurring between the 220 m and 210 m contours. The unique behaviour in this area may be attributed to the influence of the Dundas bedrock valley (See Figure 3.8) which was mapped through this area (Bajc *et al.*, 2009).

Differences between deep and shallow groundwater levels (heads) are presented in Figure 3.51 to show the direction of vertical flow (i.e., up or down). Again, some areas are blanked out to reflect where overburden water levels are sparse. The vertical head differences are larger in the southern half of the model; this is attributed to the presence of more low permeability confining units that separate the shallow and deep groundwater systems. Vertical gradients are generally downward across the Galt Moraine, particularly to the west of St. George. This type of behaviour is consistent with the hummocky topography and the occurrence of several till units separating

the shallow overburden aquifer systems from the deeper bedrock. A downward trend is also noticeable in the vicinity of the Lynden wellfield where shallow water levels are likely perched and separated from bedrock by thick deposits of silt and clay. Upward trends are noted in the vicinity of river valleys and are quite strong immediately to the east of St. George. This upward gradient has been confirmed recently based on field observations by Lotimer and Associates (2017).

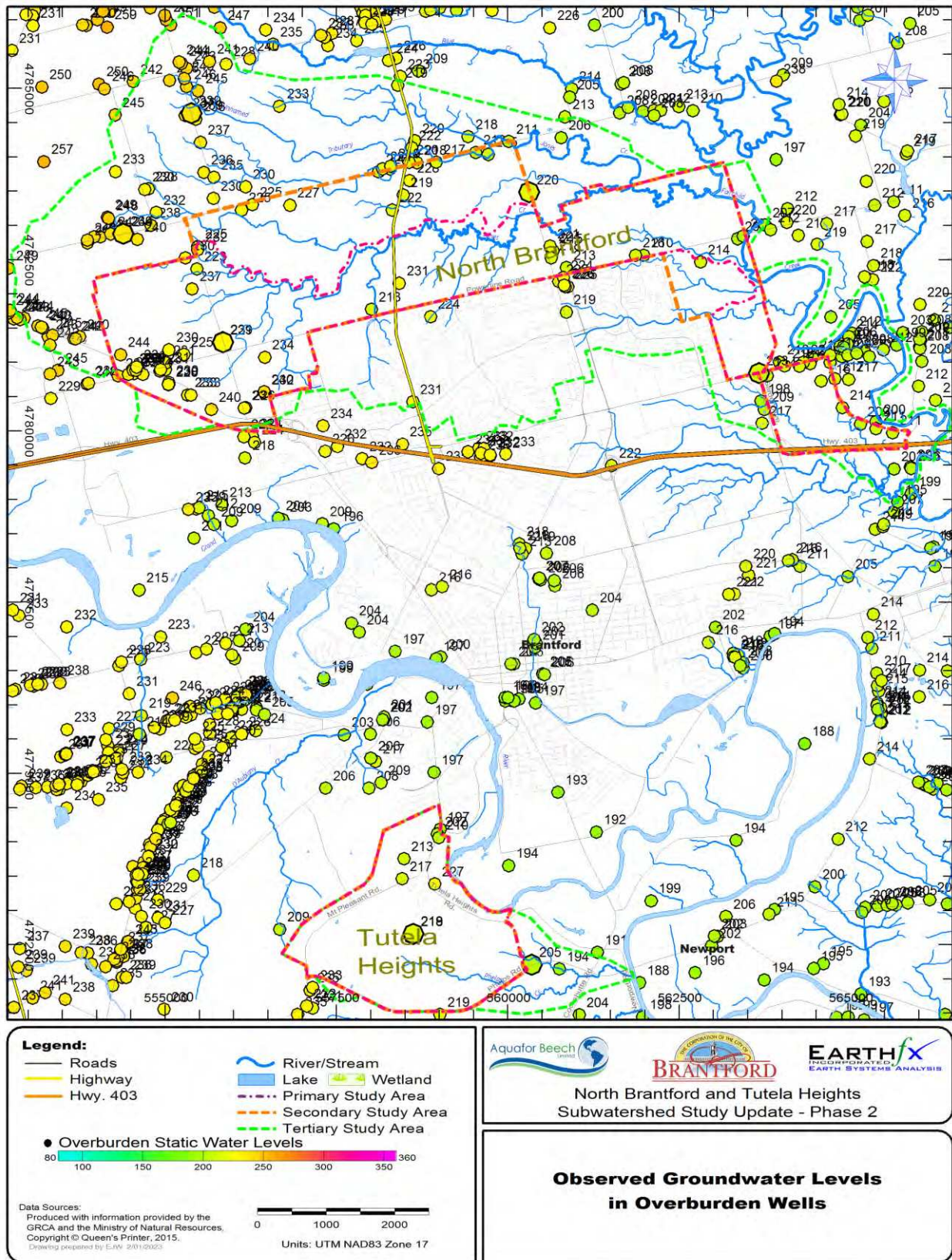


Figure 3.47: Observed groundwater levels (masl) in overburden wells.

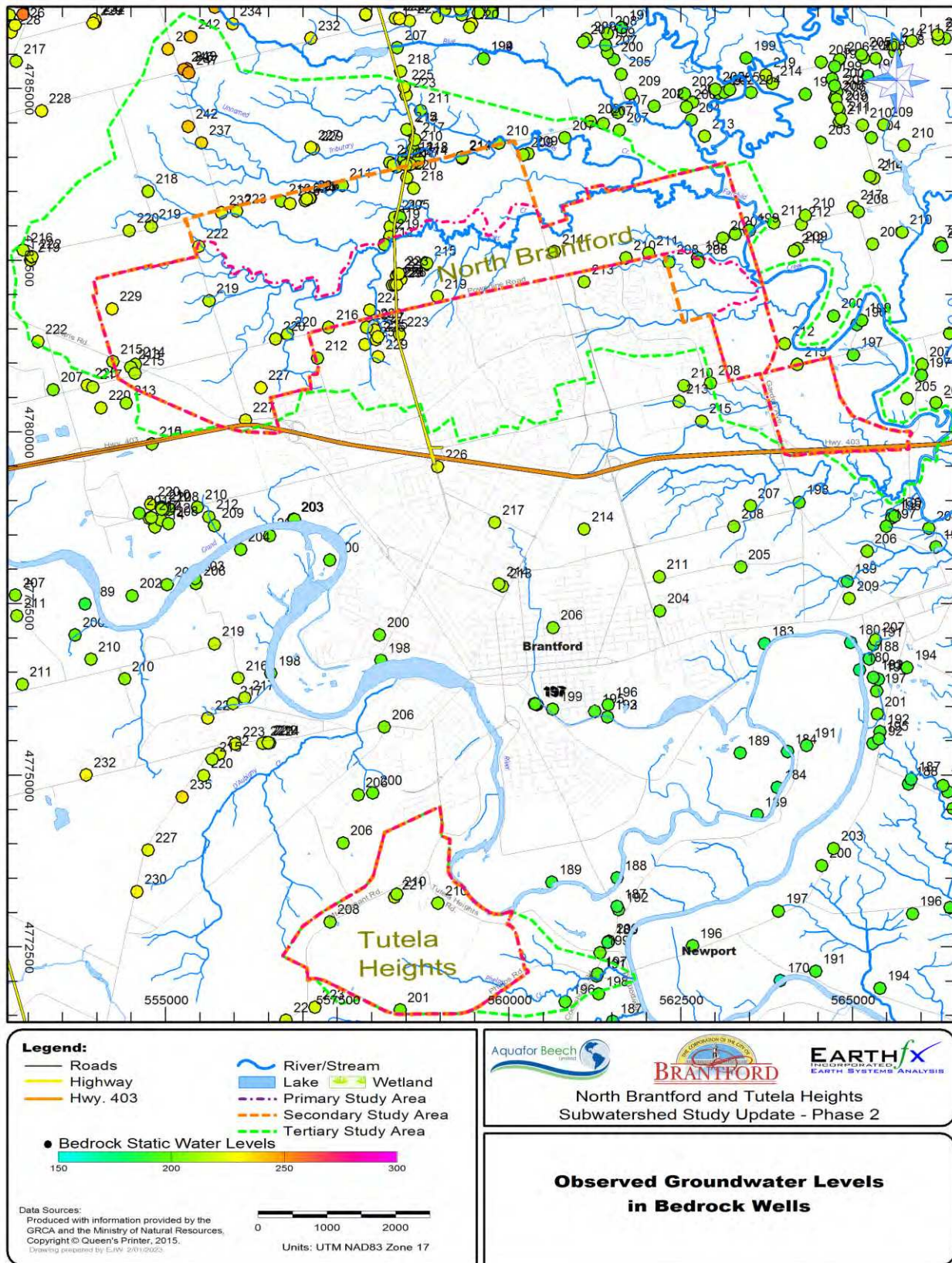


Figure 3.48: Observed groundwater levels (masl) in bedrock wells.

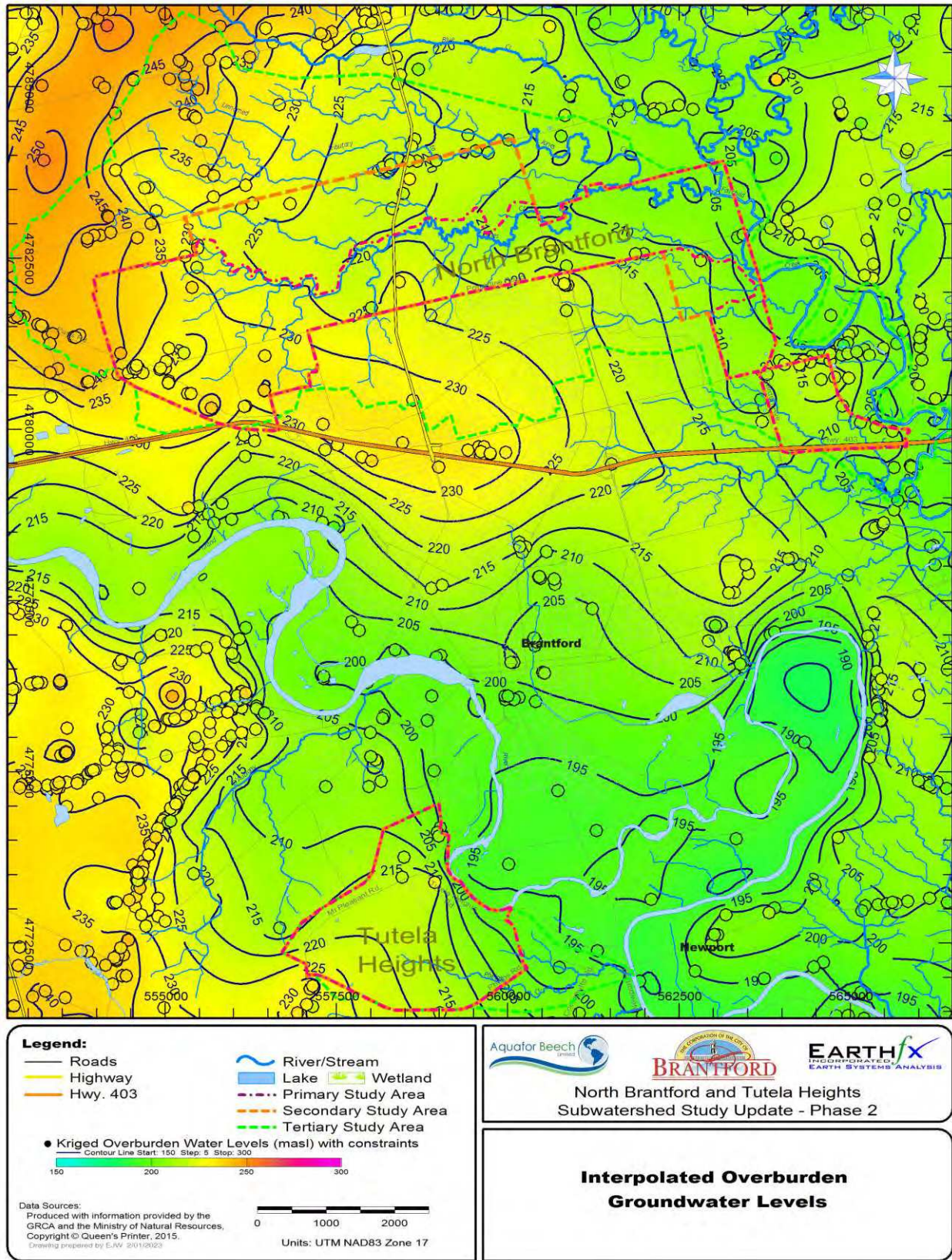


Figure 3.49: Interpolated groundwater levels (masl) in the overburden.

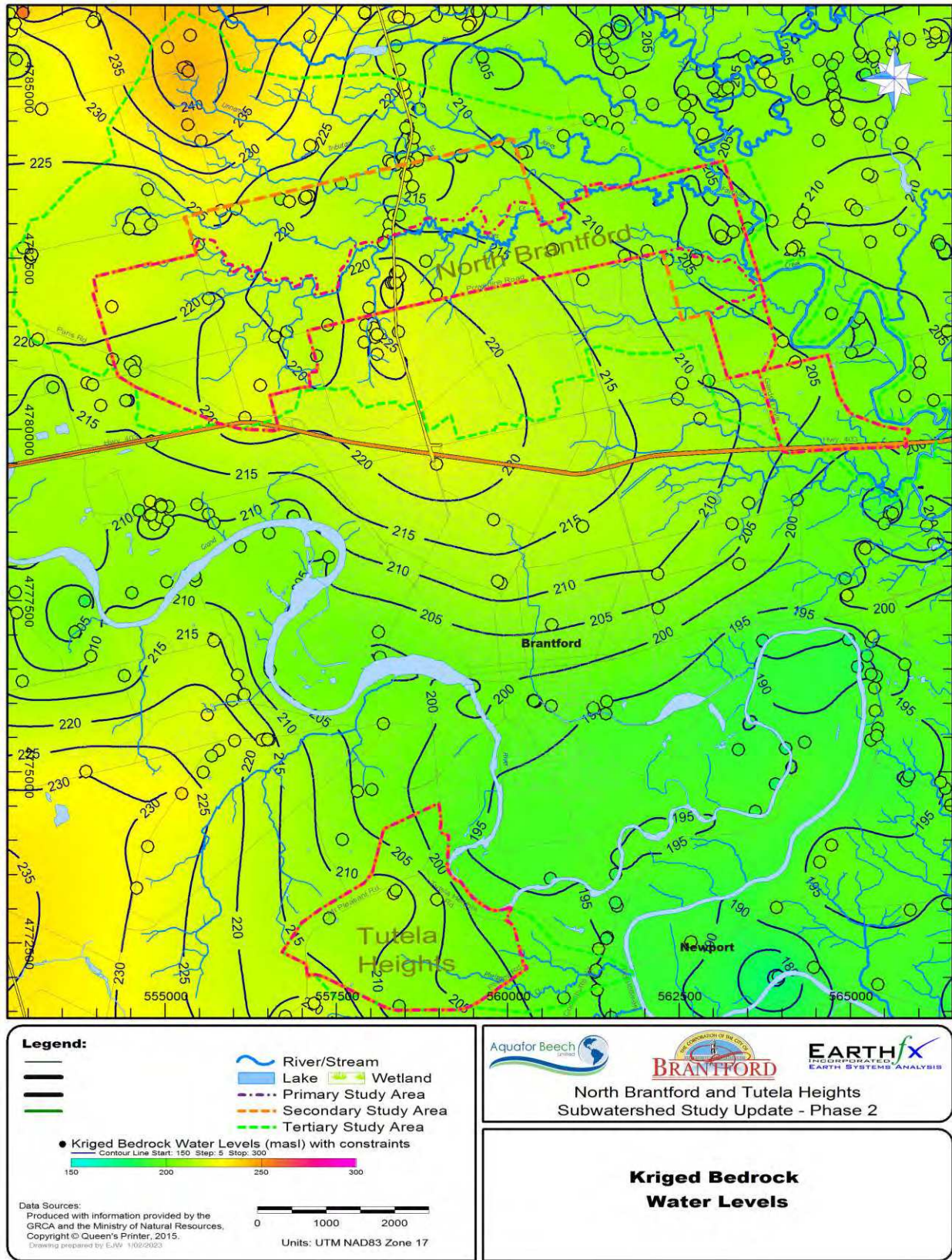


Figure 3.50: Interpolated groundwater levels (masl) in the bedrock.

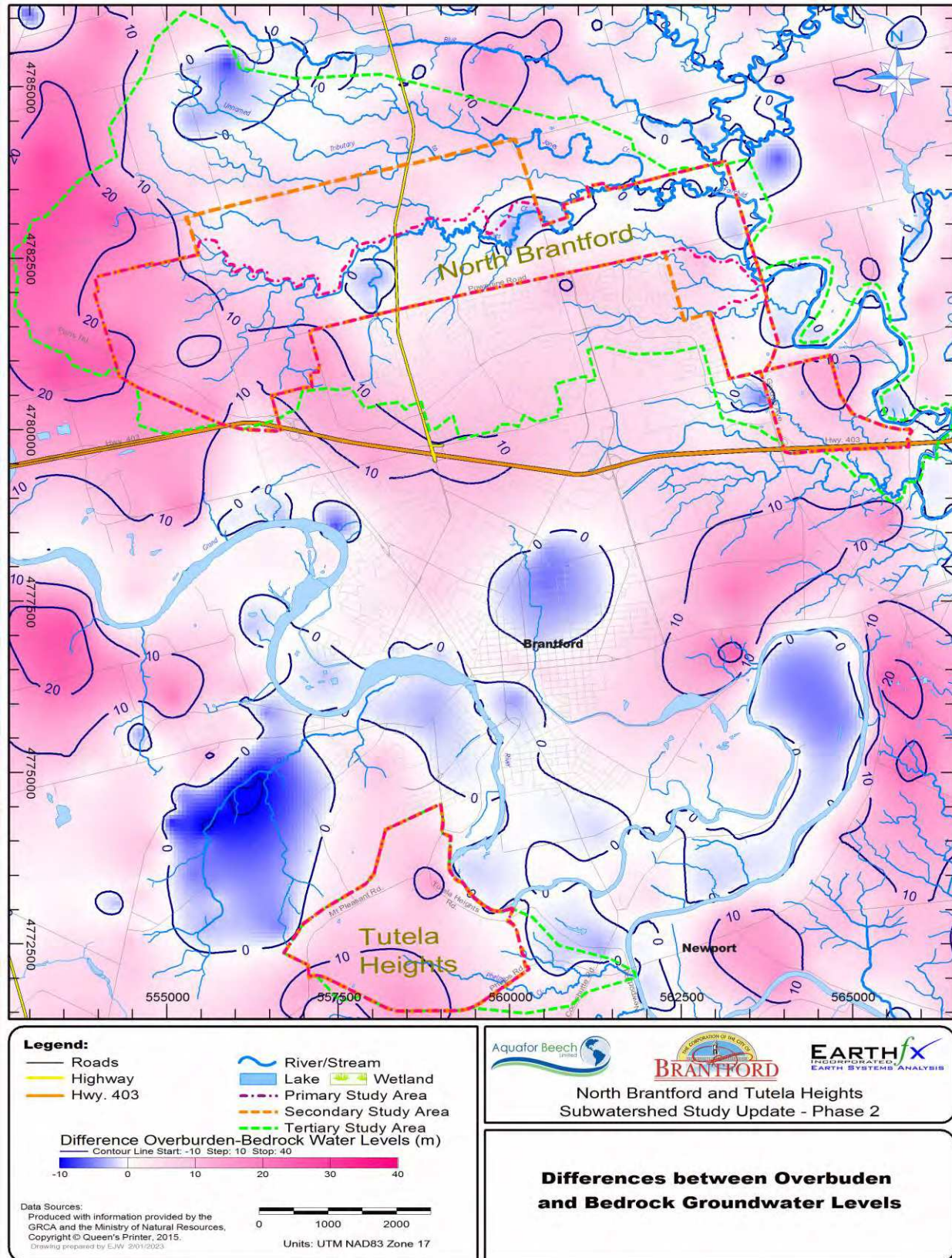


Figure 3.51: Vertical head (potential) difference between the overburden and bedrock aquifers.

3.2.7.1 Groundwater Takings

The MECP maintains a database of Permits to Take Water (PTTW) issued under the Ontario Water Resources Act for water takings larger than 50,000 litres per day (L/d). The PTTW database includes information on the maximum permitted water taking rates along with the maximum number of hours per day and days per year of permitted operation. The permits are classified by primary and secondary purposes (e.g., water supply/municipal or agriculture/tobacco). While PTTW holders are required to report water use, actual water use information is not part of this database. Instead, a separate database, the MECP the Water Taking Reporting System (WTRS), contains self-reported information on actual water use.

A total of 20 active permits were found in the most recent PTTW database. This included 8 surface water and 14 groundwater takings. Takings related to activities that were considered non-consumptive or temporary (such as construction dewatering), were not included. Permit data are listed in Table 3.8; locations and primary/secondary purposes for the taking are shown on Figure 3.52. Of these, two permits were located within the North Brantford area. One permit is a groundwater taking for golf course irrigation; the other is a surface water permit for row crops.

Table 3.8: Summary of water takings in the study area.

Taking Type	Permit Number	Primary Purpose	Secondary Purpose	Source Name	Maximum L/d	Maximum Day/yr
Groundwater	0545-ABDQJF	Commercial	Golf Course Irrigation	Well 1	1,278,000	70
	0612-C9GPYC	Recreational	Aesthetics	Well 1	200,000	75
	1058-ADUKZX	Water Supply	Municipal	Well 1	2,358,720	365
				Well 2	2,661,120	365
	1343-BYAQ2C	Agricultural	Field/Pasture Crops	Phelps Pd.	1,980,000	64
	1517-ASWQAT	Water Supply	Campgrounds	Well A	405,000	365
				Well B	405,000	365
				Well C	405,000	365
	1818-A82QCE	Industrial	Manufacturing	Well 5	97,920	365
Well 6				57,600	365	
3527-9NSKF3	Industrial	Aggregate Washing	West	5,876,000	275	

Taking Type	Permit Number	Primary Purpose	Secondary Purpose	Source Name	Maximum L/d	Maximum Day/yr
	5373-C7GLHJ	Agricultural	Field/Pasture Crops	157	1,126,080	120
	8106-97XN5X	Commercial	Golf Course Irrigation	Irrigation Pd.	1,362,000	150
	1308-AZ4M52	Agricultural	Field/Pasture Crops	Patterson Cr.	2,750,000	130
Surface Water	2375-BLHMW5	Water Supply	Municipal	Grand River	260,000,000	365
	4118-ALKKNM	Industrial	Power Production	Grand River	371,520,000	365
	6052-9RGR3G	Agricultural	Tobacco	Grand River	2,210,000	16
	6751-9GXS8U	Commercial	Golf Course Irrigation	Fairchild Cr.	1,015,000	184
	7511-A4SPUR	Agricultural	Field/Pasture Crops	Jones Cr.	328,000	30

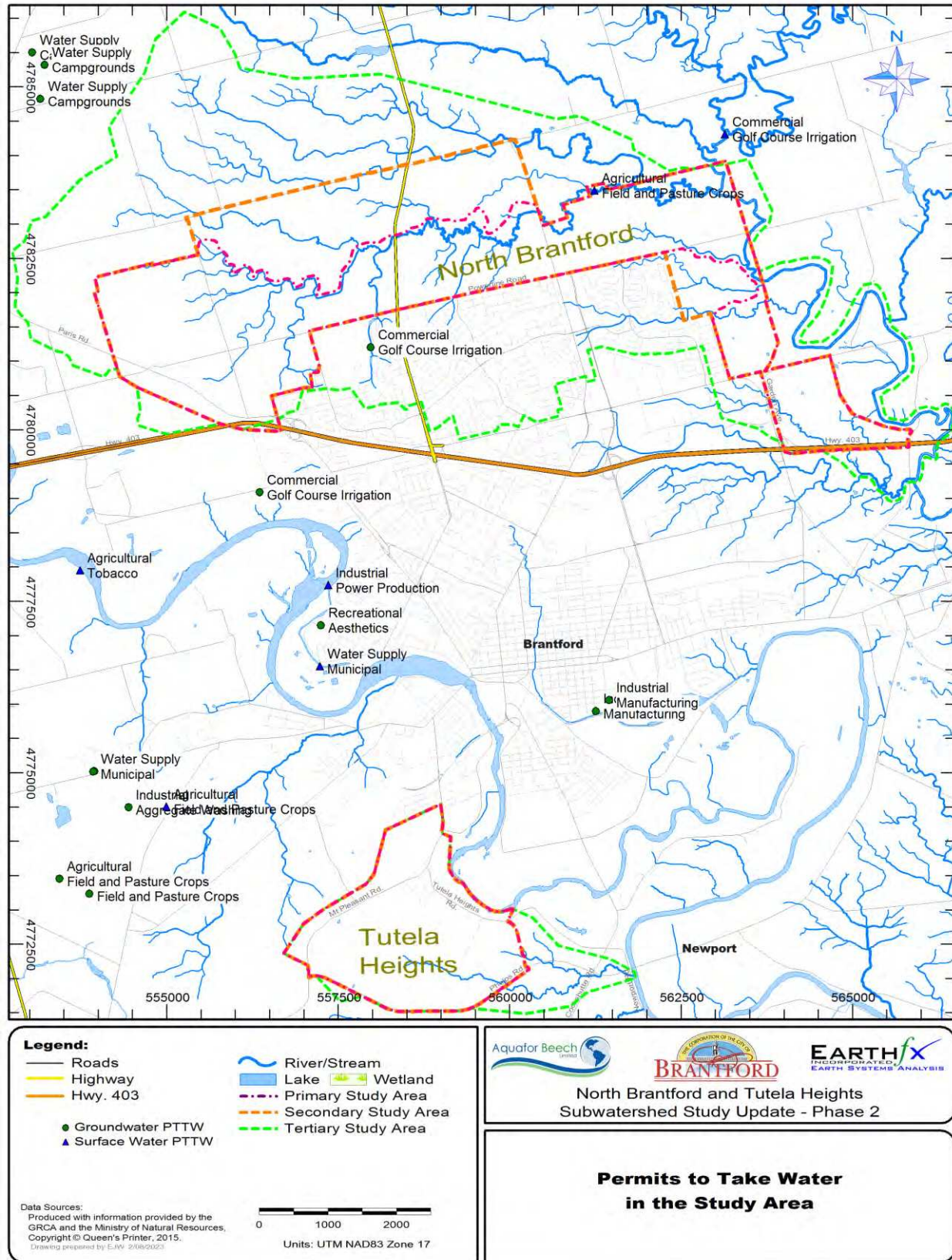


Figure 3.52: Location and purpose of permits to take water (PTTW) in the study area.

3.2.8 Recharge and Evapotranspiration

A large number of factors affect the hydrologic processes that control the rates of infiltration, overland runoff, evapotranspiration, and groundwater recharge. These factors include:

1. climate (e.g., precipitation (rates and form), temperature, and solar radiation);
2. topography-related properties (e.g., slope, slope aspect, and the cascade network);
3. vegetation and land-cover related properties (e.g., cover density and percent imperviousness);
4. soil-type and surficial geology properties (e.g., field capacity and wilting point).

3.2.8.1 Climate

Climate is the key driving force of hydrologic response and a critical data set for a hydrologic model. Climate data (precipitation and temperature) were compiled from Environment Canada’s Atmospheric Environment Service (AES) archive. The number of active climate stations in southern Ontario stations has fallen significantly in recent years. Only two stations within a 25-km radius of Brantford are still active (Figure 3.53). Fortunately, the Brantford Airport (6140942) station (location shown in Figure 3.53) has both hourly and daily average climate data from 2015 onward although the data have considerable gaps. The nearby Brantford MOE (6140954) station (Figure 3.53) has historic data from 1960 to 2013. The data from Brantford MOE was nearly continuous up to 2006 but the number of missing days and gaps in the data increased significantly with time beyond that point. The Roseville (6147188) and Scotland (6147664) stations (located over 20 km from the study area) had overlapping data periods and were used to infill the missing data and create a continuous long-term data set for analysis extending from WY1960 through WY2022 (a water year (WY) begins on October 1st of the preceding calendar year). As noted earlier, a new continuous EC data set that integrates radar and station observations will be used for hydrologic modelling.

Table 3.9: AES Climate stations used for historical climate analysis.

Station ID	Station Name	Easting (m)	Northing (m)	Start Date Data	End Date Data
6140942	BRANTFORD AIRPORT	554376	4776301	Dec 12 2014	Current
6140954	BRANTFORD MOE	562355	4775907	Jun 01 1960	Jan 20 2013
6147188	ROSEVILLE	542657	4800219	Oct 17 1972	Current
6147664	SCOTLAND	546640	4761066	May 06 1971	Feb 27 2014

3.2.8.1.1 Precipitation and Temperature

Figure 3.54 presents the annual average precipitation observed in the study area for the 62-year period showing long-term trends and the number of days with missing data per year. Estimated average annual precipitation between WY1961 and WY2022 was 848 millimetres per year (mm/yr). Two cycles of wet and dry years can be seen using the seven-year running average values. Extreme dry years (annual value less than 656 mm/yr (1.5 standard deviations)) occurred in 1963, 1998, 2001, 2007, and 2015. Extreme wet years (annual value more than 1040 mm (1.5 standard deviations)) occurred in 1974, 1986, 1996, 2011, and 2013.

As was noted from the PGMN well data, groundwater levels showed no spring recovery in 2021 and no fall recovery in 2022. This indicates that even though the annual rainfall volumes were not extremely low, timing of the rainfall shortages can have a significant impact on response.

Monthly average precipitation for the period is shown in Figure 3.56. The range in values (shown as the 25th and 75th percentile) is relatively uniform but is much higher in the summer months where convective storms dominate. The average monthly occurrence of daily precipitation events exceeding 1, 5, 10, 20, and 30 mm/d are presented in Figure 3.57. The percentages are normalized to the total number of precipitation events (i.e., days with measured precipitation above 1 mm). The graph shows that events above 30 mm are very rare. Days with precipitation less than 30 mm are distributed fairly evenly during the month of April to November. Larger events occur mainly in the summer months (June through September) in the form of high-intensity convective storms.

The precipitation form is an important input to the snowmelt and snow accumulation analysis. Precipitation form (as snow or rain) was available for the Brantford MOE station but is not reported currently. Precipitation form is also not available for the new EC CaSPAR data.

Monthly average mean, maximum, and minimum temperatures are shown in Figure 3.58. The values are typical for southern Ontario and the daily range in temperatures is relatively uniform over the year.

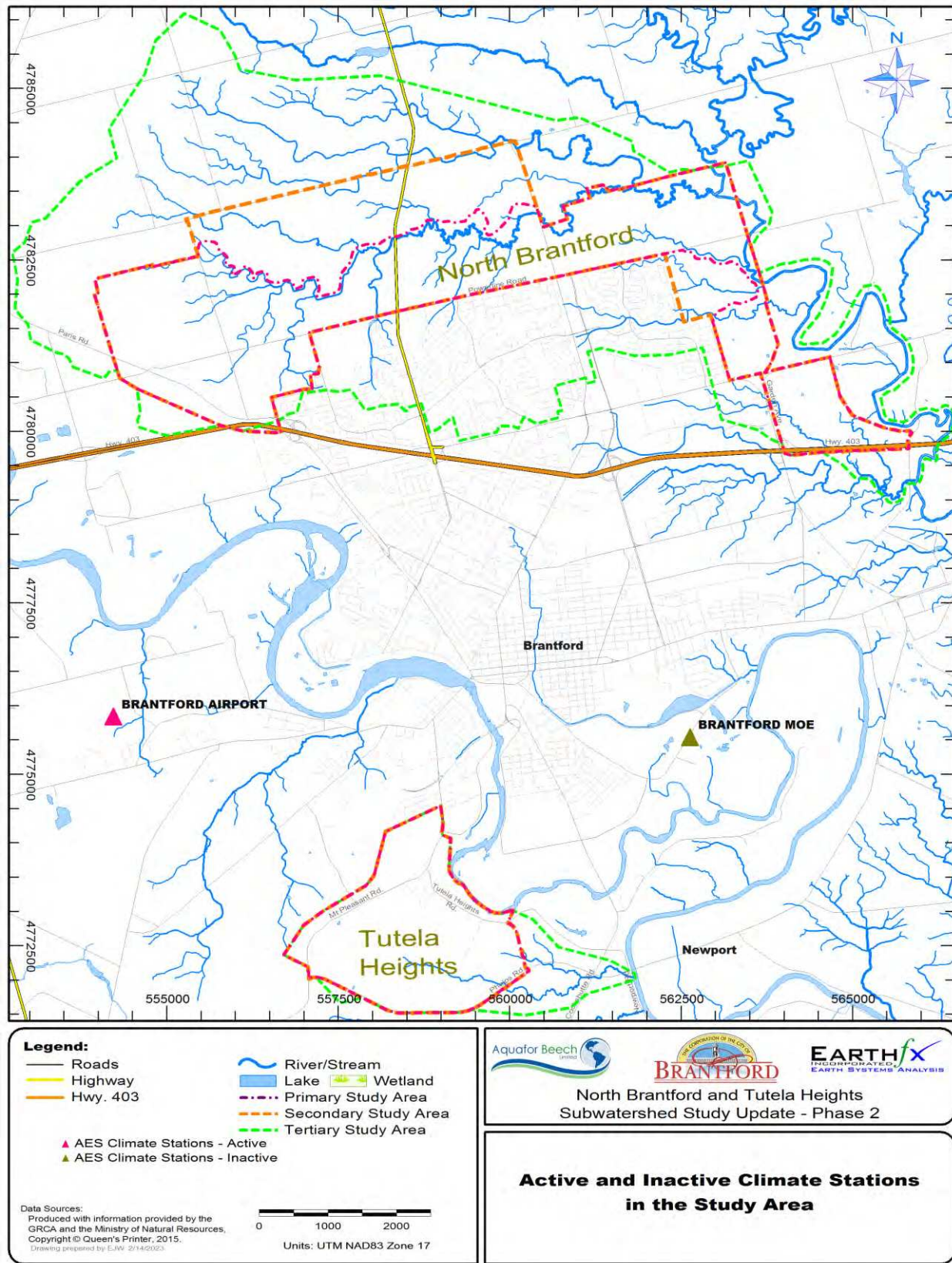


Figure 3.53: Active and inactive AES climate stations in the study area (with data after 2011).

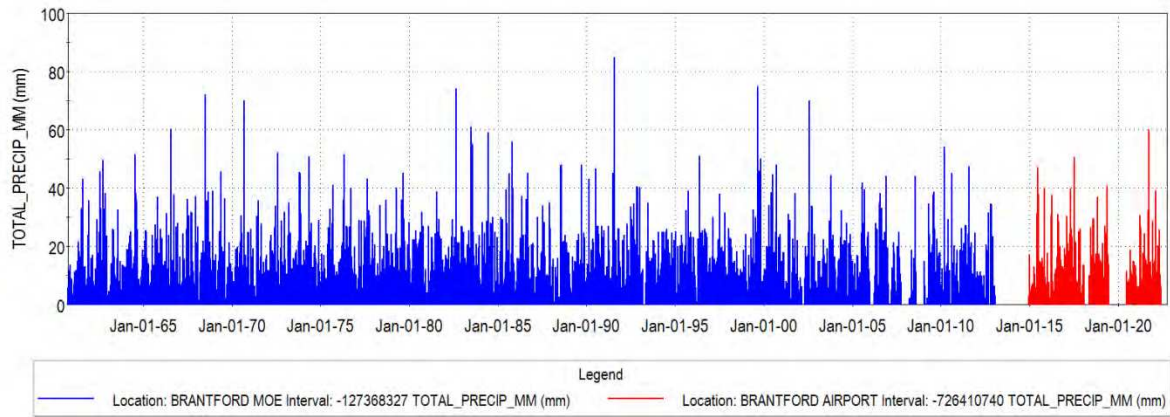


Figure 3.54: Daily precipitation for Brantford MOE (6140954) and Brantford Airport (6140942), WY1961 to WY2022.

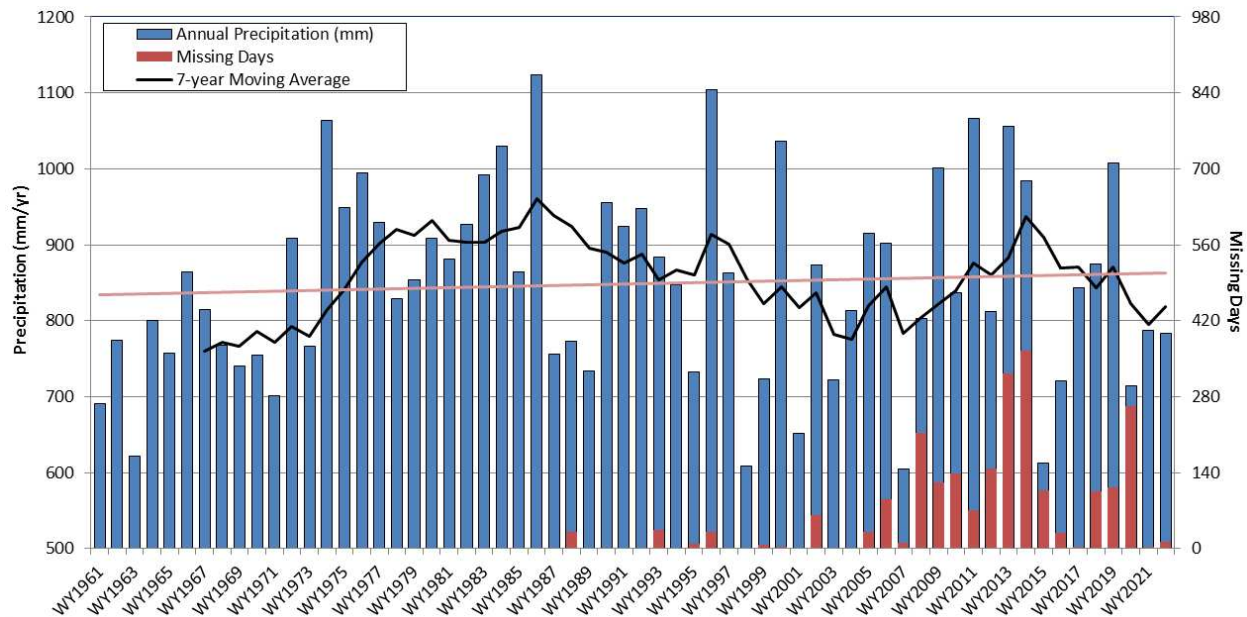


Figure 3.55: Annual average precipitation in the study area (Brantford stations, WY1961 – WY2022) and number of missing days per year.

3.2.8.1.2 Solar Radiation

Incoming solar radiation data are used in evaluating potential ET and snowmelt. The values are controlled primarily by the number of possible hours of sunshine per day and the percent cloud cover. Solar radiation data are collected at very few stations. Previous studies by Earthfx showed that the widely-separated Ontario solar radiation stations exhibited good inter-station correlation. An incoming solar radiation dataset was compiled using average measurements from four climate stations maintained by EC after 1985: 611KBE0 (Egbert CARE); 6142285 (Elora Research Station); 6158350 (Toronto); and 6158740 (Toronto MET Research Station). These data end about 2003 and were supplemented by measurements from the University of Waterloo, York University, the Burford Tree Farm, and the University of Toronto Mississauga campus. Where direct observations were missing, solar radiation was estimated by the Hargreaves and Samani (1982) method which uses daily minimum and maximum temperatures to correct incidental extraterrestrial radiation to match observed local conditions.

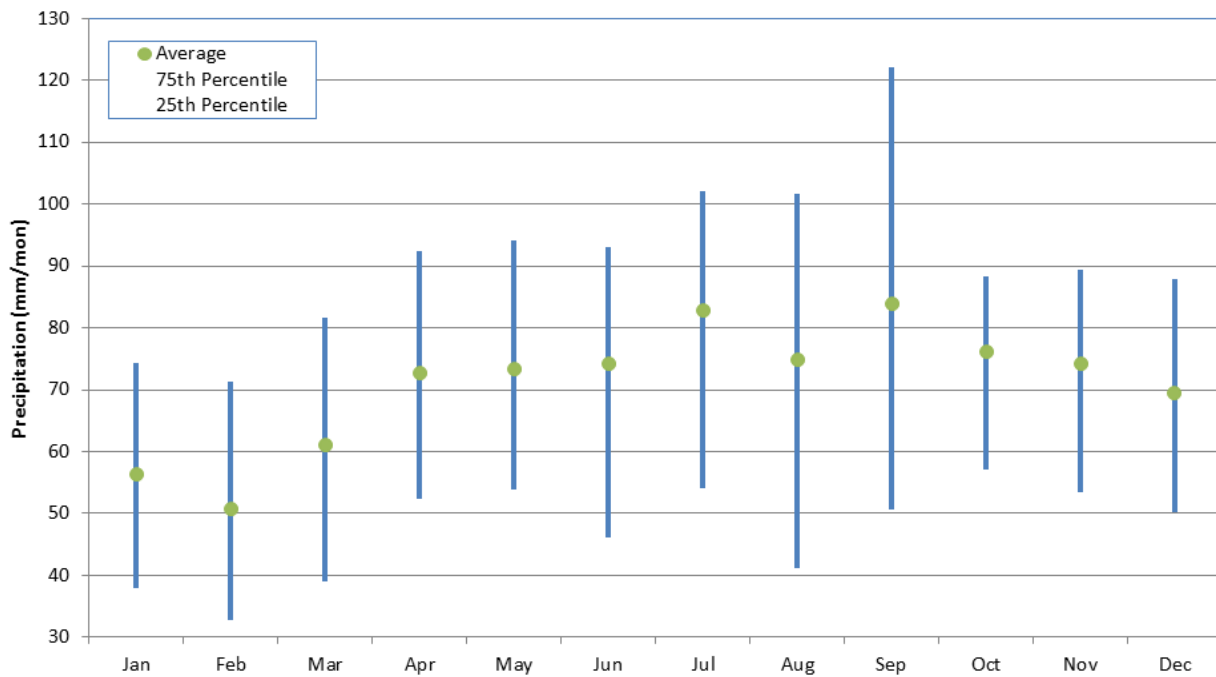


Figure 3.56: Monthly average precipitation, in mm/mon, for WY1961 to WY2022 and range in the data.



Figure 3.57: Monthly percentage of daily precipitation events above specified size relative to total number of precipitation events for WY1961 to WY2022.

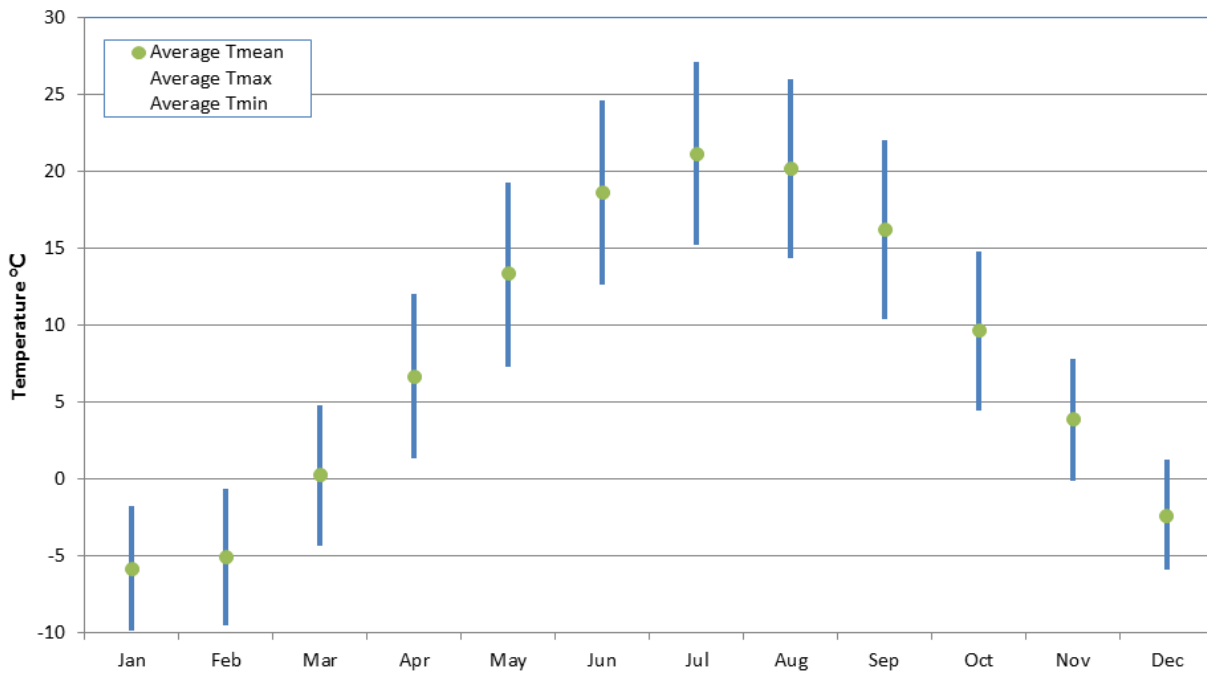


Figure 3.58: Monthly average mean, maximum, and minimum temperatures, in °C, for WY1961 to WY2022.

3.2.8.2 Topography

Topography affects groundwater recharge in a number of ways, as slope, aspect and closed depressions all affect runoff and infiltration. Topography based on recent LiDAR surveys was discussed earlier and shown in Figure 3.4. Slope and slope aspect values were calculated from the DEM using a nine-point planar regression technique that fits a plane to every cell and its eight surrounding cells (see Moore *et al.*, (1991)). Topographic slope classes for the study area is shown in Figure 3.59 and highlights the steep slopes along the edges of stream valleys in the North Brantford and Tutela Heights areas.

Topographic data and terrain analysis techniques were used to evaluate the overland flow routing pathways. An 8-direction steepest-descent method was selected because it generates an efficient many-to-one cascade network. A portion of the cascade flow network around North Brantford along with land surface topography is presented in Figure 3.60.

3.2.8.3 Land-use and Cover

Land use and land cover are important inputs to the assessment of infiltration. The available source for land use/land cover data is primarily the Southern Ontario Land Resource Information System (SOLRIS v3; MNRF, 2019). A large number of land-use categories are found in the study area; their relative distribution in the North Brantford and Tutela Heights areas is summarized in Figure 3.61. The spatial distribution of land use classes is shown on Figure 3.62. The largest land use categories are “Tilled” and “Undifferentiated”. Undifferentiated land use includes agricultural types such as orchards, vineyards, perennial crops and idle land more than 10 years out of production, urban brown fields, hydro and transportation right-of-ways, upland thicket, and other open lands. Based on an analysis of airphotos, this category appears to be mostly idle lands and would likely behave similar to tilled lands. Together with “tilled” land, tree plantations, and hedgerows, these categories represent about 67% of both areas. The next largest general category includes pervious and impervious built-up areas and transportation (roads and airports) which represents 20 and 21% of the North Brantford and Tutela Heights areas, respectively. These percentages will change significantly as the agricultural and idle lands are converted to residential and commercial land.

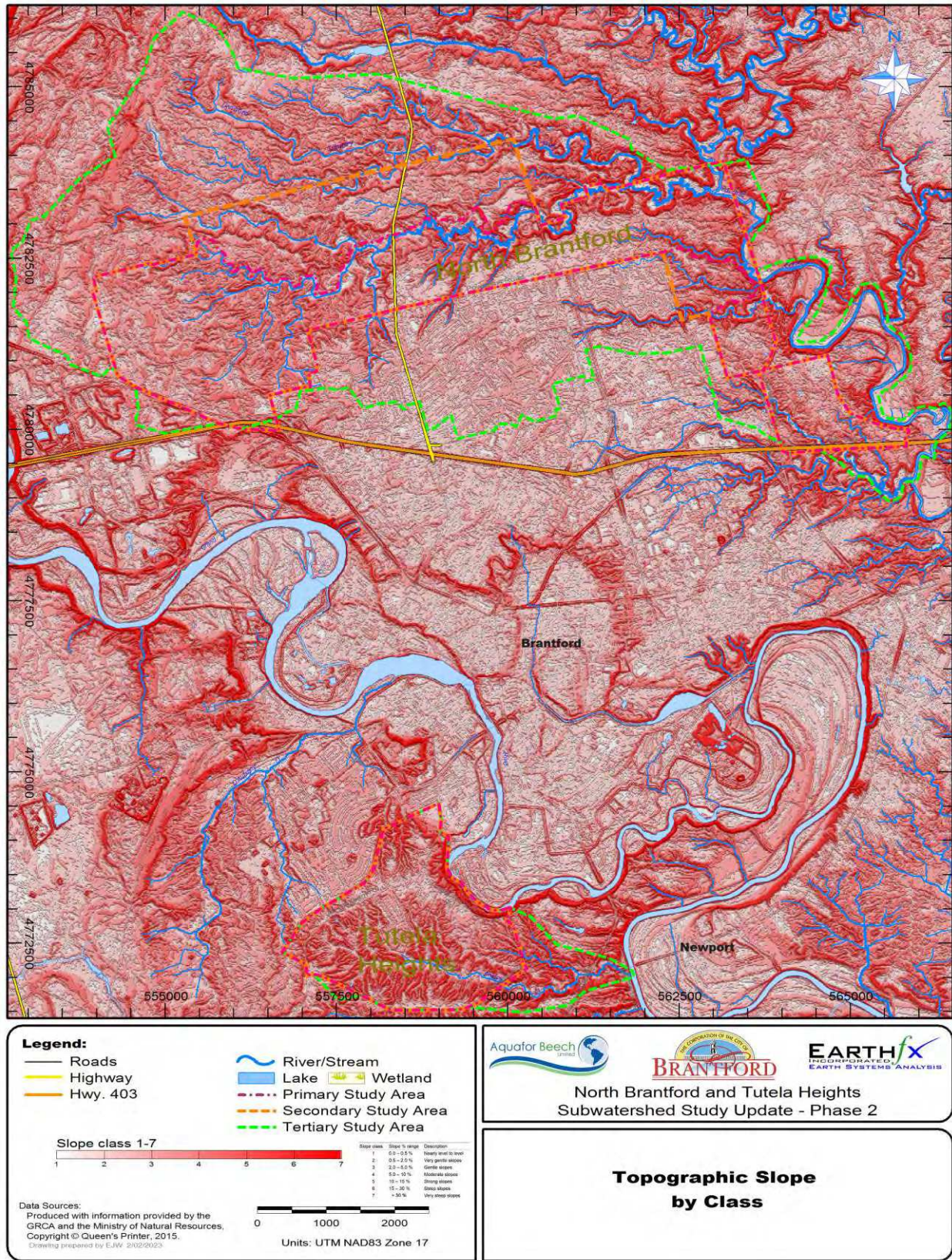


Figure 3.59: Topographic slope classes in the study area.

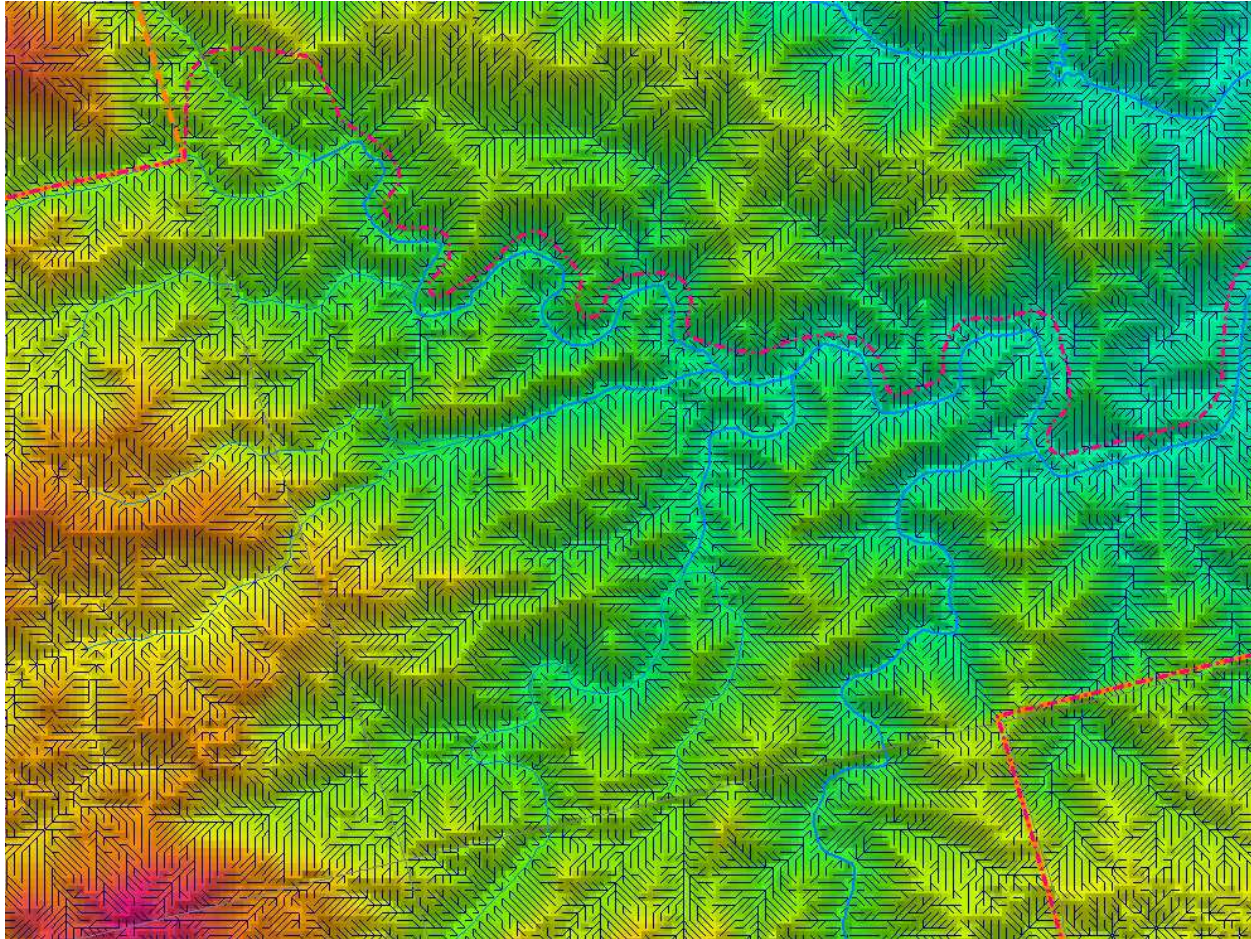


Figure 3.60: Portion of the cascade overland flow network in North Brantford.

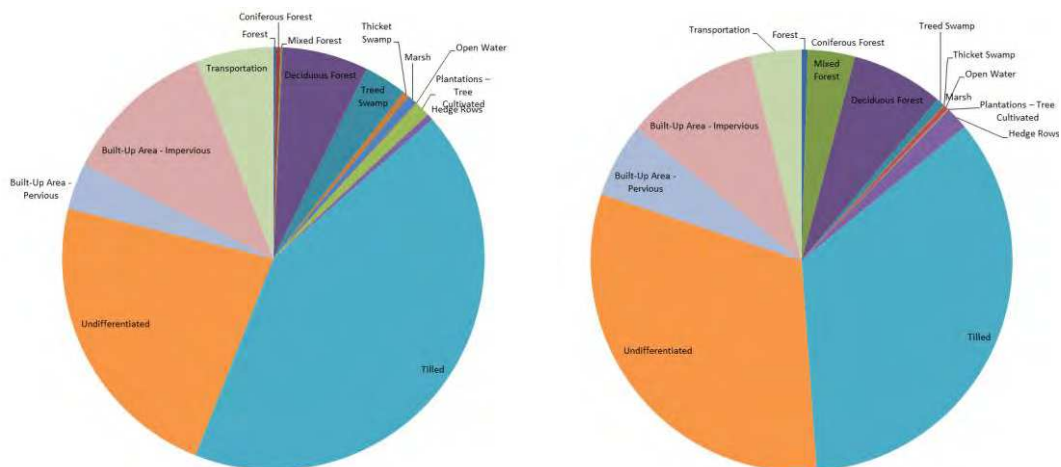


Figure 3.61: Distribution of land use classes in North Brantford (left) and Tutela Heights (right).

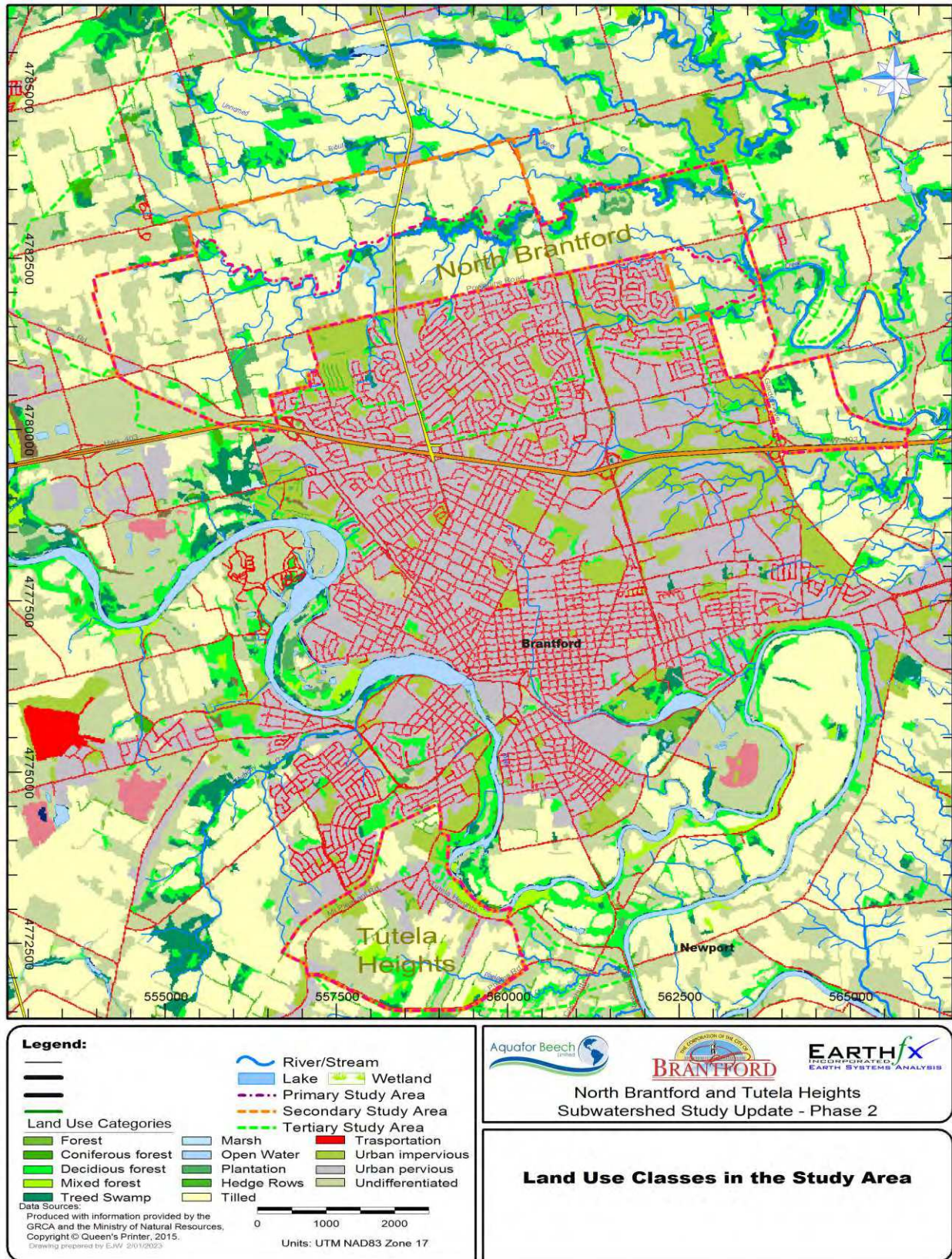


Figure 3.62: Land use classes in the study area.

Figure 3.63 shows percent impervious based on the SOLRIS v3 land use classes and the percent impervious values assigned to each land use class for the Fairchild Creek PRMS model. Although values are not likely to be identical within each land use classes, the assumption of uniform properties was made to simplify the modelling process. Further differentiation of land uses within the urbanized areas would refine the distribution of imperviousness.

3.2.8.4 Soil Properties

Soil properties have a significant influence on hydrological processes because they control the amount of water that can infiltrate and be transmitted to the water table as well as the amount of water lost to ET. Digital soil mapping is available for Ontario and the associated database contains useful information for hydrologic analysis. Figure 3.64 shows the soil map for the study area, where soils outside the urbanized area have been grouped according to the reported soil texture for the A horizon. As can be seen, the predominant soil type in the North Brantford and Tutela Heights areas is a silt loam, reflecting the glaciolacustrine parent material.

3.2.8.5 Evapotranspiration

Simulated rates of Actual Evapotranspiration (ET) from the PRMS hydrologic model are shown in Figure 3.65. Actual ET includes evaporation from the canopy, sublimation, and losses from the soil zone. ET from the soil zone depends on infiltration, plant type, root zone depth, season, temperature and solar radiation and is frequently rate limited in summer when the soil dries out.

Lower rates of ET are generally observed in the upland areas, which dry out more quickly than the lowland areas and swales that feed the intermittent headwater streams. Higher ET is also predicted in the more permeable alluvial sediments mapped near the streams, where recharge is higher, and where runoff accumulates leading to more available water.

The estimated average annual water surplus, defined as the difference between Precipitation and ET, is shown in Figure 3.66.

3.2.8.6 Groundwater Recharge

Simulated recharge rates from the PRMS hydrologic model reflect the variability in the study area (Figure 3.67). High recharge occurs in a small western portion of the North Brantford secondary study area, but overall recharge is very low in both the North Brantford and Tutela heights secondary study areas. Some recharge does occur in the alluvial sediments in the riparian areas, but that recharge water likely discharges into the nearby stream reaches.

Note that high recharge occurs in the sands and gravels that are present in the existing urban area.

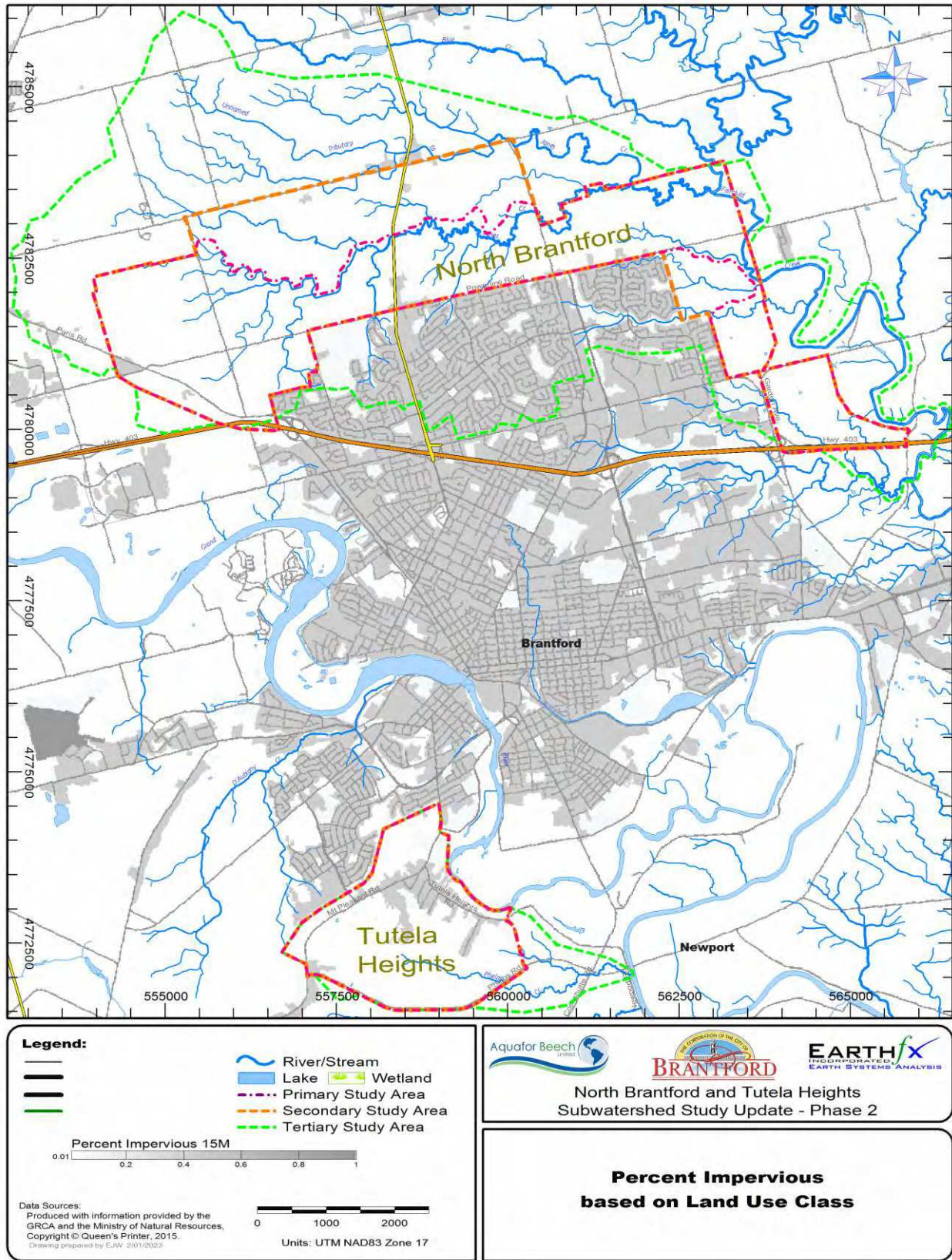


Figure 3.63: Percent imperviousness as assigned based on SOLRIS v3 land use classes.

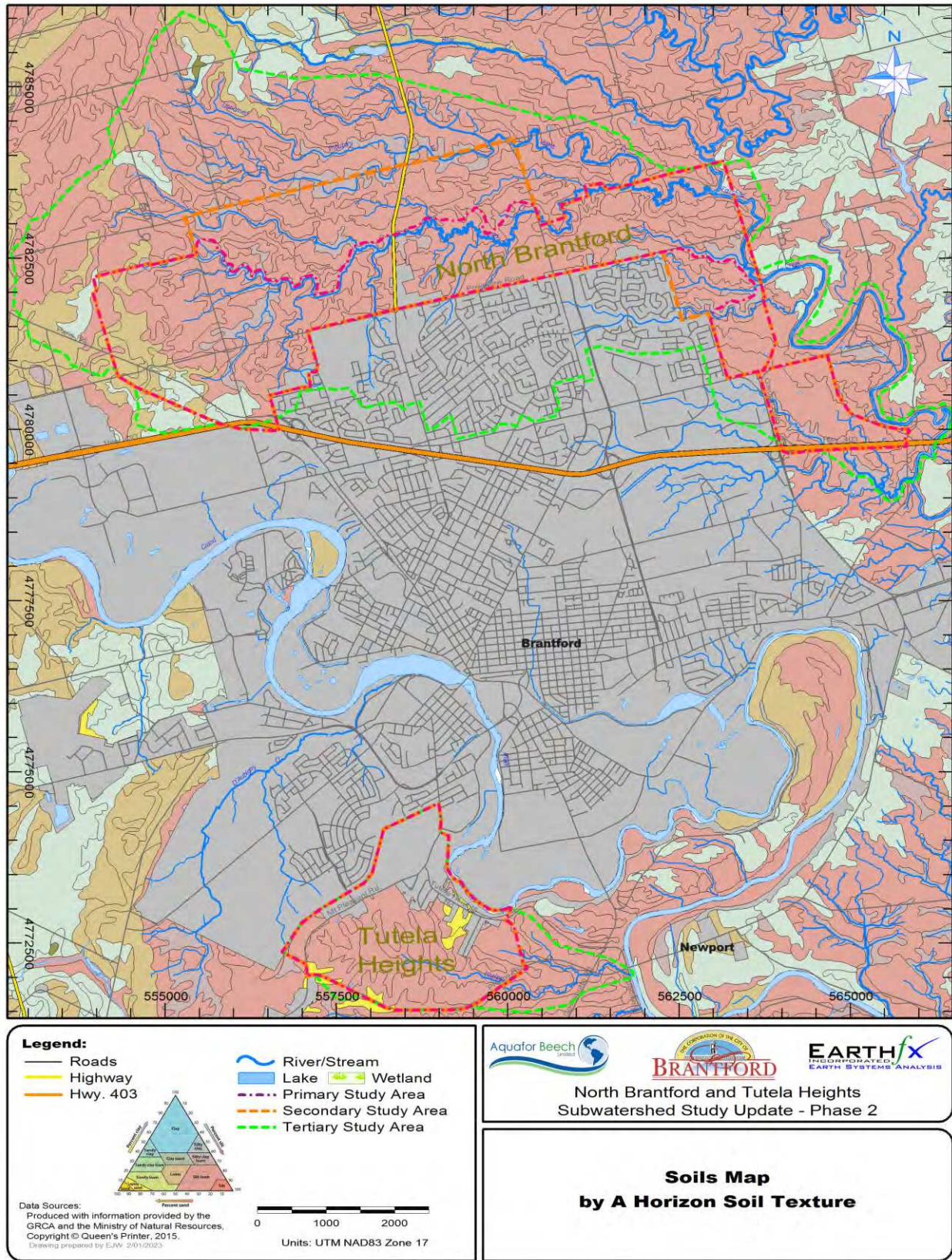


Figure 3.64: Soils mapping based on A Horizon texture.

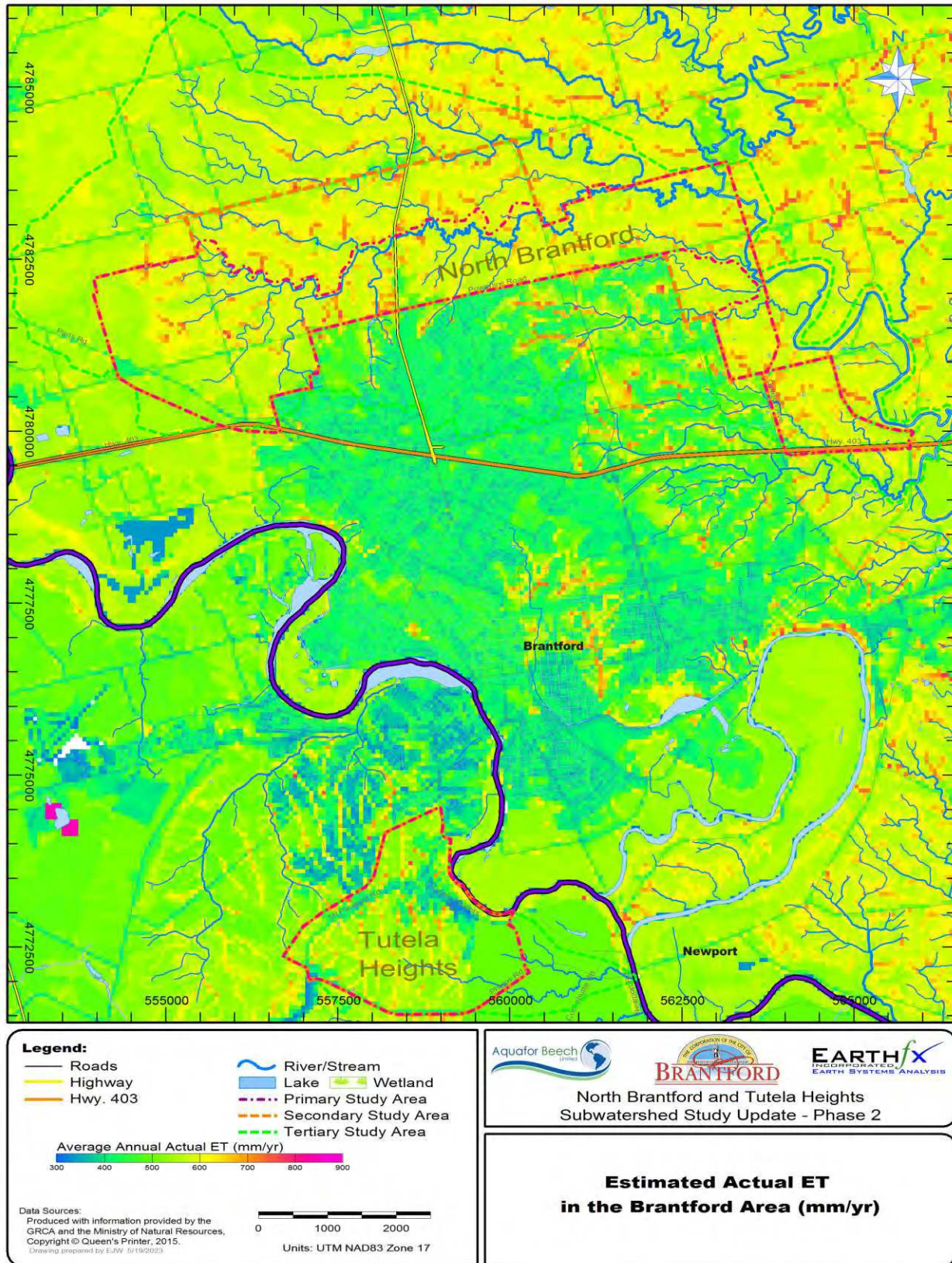


Figure 3.65: Estimated annual average evapotranspiration (ET) (mm/yr).

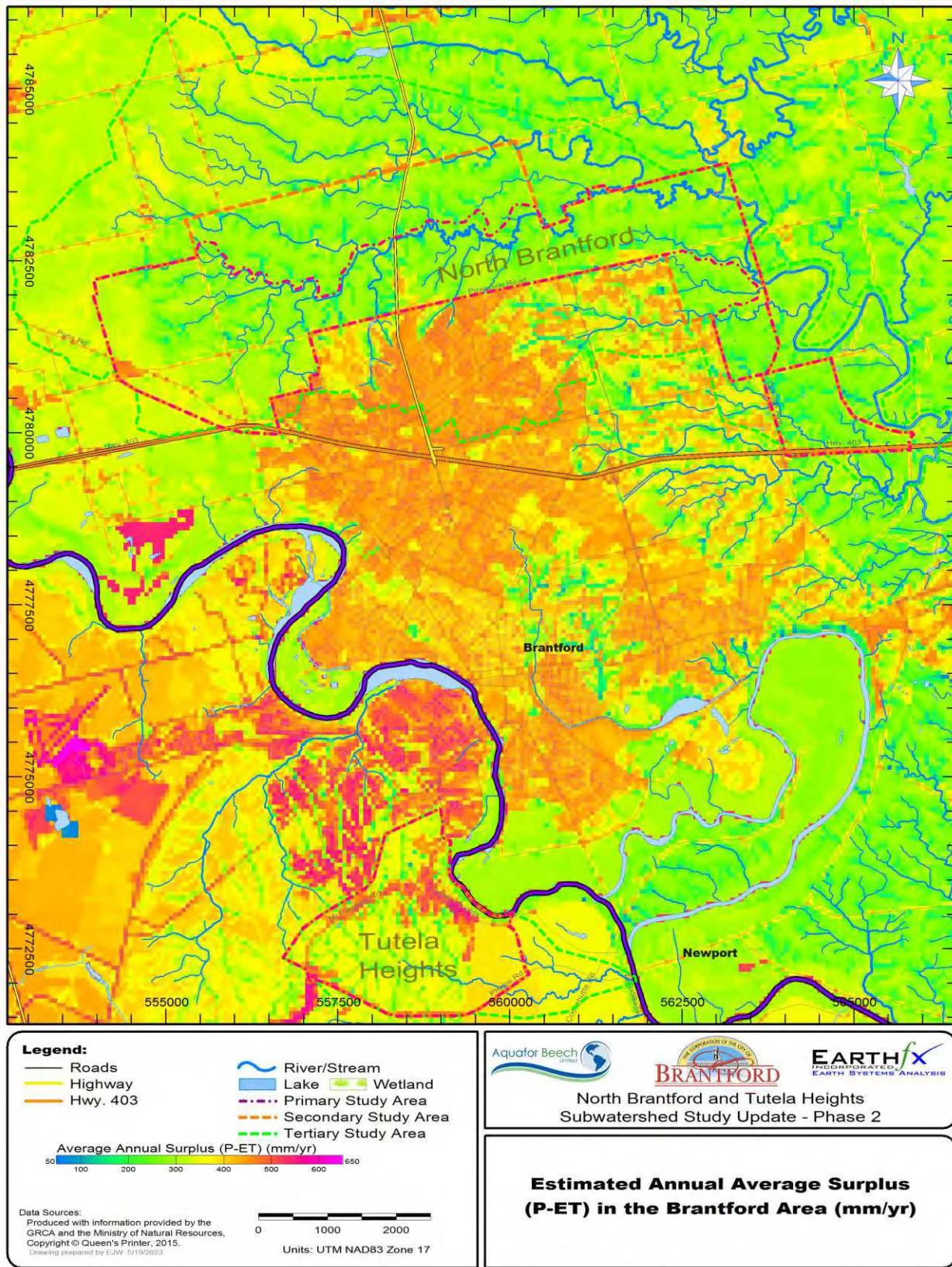


Figure 3.66: Estimated annual average surplus (Precipitation - ET) (mm/yr)

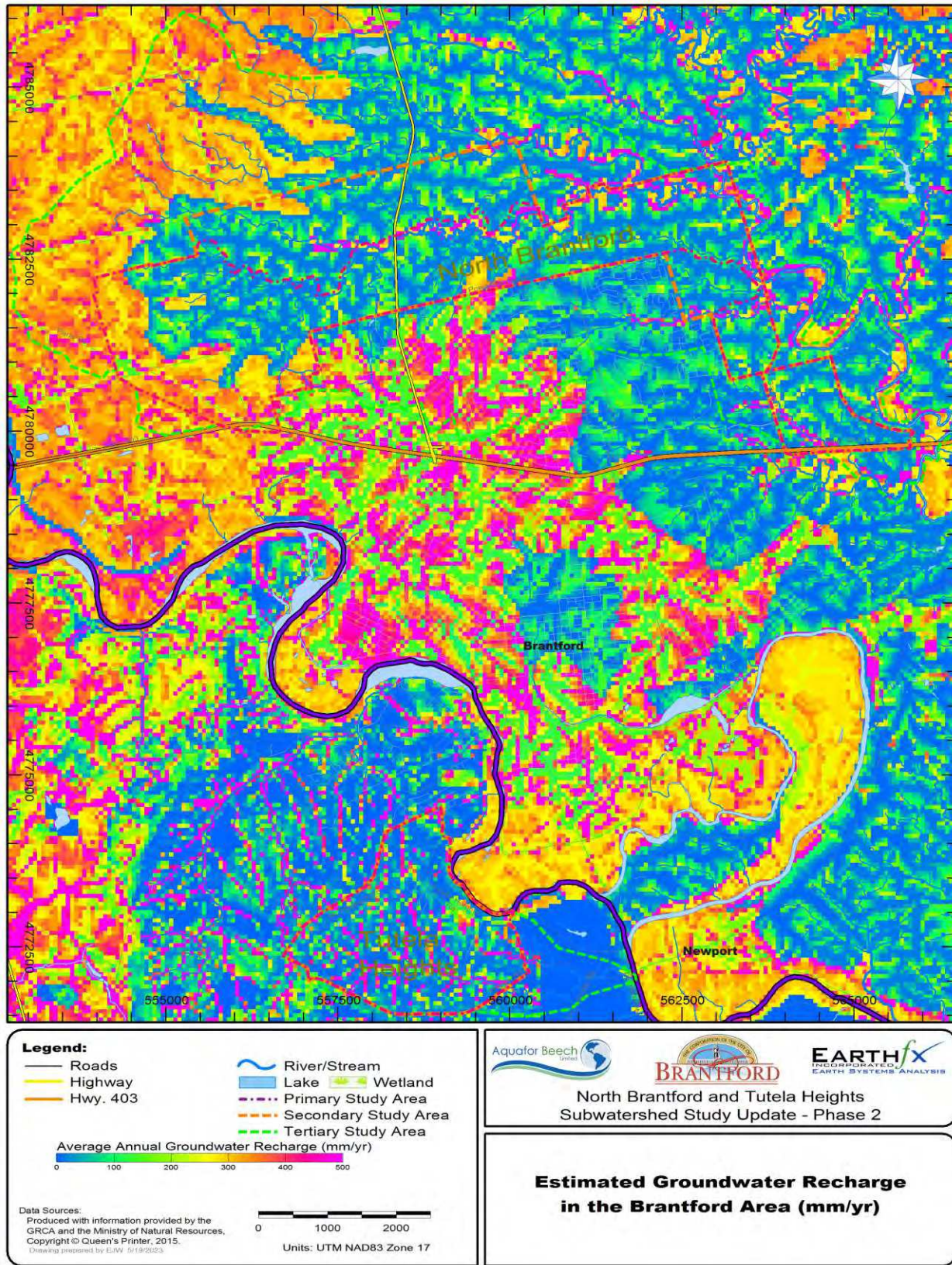


Figure 3.67: Estimated annual average groundwater recharge (mm/yr).

3.3 Surface Water Resources

The surface water component of this study inventories the network of existing drainage channels through the Study Area. Further field analyses and modeling are completed to determine the environmental function of these drainage features and to establish any associated flooding and erosion hazards. The resulting environmental features and natural hazards are then used to identify constraints to future development, as well as restoration opportunities.

Constraints to future development related to surface water resources are defined in the subsequent report sections under the following topics:

- Headwater drainage features – defines management recommendations for the small headwater drainage channels throughout the Study Area;
- Fluvial geomorphologic resources – defines erosion hazard considerations for the streams as well as restoration opportunities; and
- Hydrology/hydraulics and flooding – defines the estimated flood flows, flood levels, and associated floodplain hazard lands.

3.3.1 Headwater Drainage Feature Assessment

Headwater drainage features (HDFs) typically consist of shallow, seasonally-ephemeral drainage features which provide primary and secondary inputs into more defined watercourses. HDFs vary in both form and function and may provide direct (both permanent and seasonal) habitat for fish. Examples of aquatic habitat types present in HDFs include refuge pools, seasonal spawning and nursery areas, and thermal refugia in areas of groundwater discharge. HDFs also provide indirect habitat by transport of detritus/invertebrates to downstream reaches (Stanfield, 2017). Further descriptions of HDF form and function are contained below in **Section 3.3.1.1**.

Examples of HDFs include small streams, springs, wetlands, swales, and ditches (natural or human-modified). These features are also important sources, conveyors, or sinks of sediment, nutrients, and flow. Some HDFs may function as important habitat for terrestrial and wetland species as breeding areas or corridors for travel.

HDFs have not traditionally been a part of most aquatic monitoring efforts. However, understanding of the importance of such features has been growing and HDFs are now protected features under certain local and provincial regulations. The *2020 Growth Plan for the Greater Golden Horseshoe*, prepared under the *Places to Grow Act* (2005), considers HDFs to be a component of the "significant surface water contribution areas" and recommends their protection as Key Hydrologic Features. The Brantford OP further defines protections around Key Hydrologic Features, stating that, "outside of settlement areas, development or site alteration is not permitted in ... key hydrologic features" (City of Brantford, 2022). Refer to OP Policy 5.6.3.b for exemptions to these protections.

As a part of the Phase 1 study completed by GM Blue Plan, in association with Ecosystem Recovery, HDFs were assessed within the Brantford Urban Boundary expansion area following the TRCA and

CVC Guidance Document and methodologies (CVC & TRCA, 2014). Moreover, GRCA was involved to discuss and confirm management recommendations proposed for the HDFs identified in the study. Overall, 27 km of HDFs were confirmed as a part of the Phase 1 study. However, preliminary desktop analysis identified approximately 48 km of HDFs across the study area, representing approximately 63 % and 75 % of the overall drainage area in the North Brantford and Tutela Heights study areas, respectively. The Phase 1 study noted that due to access constraints, the number of confirmed features was below the actual value within the study area. As such, additional investigations were proposed to assess and evaluate the remaining features in the study area.

The Phase 1 Update study was originally proposed to include an assessment of HDFs to identify features and determine the appropriate level of management applicable to each within the Study Area(s), building on the Phase 1 results prepared by GM BluePlan. Methodologies were to follow those outlined by the Phase 1 study, following the TRCA and CVC Guidance Document and methodologies (CVC & TRCA, 2014). However, TRCA/CVC Guidelines state specifically that the first assessment period is to be during the spring freshet. Due to issues obtaining landowner access, the first and most critical round of the assessment was unable to be completed during the appropriate timing window. As such, the features identified during the Arc Hydro desktop analysis could not be field verified and field HDF assessments were not completed following the TRCA/CVC Guidelines, leaving an incomplete assessment and inadmissible analysis for the purpose of developing management criteria. Methodology proposed as a part of this study are discussed below, along with results of the preliminary, desktop exercise overlaid with the Phase 1 results and management recommendations. It is assumed that the potential features identified using the desktop analysis, as shown in **Figure 3.68** with black line features, are to be assessed at a later stage following the methodology discussed hereafter.

3.3.1.1 Methodology

The Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (CVC & TRCA, 2014), hereafter “the Guidelines”, were used to classify HDFs within the Study Area. The Guidelines were developed to provide direction to practitioners for aquatic features that are not clearly covered by existing policy and legislation as being important eco-hydrological features (e.g., perennial streams and provincially significant wetlands) but may contribute to the overall health of a subwatershed. The Guidelines attempt to evaluate, in a consistent way, the contribution of sediment, food and flow transport to downstream reaches, as well as the use of these features by biota (CVC & TRCA, 2014).

To distinguish HDFs from watercourses, the following definitions were utilized per the Ontario Stream Assessment Protocol (OSAP) and the CVC & TRCA document:

- HDFs are non-permanently flowing drainage features that may not have defined bed or banks; they are first-order and zero-order intermittent and ephemeral channels, swales and connected headwater wetlands, but do not include rills or furrows.
- Features within a valley are typically not considered HDFs.
- A HDF has a catchment of at least 2.5 ha in size.

In order to identify possible HDFs, a drainage network for the North Brantford and Tutela Heights Study Area from GRCA was rasterized and used to recondition a 2021 bare earth Digital Elevation Model (DEM) provided by the City of Brantford. The input DEM was originally created from a LiDAR point cloud (+/-8cm NVA (Non-Vegetated Vertical Accuracy) at 95% confidence level, +/- 11.9cm Horizontal Accuracy at 95% confidence Level) and has a horizontal spatial resolution of 0.5 m x 0.5 m. The reconditioned DEM was then processed using Arc Hydro to fill in local depressions to correct potential processing problems. Next, flow direction and flow accumulation rasters were then created. Lastly, the stream network was defined from the flow accumulation raster such that any streams with a catchment of 2.5 ha would be accounted for. After the stream network was defined, the streams were segmented and the catchments delineated. The final stream raster and catchment raster were converted to vector feature classes using the Spatial Analyst extension, and the stream order was then classified using the Spatial Analyst extension. Field maps were prepared for Aquafor Beech biologists by overlaying the stream and catchment layers on aerial images, as shown in **Figure 3.68**:

A Standard Survey Type was to be applied, according to the recommendations in the Guidelines. This requires the use of the following modules of the Ontario Stream Assessment Protocol (OSAP) to assess HDFs:

- Section 4: Module 10 (Constrained Headwater Sampling); and
- Section 4: Module 11 (Unconstrained Headwater Sampling).

HDF sampling locations were to be chosen based on land access and road crossings, where possible. However, due to the size of the Study Area, land access was not granted for all HDF assessment areas and road crossings were not always available. Where land access was not granted, Section 4: Module 10 of OSAP was to be used.

Per the CVC & TRCA Guidelines and as discussed above, the OSAP Headwater module was to be completed three (3) times at each sampling location to assess the HDFs throughout the year:

- Site Visit #1: Conducted from March-April, during the spring melt (frost-free conditions). ArcHydro segments to be confirmed in the field.
- Site Visit #2: Conducted in April-May, when high melt flows have ceased. This visit ideally occurs before leaf-out, so that features can be easily observed.
- Site Visit #3: Conducted in July-August, or when temperatures are consistently warm and conditions are dry. The purpose is to confirm hydrology, fish presence, and groundwater indicators.

Using the Guidelines, the results of the HDF assessments were to be integrated with aquatic/terrestrial habitat observations, amphibian surveys, hydrology, and Species at Risk data.

Once field surveys were complete, the HDFs were to be assessed in four (4) steps, based on criteria outlined in the Guidelines, to classify each HDF:

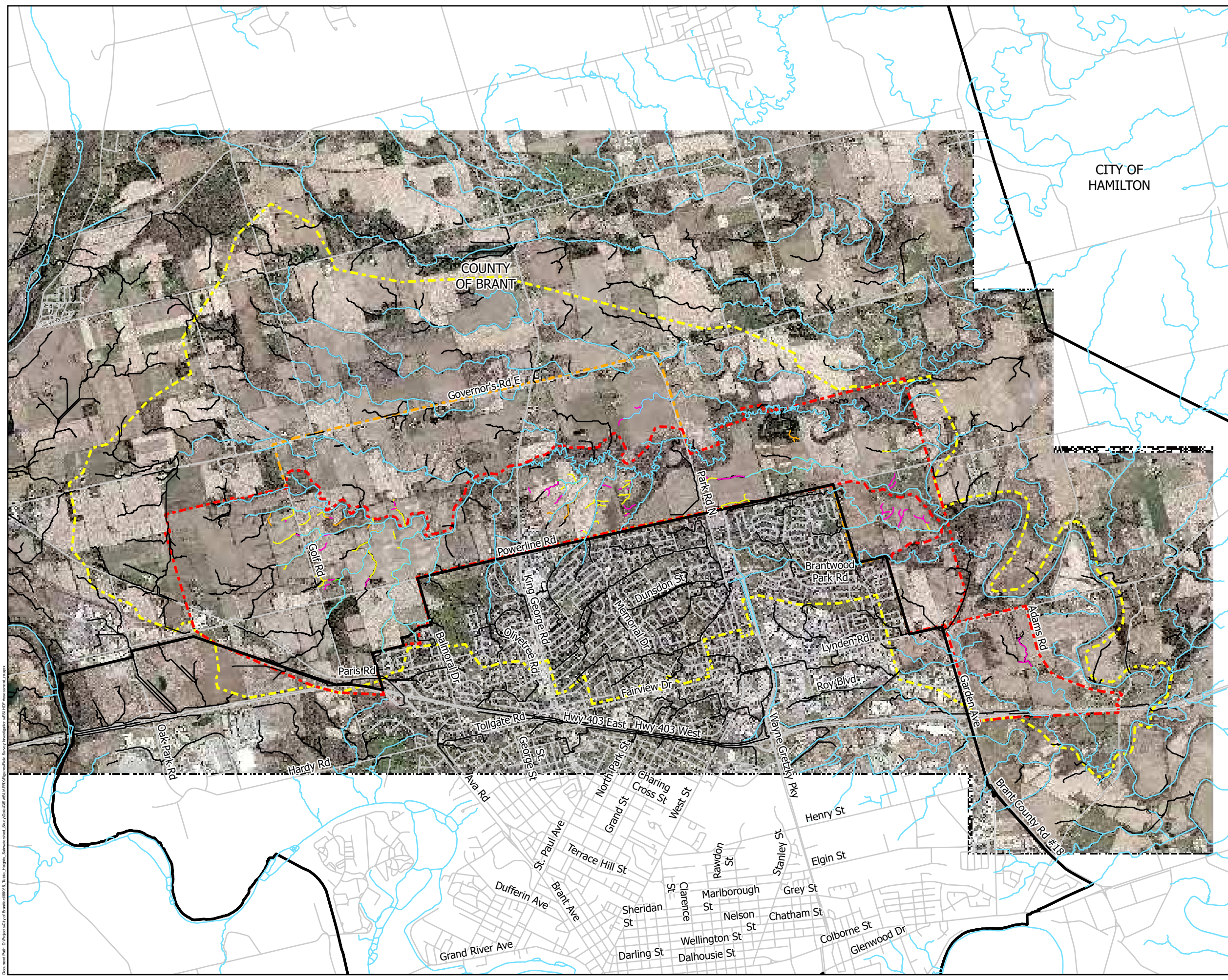
Step 1: Hydrology Classification: Flow conditions are classified into hydrology types

Step 2: Riparian Classification: The feature is classified with regard to riparian conditions

Step 3: Fish and Fish Habitat Classification: Fish and fish habitat is classified based on the presence of fish

Step 4: Terrestrial Habitat Classification: Features are classified based on the presence of breeding amphibians and wetlands

Finally, the results of Steps 1-4 were to be summarized and used in the Flow Chart within the CVC & TRCA Guidelines to assign a Management Recommendation (**Figure 3.69**).



Legend

- Potential HDF
- Road Centreline
- ▭ Municipal Boundary

Subwatershed Study Area:

- ▨ Primary
- ▨ Secondary
- ▨ Tertiary

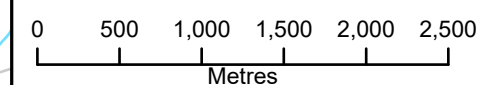
GM BluePlan HDF Assessment:

- Protection
- Conservation
- Mitigation
- No Management Required
- Unclassified

Figure 3.68 (1 of 2)

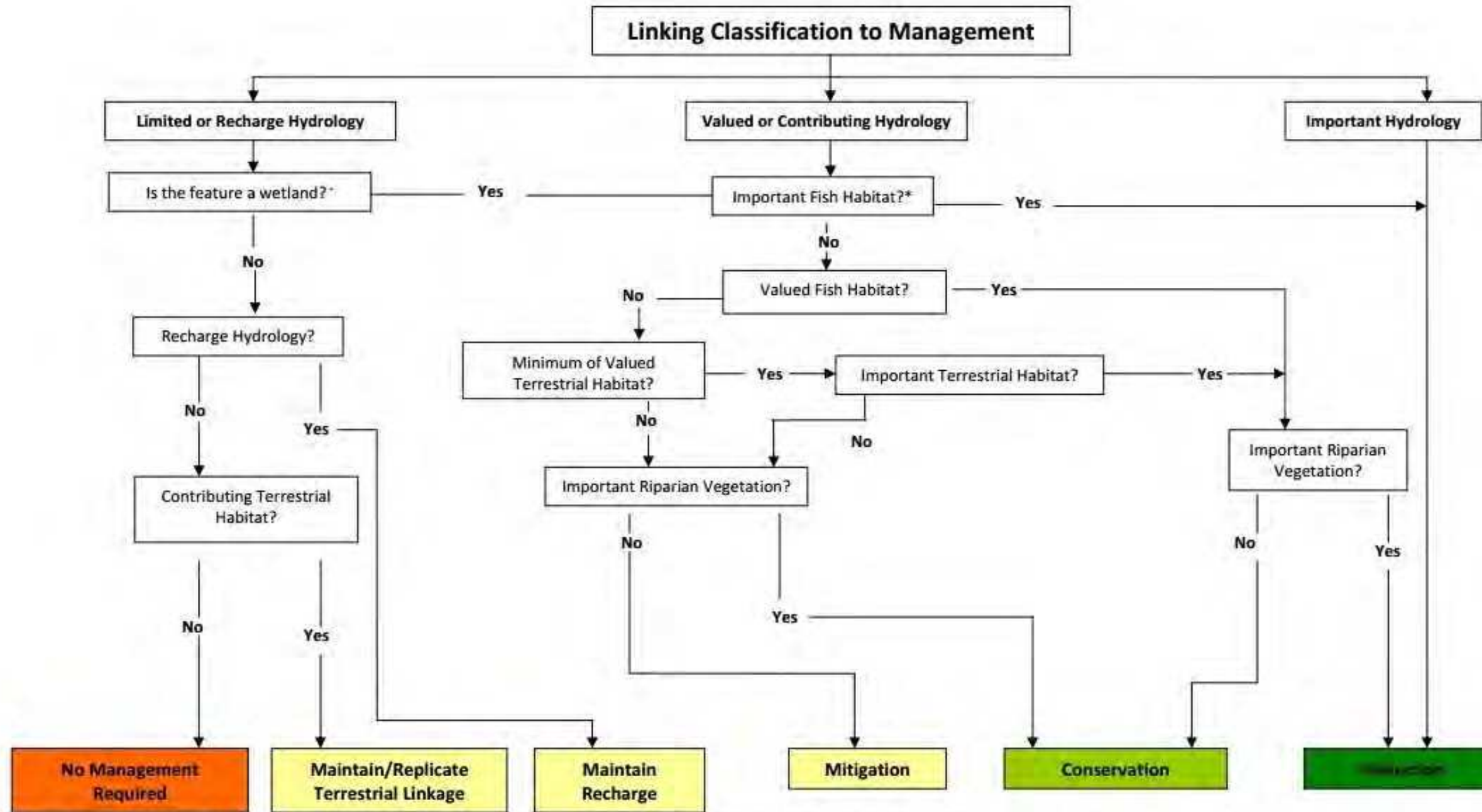
Arc Hydro Desktop Analysis & Potential HDFs

Date: 2022-11-10
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: J.R.



3.3.1.2 HDF Classifications and Management Recommendations

As discussed above, the first site visit where potential features are to be field-verified was not able to be completed following the outlined methodology and, as such, field assessments were not completed following the TRCA/CVC Guidelines. As potential features could not be field-verified, many features could potentially be missed or misrepresented during the classification and management exercises, particularly as the Guidelines apply to definitions and requirements associated with each Management Recommendation as depicted in **Figure 3.69** and as listed in **Table 3.10**. Management Recommendations were carried forward from the Phase 1 reporting and shown in **Figure 3.68**: alongside the Arc Hydro desktop analysis and potential HDFs. Again, it is assumed that the potential features identified using the desktop analysis that were not confirmed as a part of this study phase, as shown in **Figure 3.68** with black line features, are to be assessed at a later stage following the aforementioned methodology.



*Other Conservation Authority policies or other legislation with respect to wetlands, watercourses and/or species at risk need to be assessed in the context of this key.
+Note that headwater wetlands are considered to be HDFs in the context of this guideline.

Figure 3.69: HDF Management Criteria Flow Chart

Table 3.10: Definitions of Management Recommendations (CVC & TRCA, 2014)

HDF Management Recommendation	Definition
<p>Protection (Important Functions)</p>	<ul style="list-style-type: none"> • Protect and/or enhance the existing feature and its riparian zone corridor, and groundwater discharge or wetland in-situ; • Maintain hydroperiod; • Incorporate shallow groundwater and base flow protection techniques such as infiltration treatment; • Use natural channel design techniques or wetland design to restore and enhance existing habitat features, if necessary; realignment not generally permitted; and • Design and locate the stormwater management system (e.g. extended detention outfalls) are to be designed and located to avoid impacts (i.e., sediment, temperature) to the feature.
<p>Conservation (Valued Functions)</p>	<ul style="list-style-type: none"> • Maintain, relocate and/or enhance drainage feature and its riparian corridor; • If catchment drainage has been previously removed or will be removed due to diversion of stormwater flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage), as feasible; • Maintain or replace on-site flows using mitigation measures and/or wetland creation, if necessary; • Maintain or replace external flows; • Use natural channel design techniques to maintain or enhance overall productivity of the reach; and • Drainage feature must connect to downstream.

HDF Management Recommendation	Definition
<p>Mitigation (Contributing Functions)</p>	<ul style="list-style-type: none"> Replicate or enhance functions through enhanced lot level conveyance measures, such as well-vegetated swales (herbaceous, shrub and tree material) to mimic online wet vegetation pockets, or replicate through constructed wetland features connected to downstream; Replicate on-site flow and outlet flow at the top end of the system to maintain feature functions with vegetated swales, bioswales, etc. If catchment drainage has been previously removed, due to diversion of stormwater flows, restore lost functions through enhanced lot level controls (i.e. restore original catchment using clean roof drainage); and Replicate functions by lot level conveyance measures (e.g. vegetated swales) connected to the natural heritage system, as feasible and/or Low Impact Development (LID) stormwater options (refer to Conservation Authority Water Management Guidelines for details).
<p>Mitigation (Recharge Functions)</p>	<ul style="list-style-type: none"> Maintain overall water balance by providing mitigation measures to infiltrate clean stormwater, unless the area qualifies as an Area of High Aquifer Vulnerability under the Oak Ridges Moraine Conservation Plan (ORMCP) or Significant Recharge Areas under the Source Water Protection Act. These areas will be subject to specific policies under their respective legislation. Terrestrial features may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with them.
<p>Mitigation (Terrestrial Functions) (note: HDF type not present in the Study Area)</p>	<ul style="list-style-type: none"> Maintain the corridor between the other features through in-situ protection or if the other features require protection, replicate and enhance the corridor elsewhere If the feature is wider than 20 m, it may need to be assessed separately through an Environmental Impact Study to determine whether there are other terrestrial functions associated with it.
<p>No Management Required (Limited Functions)</p>	<ul style="list-style-type: none"> The feature that was identified during desktop pre-screening has been field verified to confirm that no feature and/or functions associated with HDFs are present on the ground and/or there is no connection downstream. These features are generally characterized by lack of flow, evidence of cultivation, furrowing, the presence of a seasonal crop, and lack of natural vegetation. No management recommendations required.

The Evaluation, Classification, and Management of Headwater Drainage Features Guidelines set forth by the CVC and TRCA (CVC & TRCA, 2014) was developed with guidance from multiple stakeholder groups and is recognized by municipalities as a tool to provide direction specifically with regard to HDF management. This study was to therefore utilize the Management Recommendations set forth by the Guidelines when developing land-use constraints; see **Section 4.3.2** for further discussion of HDF management as related to municipal natural heritage policies and developmental constraints.

It should be noted that the Guidelines and Classification process recommends that features defined by, “...evidence of cultivation, furrowing, presence of a seasonal crop, lack of vegetation, and fine textured soils,” should be considered to provide Limited or Recharge Hydrologic Functions (CVC & TRCA, 2014). These defining characteristics are typical of agricultural fields, of which contain some of the larger and potentially hydrologically significant drainage features. This is typically the case for features given the lowest management recommendations within subwatersheds, and would likely be the case for the North Brantford and Tutela Heights Study Areas, that are not ponds. Furthermore, these assessments do not account for agricultural features that are tiled. In these cases, management recommendations would be up-ranked if the agricultural fields would be left to re-naturalize making these areas suitable for restoration works. It is the opinion of Aquafor Beech Limited that additional HDF Assessments be undertaken on features identified on agricultural properties prior to any development approval in order to accurately assess hydrologic functions of these features. This is especially the case if cultivated lands are allowed to go fallow in the intervening time between the development of initial management recommendations and landuse development applications.

3.3.1.3 Conclusions

Figure 3.68: displays the potential HDFs and Assessment Areas based on the preliminary Arc Hydro desktop analysis alongside the Management Recommendations for HDFs assessed during the Phase 1 report. As project constraints restricted field investigations to after the timing window(s) discussed in the TRCA/CVC guidelines, HDF Assessments could not be completed for the Study Area(s) and therefore, Management Recommendations applicable to each category of HDF could not be defined outside of those presented during the Phase 1 report. Management Recommendations as defined as a part of this study were to be used to inform the developmental constraints and opportunities and therefore must be considered before moving forward with the final developmental constraints and opportunities. As HDFs are managed under the Brantford OP as Key Hydrologic Features, stating that, “outside of settlement areas, development or site alteration is not permitted in ... key hydrologic features” (City of Brantford, 2022), features that were not assessed as a part of the Phase 1 or Phase 1 Update study due to landowner restrictions should be assessed prior to any development approval in order to accurately assess hydrologic functions of these features. Management Recommendations identified as a part of the Phase 1 study, as confirmed by the GRCA, are recommended to be carried forward into further planning and development stages.

3.3.2 Fluvial Geomorphologic Resources

Fluvial geomorphology is the study of the processes associated with streams and rivers, including stream hydraulics and sediment movement. Variables that influence the morphology of a stream include discharge, velocity, sediment load and size, channel slope, and the width and depth of the channel. A change in one of these variables will eventually alter another variable causing the channel to adjust. Land-use changes within a subwatershed can alter the amount of surface runoff and the amount of sediment reaching a stream. This can result in erosion and flooding problems, as well as poor aquatic habitat. Channel restoration works can mitigate the impacts of land-use change, through natural channel design or other river engineering approaches.

3.3.2.1 Study Objectives

Within the overall study goal of responsible environmental and economic management of water resources, the objective of the fluvial geomorphology component is to characterize stream and river channels, particularly with respect to erosion and channel stability. As such, detailed geomorphic assessments of watercourses have been completed for Fairchild Creek, Jones Creek, and Phelps Creek within the Urban Boundary. Within the Fairchild Creek, Jones Creek, and Phelps Creek subwatersheds, the geomorphic assessments provide a basis for recommendations with respect to development constraints (for sensitive stream reaches), mitigation of existing erosion problems, and opportunities for stream restoration which will improve future channel stability, protect infrastructure and property, and enhance ecological habitat.

The purpose of this assessment is to identify and evaluate the development constraints associated with each watercourse as they apply to those properties identified for development.

The following has been presented in this section:

- Reach delineations for the updated hydrology and characterizations for Fairchild Creek, Jones Creek, and Phelps Creek including classification of geomorphic stability through use of Rapid Geomorphic Assessments (RGAs)
- Assessment of erosion potential using results of field assessment-based reach characterizations, and MNR Erosion Allowance Guidelines for Watercourses in Valley Settings (2002)
- Delineation of a long-term stable slope setback, approximated using the MNRF guidelines for toe erosion, 3:1 stable slope estimates and 6 m erosion access allowance.

3.3.2.2 Fluvial Geomorphic Setting

The City of Brantford Phase 1 Subwatershed Study was completed in 2020 for the main trunk channels of Jones Creek, Fairchild Creek and most of Silver Creek. Three boundaries were identified in the 2020 study as the Primary Boundary of the existing municipally developed limit, the Secondary Boundary of currently proposed development, and a Tertiary Boundary for future development.

This current study looked to expand the existing hydrologic dataset by evaluating the reaches within North Brantford and Tutela Heights that lie within the Primary and Secondary Boundary by infilling data gaps between those watercourses that were assessed for erosion potential, geomorphic stability and channel parameters in the Phase 1 Subwatershed Report (2020). Erosion monitoring locations were established along four reaches in the 2020 report and detailed geomorphic surveys were conducted. This report has continued the established geomorphic monitoring protocol where access was granted.

Access to field investigation was not consistent throughout the study area. Of the 264 property parcels identified in this study, 52 parcels contained watercourses that identified for analysis as a part of this investigation. Of those 52 parcels, only 23 were accessible, including publicly owned lands, as a result of landowner response.

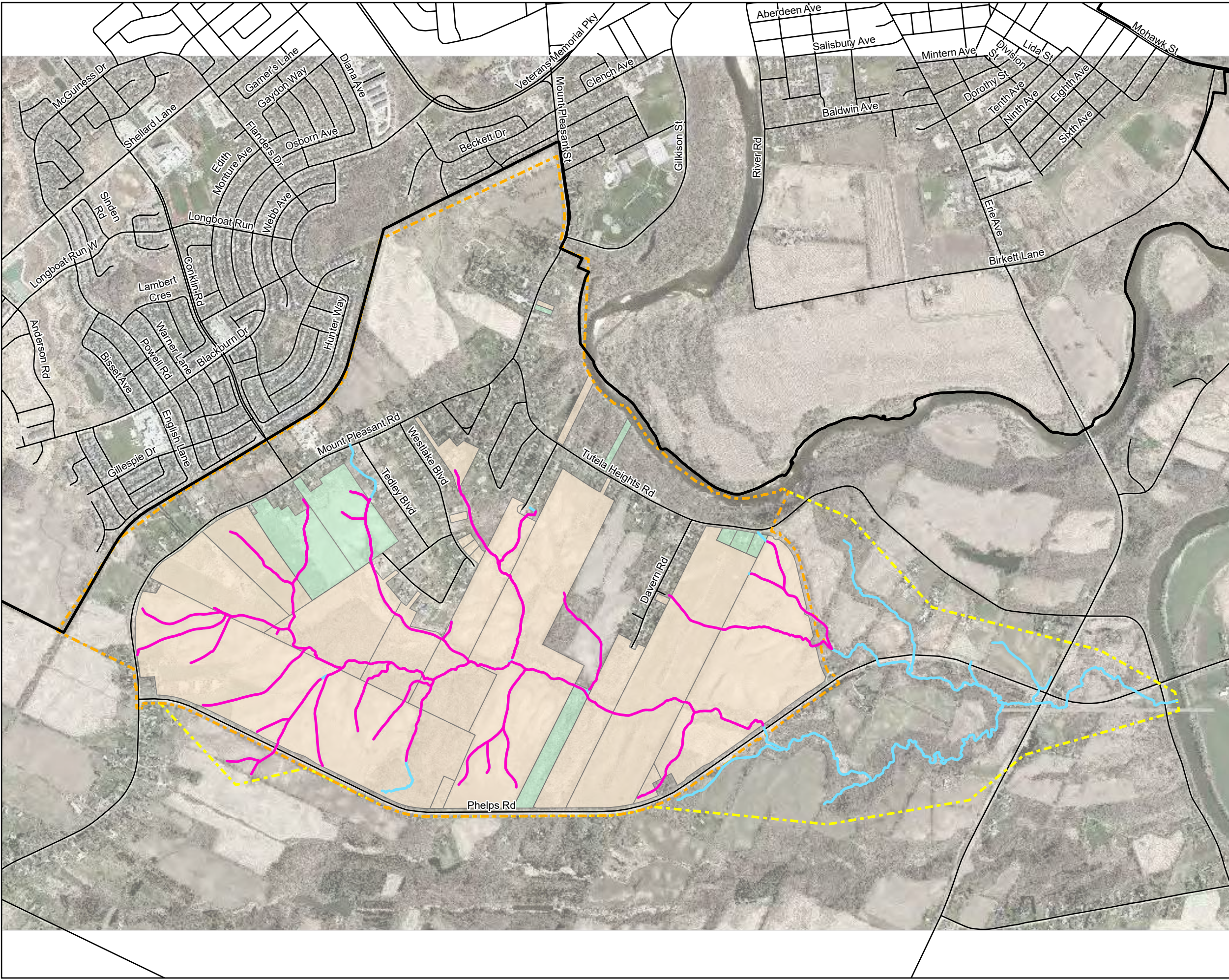
Figure 3.70 and **Figure 3.71** map the extents of the watercourse assessed in the 2020 SWS study for the City of Brantford (green reaches) and those included in the scope of this study (pink). The extents of the property that provided access to field investigation is shown in (light green) in relation to those properties that did not provide access (light pink). The investigations carried out as a part of this study will be required for those properties that did not provide access to field investigation before developable constraints on these properties can be determined.

During the field walks, the geomorphology of each watercourse was analyzed to characterize the stream system within the context of the erosion assessment. Erosion is a natural process and natural streams and rivers should be considered dynamic allowing for gradual and long-term channel adjustments that may occasionally include more dramatic changes due to high magnitude flood events.






Sediment aggradation and degradation are processes that create and maintain geomorphic features within a river. However, changes within a subwatershed (such as deforestation or urbanization) can create an unbalance within these processes resulting in erosion that is unnatural, or unhealthy for the system. Therefore, completing a geomorphic assessment is important in order to identify the natural processes and areas of excessive erosion or sedimentation.

Reach delineation is an approach whereby a watercourse is spatially grouped by channel characteristics and processes. Stream reaches are lengths of channel that display relative homogeneity with respect to the controlling and modifying influences of channel form. As such, channel characteristics, functions and processes are relatively constant within a reach, and reaches can be used to help identify management objectives and restoration opportunities.




The reach characteristics and photographic inventory of each of the major watercourses in the Study Area are summarized in **Appendix Q**, including the average channel dimensions, RGA scores where relevant, bed composition, bank stratigraphy, and areas of existing erosional risks. Reaches were defined by key factors, including hydrology, gradient, geology, valley setting, sinuosity, and riparian vegetation. Reach verification was completed through a synoptic-level field investigation to document channel morphology, prominent channel processes, and channel stability.



Legend

-  Watercourse (GRCA)
-  Road Centreline
-  Municipal Boundary
-  No Private Property Access Granted
-  Private Property Access Granted

Subwatershed Study Area:

-  Primary
-  Secondary
-  Tertiary

Reach and HDF Assessment:



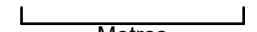
-  Phase 1, 2020 Study
-  Phase 2, 2022 Study

Figure 3.71
Reaches Assessed in Tutela Heights
Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: Town of Brantford
 Created by: J.R.

0 500

 Metres

2

3.3.2.3 Reach Characterization

During the field investigation, the geomorphology of each watercourse was assessed to characterize the stream system within the context of the erosion assessment. Erosion is a natural process and natural streams and rivers should be considered dynamic allowing for gradual and long-term channel adjustments that may occasionally include more dramatic changes due to high magnitude flood events.

As a tool to help evaluate the existing geomorphic conditions within the channel, Rapid Geomorphic Assessments (RGA) (MOE, 1999) were completed for relevant reaches. The RGA protocol uses a series of visual indicators to determine whether the stream is stable or in adjustment based on a percentage score. The stability of the channel is assessed by adjustments in slope and elevation, either an increase elevation due to sediment deposition (i.e., aggradation) or a decrease in elevation due to bed erosion (i.e., degradation). Evidence of increases in bank-to-bank channel width (i.e., widening) and changes in the planform regime (planimetric form adjustment) are also part of the RGA method. The standard approach adopted for the Fairchild Creek, Jones Creek and Phelps Creek assessments was to exclude indicators representing specific features not contained in the reach. For example, the “exposed bridge footings” indicator would be left blank and not included in the factor scoring if no bridges were contained within the reach. **Table 3.11** summarizes the stability classifications associated with the RGA stability index scores and detailed RGA results are provided in **Appendix C**. The RGA method is most appropriate for systems with natural or semi-natural alluvial boundaries that are capable of adjusting to flow changes in water and sediment. Therefore, engineered channels that have been completely stabilized (e.g., concrete or gabion basket channels) were not evaluated with an RGA. Reaches where the channel was characterized as a drainage ditch or agricultural swale were also omitted from the assessment.

Table 3.11: Guidelines for the Interpretation of RGA Results and SI Values.

Stability Index (SI) Value	Interpretation	Comment
$0 \leq SI \leq 0.25$	Stable	The morphological features do not show evidence of the progressive alterations. Variance in the dimensions of the morphological features is within acceptable levels
$0.25 \leq SI \leq 0.4$	Transitional	The type and variance of observed morphological features indicates that the stream channel is in, or about to begin, the initial stages of adjustment.
$0.4 \leq SI \leq 1.0$	In Adjustment	The type of morphological features suggests that the channel system has been de-stabilized and is in adjustment.

Results of the RGAs are summarized in **Table 3.12**. All of the assessed reaches on Jones Creek and Fairchild Creek were classified as being transitional, with the dominant adjustment processes for the reaches assessed in Phase 1 Update as widening (pink entries). The entries for all reported reaches from both Phase 1 (2020) and Phase 1 Update (this study) have been included.

Table 3.12: Dominant Geomorphic Adjustment Processes (based on RGA Results)

Watercourse	Reach	RGA		
		Stability Index	Classification	Dominant Process
Jones Creek	JC TRIB K-1A	0.36	In Transition	Widening
Jones Creek	JC TRIB K-1B	N/A	Engineered	N/A
Jones Creek	JC TRIB K-1C	0.357	In Transition	Widening
Jones Creek	JC-E	0.5	In Adjustment	Aggradation
Jones Creek	JC-C	0.5	In Adjustment	Aggradation
Jones Creek	JC-A	0.44	In Adjustment	Degradation
Jones Creek	JC-B	0.42	In Adjustment	Degradation
Jones Creek	JC-D	0.41	In Adjustment	Aggradation
Jones Creek	JC-H	0.39	In Transition	Aggradation
Jones Creek	JC-K	0.36	In Transition	Degradation
Jones Creek	JC-G	0.34	In Transition	Aggradation
Jones Creek	JC-O	0.32	In Transition	Degradation
Jones Creek	JC-I	0.31	In Transition	Degradation
Jones Creek	JC-F	0.31	In Transition	Aggradation
Jones Creek	JC-J	0.29	In Transition	Aggradation
Jones Creek	JC-L	0.26	In Transition	Degradation
Jones Creek	JC-S	0.25	In Transition	Degradation
Jones Creek	JC-R	0.25	In Transition	Degradation
Jones Creek	JC-N	0.25	In Transition	Degradation
Jones Creek	JC-P	0.25	In Regime	Degradation
Jones Creek	JC TRIB K	0.24	In Transition	Degradation
Jones Creek	JC-M	0.23	In Transition	Degradation
Jones Creek	JC-T	0.19	In Regime	Degradation
Silver Creek	SC	0.307	In Transition	Widening
Silver Creek	SC-A1	0.33	In Transition	Widening
Silver Creek	SC-E	0.47	In Adjustment	Widening
Silver Creek	SC-B	0.47	In Adjustment	Widening
Silver Creek	SC-D	0.47	In Adjustment	Widening
Silver Creek	SC-A	0.41	In Adjustment	Degradation
Silver Creek	SC-C	0.28	In Transition	Degradation
Fairchild Creek	LF TRIB A	0.271	In Transition	Widening
Fairchild Creek	LF TRIB B	0.29	In Transition	Widening
Fairchild Creek	LF TRIB A-C	0.27	In Transition	Widening

It should be noted that erosion is a natural process and the critical discharge at which channel boundary erosion may begin is normally exceeded several times annually, even in natural and stable systems. However, in order to protect against increased rates of erosion, and thus unstable channel adjustments, stormwater management facilities—including LIDs—will be a necessary part of future development to prevent increased peak flow rates and increased durations of critical

discharge exceedance. Future stormwater management planning will need to compare the estimated rates of threshold exceedance between the existing and proposed future development scenarios in order to establish erosion control targets.

The stability regime for all assessed reaches in both the 2020 and 2022 reports are illustrated in **Figure 3.72** and **Figure 3.73**. Dominant processes of adjustment evaluated by the RGA assessment are shown in **Figure 3.74** and **Figure 3.75**.

- Legend**
- Watercourse (GRCA)
 - Road Centreline
 - Municipal Boundary
 - No Private Property Access Granted
 - Private Property Access Granted
- Subwatershed Study Area:**
- Primary
 - Secondary
 - Tertiary
- Stability, HDF**
- In Regime
 - In Transition
 - In Adjustment
 - Not Assessed
 - RGA Does Not Apply

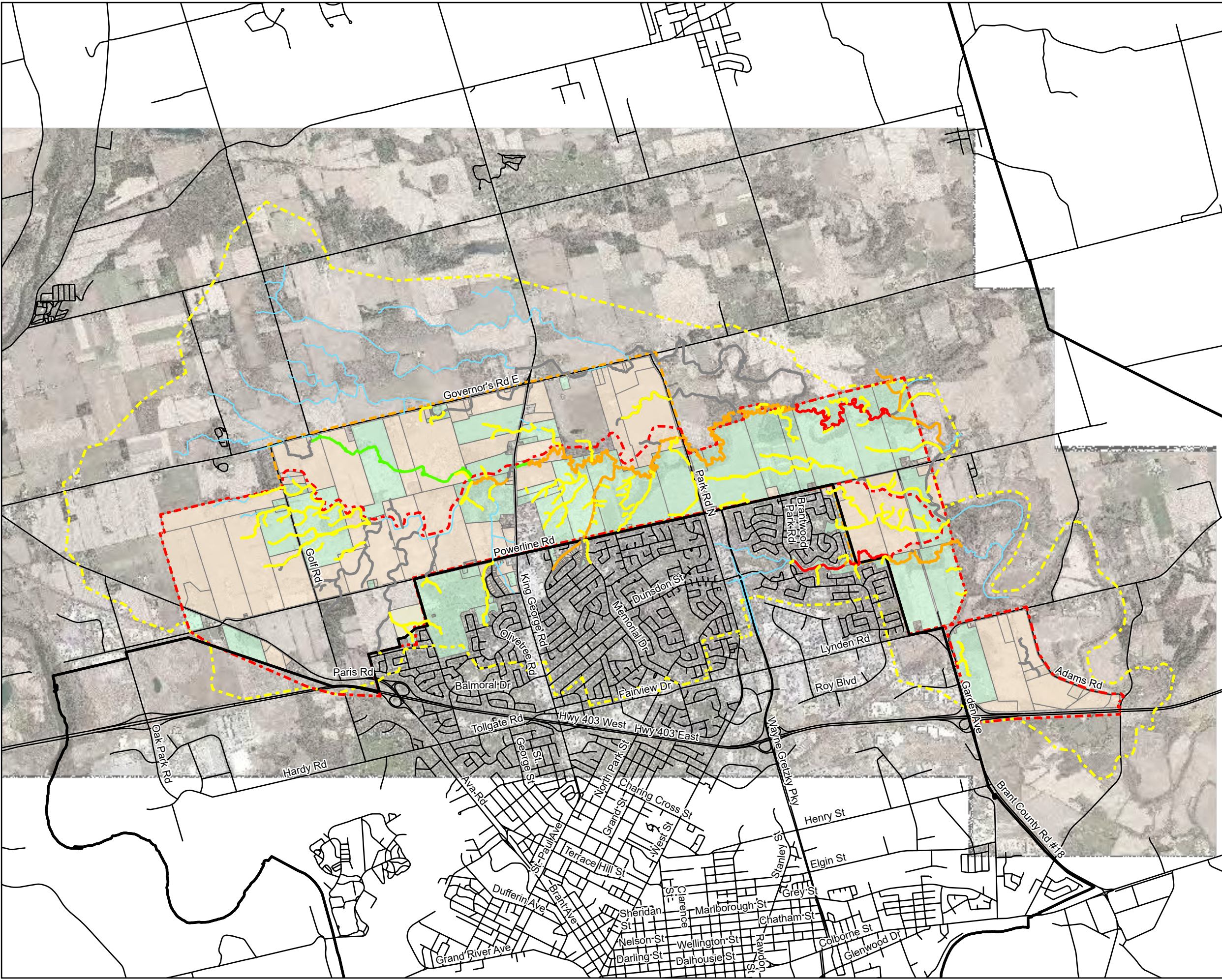
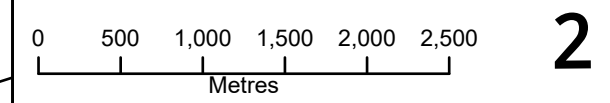
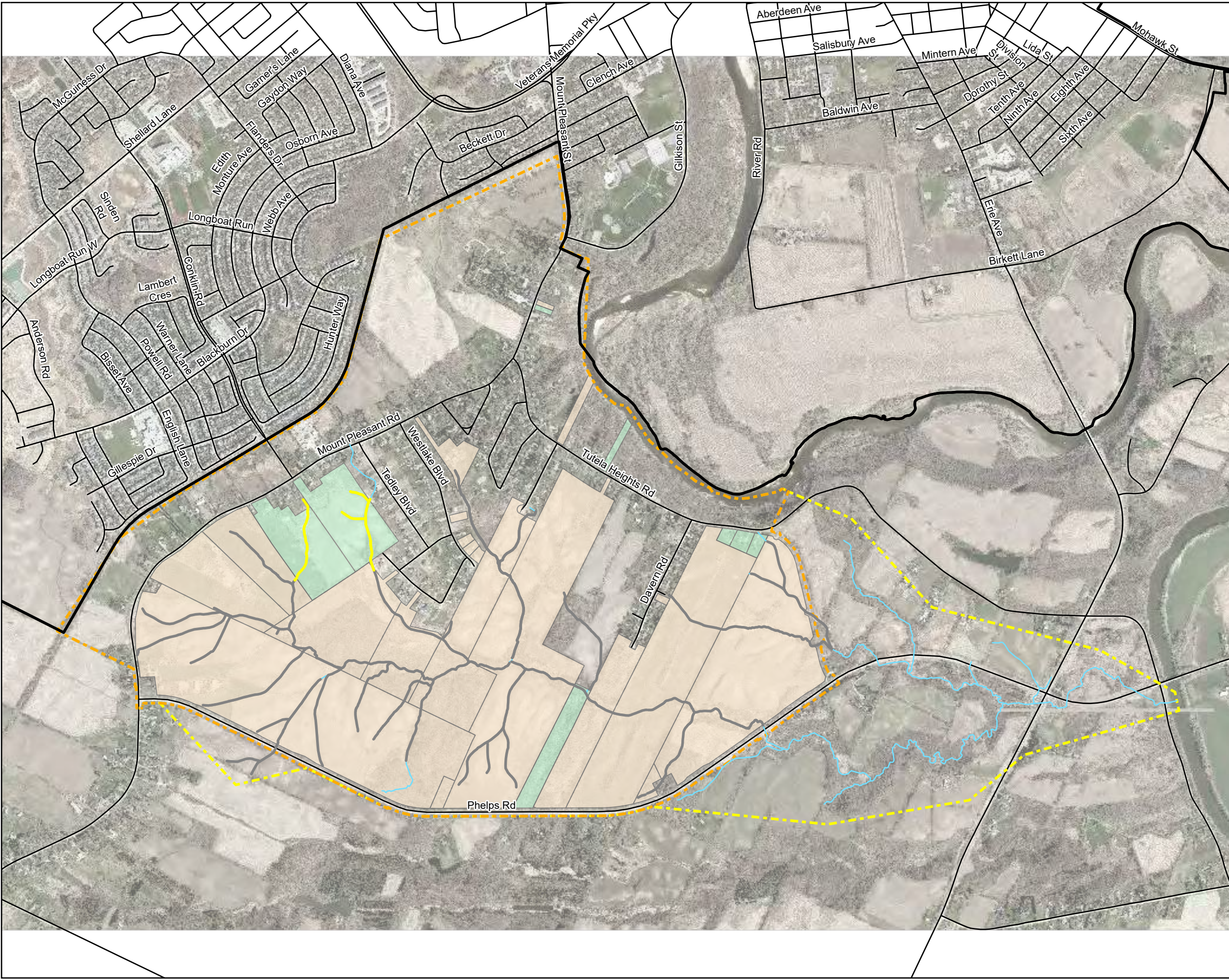


Figure 3.72
Geomorphic Stability of all Assessed Reaches in North Brantford

Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: Town of Brantford
 Created by: J.R.



Document Path: C:\Project\City of Brantford\GIS\Streams\Surveying and Aquatic Ecology\2023_12_20\RGA_ Stability_Regime.aprx
 Subwatershed Study\GIS\Streams\Surveying and Aquatic Ecology\2023_12_20\RGA_ Stability_Regime.aprx



Legend

- Watercourse (GRCA)
- Road Centreline
- Municipal Boundary
- No Private Property Access Granted
- Private Property Access Granted

Subwatershed Study Area:

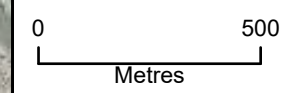
- Primary
- Secondary
- Tertiary

Stability, HDF

- In Regime
- In Transition
- In Adjustment
- Not Assessed
- RGA Does Not Apply

Figure 3.73
Geomorphic Stability of all Assessed Reaches in Tutela Heights

Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: Town of Brantford
 Created by: J.R.



Document Path: C:\Project\Cities of Brantford\GIS\Projects\Geomorphology\Streams\Surveying and Aquatic Ecology\2023_12_20\BGA_Study\Regime.aprx
 Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: Town of Brantford
 Created by: J.R.

- Legend**
- Watercourse (GRCA)
 - Road Centreline
 - Municipal Boundary
 - No Private Property Access Granted
 - Private Property Access Granted
- Subwatershed Study Area:**
- Primary
 - Secondary
 - Tertiary
- Dominant Process:**
- Aggradation
 - Degradation
 - Widening
 - Not Assessed

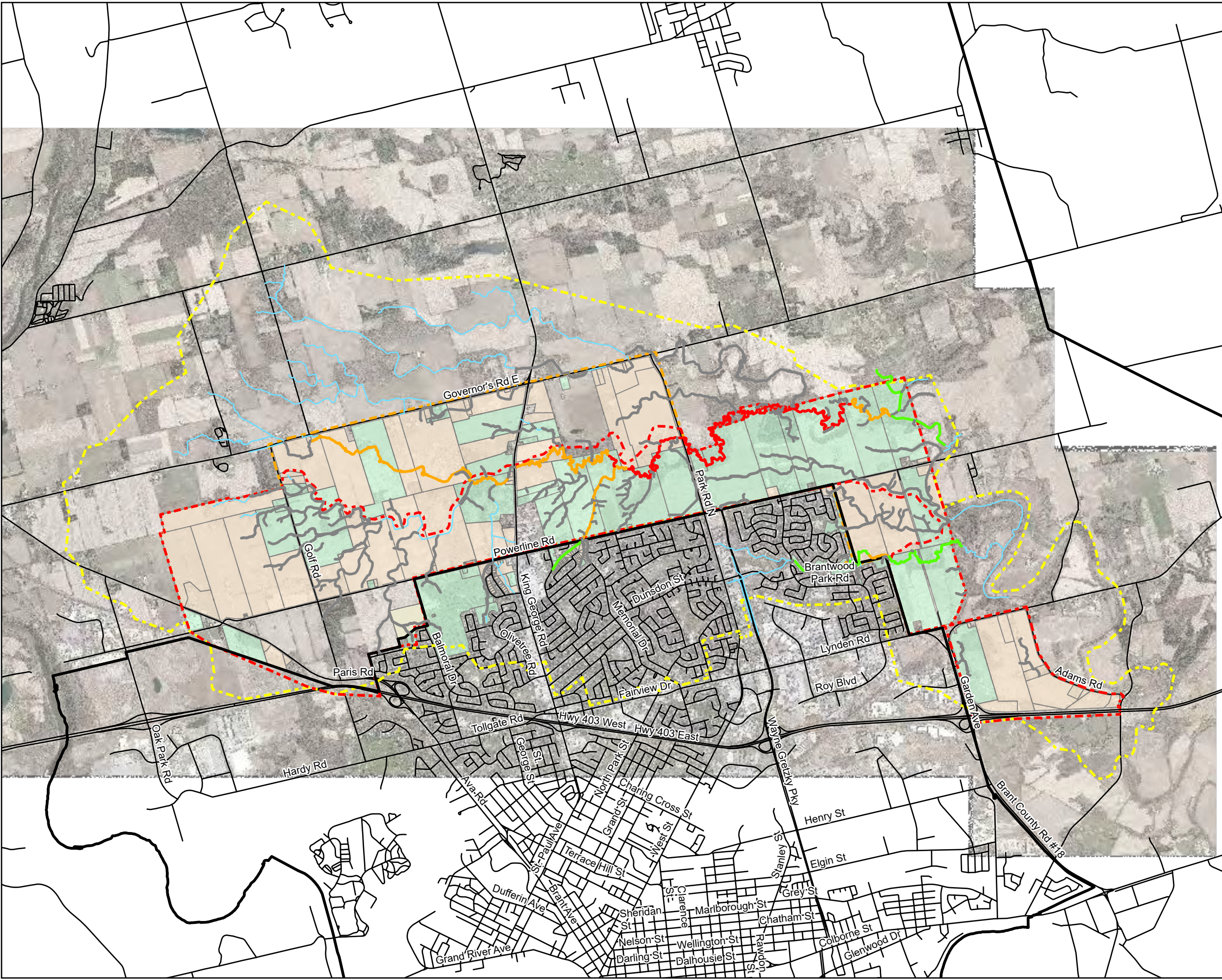
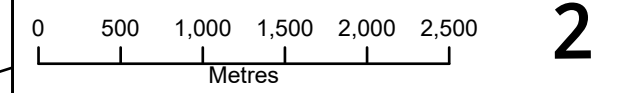


Figure 3.74
 Dominant Processes of Adjustment in North Brantford

Date: 2023-06-12
 Projection: NAD83_UTM_Zone_17N
 Data Source: Town of Brantford
 Created by: LR



3.3.2.4 Results of Geomorphic Monitoring

As a part of the ongoing monitoring from the 2020 Subwatershed Phase 1, four (4) monitoring locations were established on Jones Creek for the purposes of geomorphic monitoring of targeted tributaries. Of the four locations, access was only granted for two (2) locations for the present study. While georeferencing for the monitoring sites was not provided, maps of the monitoring locations allowed Aquafor to reproduce, in-part, the cross-sectional surveys and profile surveys within the general vicinity of the reach segments. The following summarizes the findings of that geomorphic assessment and the relevant geomorphic changes determined since the 2018 monitoring.

3.3.2.4.1 Tributary K Monitoring Site, Jones Creek

The Tributary K monitoring site is part of the Jones Creek tributary located within an unconfined valley setting, flowing across an agricultural field. The riparian vegetation zone is approximately 5-15m wide and consists of shrubs and grasses. The channel is deeply incised, with an approximate channel depth of 2-4m. The banks have a steep gradient with gully formations along the top of the banks. The channel is actively incising into red-brown clay, with pieces of native material from the banks found within the channel. Slumping is present throughout the channel, exhibited by fallen vegetated blocks from the top of bank down the slope of the bank. The banks and substrate are composed of clay and silt with some granules and pebbles.

Comparison with the 2018 monitoring data provided by the City of Brantford shows the channel to be incised into the surrounding agricultural field. While not strictly considered valley confined, it is effectively confined as the channel has incised to a depth that is more than twice the bankfull height of the channel. Bank heights were reported consistent with the geometries reported in the 2018 monitoring to enable meaningful comparisons. **Table 3.13** and **Table 3.14** summarize the channel profile and bankfull cross-section comparisons.

Table 3.13: Tributary K Comparison of Channel Profiles

Profile Characteristics	2018	2022
Bankfull Gradient (%)	0.6	0
Channel Bed Gradient (%)	0.7	0.46
Maximum Low Flow Pool Depth US (m)	0.29	0.34
Pool-pool Spacing (m)	na	10 - 20

The overall channel gradient has decreased while local scour has increased throughout the monitoring reach segment. Bank heights have decreased as a result of overall channel widening. This is likely due to increased flows, which resulted in an overall doubling in channel cross-sectional area. In turn this has increased parameters such as the wetted perimeter and hydraulic radius of the channel. The implications of these changes are that previous hydraulic models of this system may no longer reflect the current conditions.

Areas of uncertainty exist in the reproduction of the 2018 survey. As the survey data was not georeferenced and no monuments remain from the original field studies, it is possible that the

initial survey did not capture the existing variability in the reach and does not reflect an appropriate average with which to be compared to the current survey. If this monitoring location is to be maintained, field monuments in the form of iron bars will be required for analysis.

Planform and profile drawings of the Tributary K monitoring site are presented in **Figure 3.76**. The survey consists of three cross-sections along a 60 m segment of reach JC Tributary K. Cross-sections are shown in **Figure 3.77**.

Table 3.14: Tributary K Comparison of Channel Cross-sections

Bankfull Channel Characteristics	2018	2022	% Difference
Minimum Bank Height (m)	0.64	0.56	-12.50
Maximum BankHeight (m)	1.22	0.93	-23.77
Average Bank Height (m)	0.96	0.70	-27.08
Minimum Width (m)	0.88	2.15	144.32
Maximum Width (m)	2.4	4.15	72.92
Average Width (m)	1.82	3.42	87.91
Minimum Depth (m)	0.3	0.56	86.67
Maximum Depth (m)	0.6	1.09	81.67
Average Depth (m)	0.48	0.76	58.33
Minimum Width:depth Ratio (m/m)	2.03	3.64	79.31
Maximum Width:depth Ratio (m/m)	11.33	6.69	-40.95
Average Width:depth Ratio (m/m)	6.49	4.72	-27.27
Minimum Cross-Sectional Area (m ²)	0.26	0.90	246.15
Maximum Cross-Sectional Area (m ²)	0.89	2.74	207.87
Average Cross-Sectional Area (m ²)	0.56	1.65	194.64
Minimum Wetted Perimeter (m)	0.39	2.58	561.54
Maximum Wetted Perimeter (m)	1.91	4.93	158.12
Average Wetted Perimeter (m)	1.06	4.07	283.96
Minimum Hydraulic Radius (m)	0.11	0.28	154.55
Maximum Hydraulic Radius (m)	0.33	0.56	69.70
Average Hydraulic Radius (m)	0.22	0.40	81.82

*Red text indicates a negative value

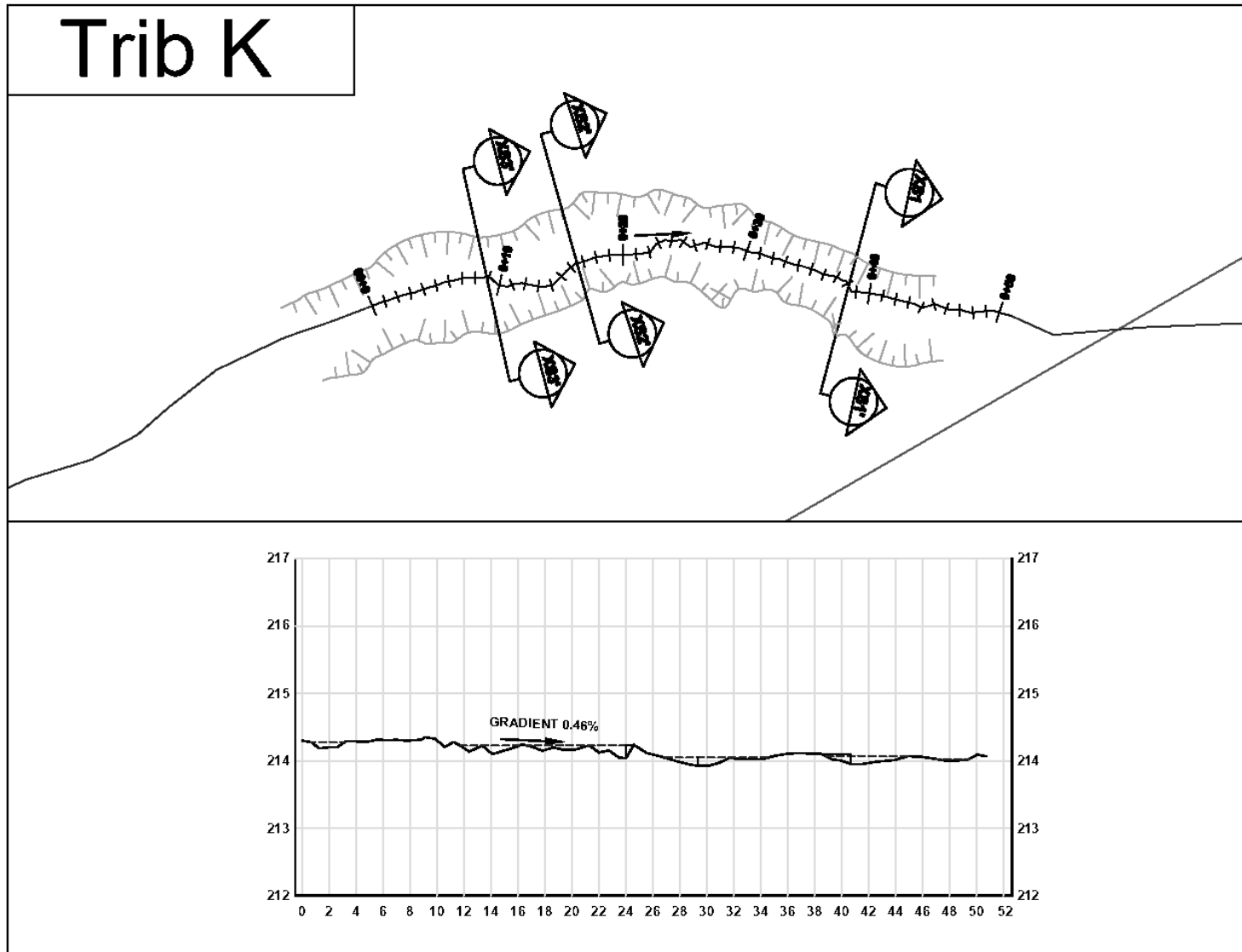


Figure 3.76: Plan and Profile of Monitoring Site Tributary K

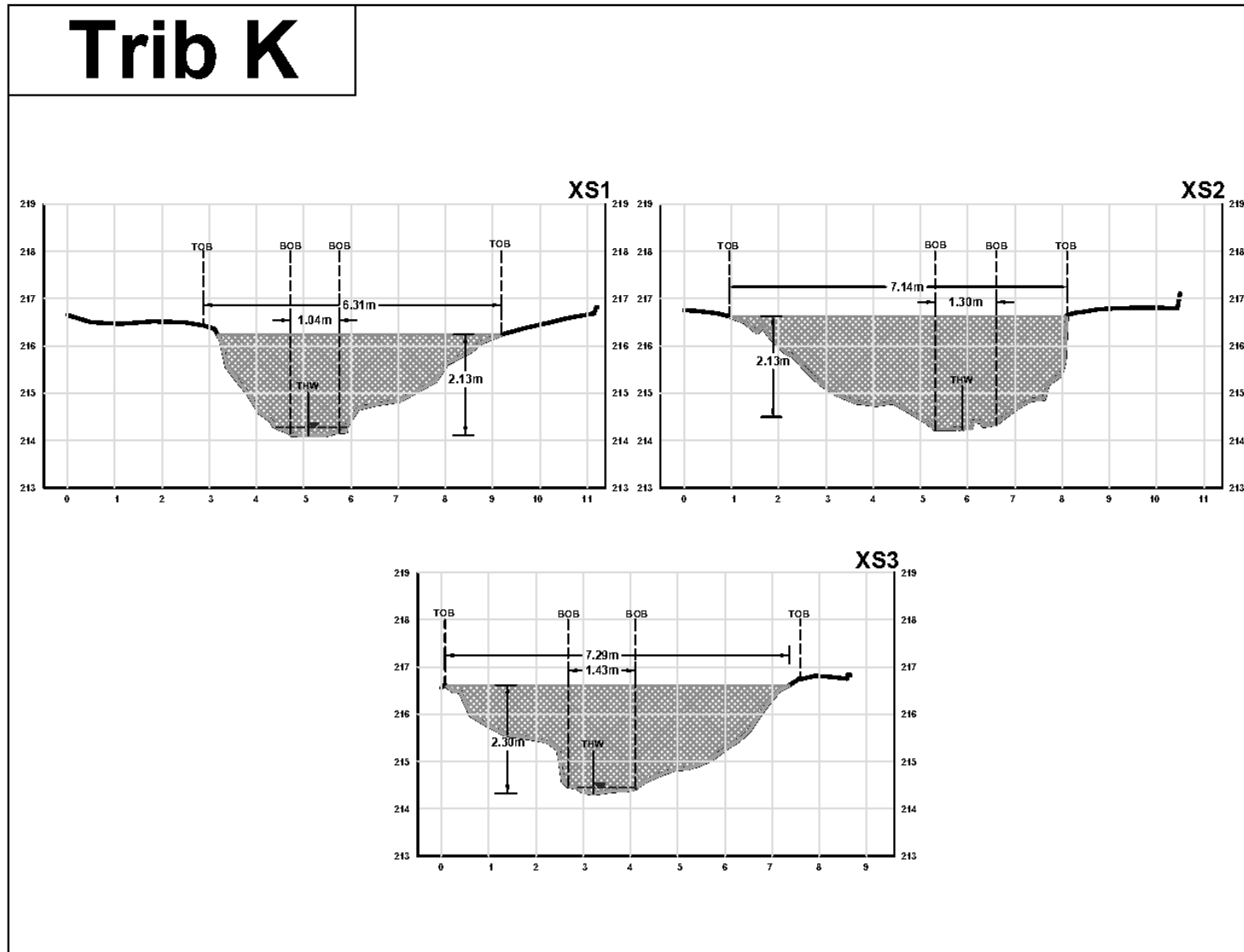


Figure 3.77: Cross Sections of Monitoring Site Tributary K

3.3.2.4.2 Jones 2 Monitoring Site, Jones Creek

The Jones 2 monitoring site is part of the Jones Creek tributary located within a confined valley setting, flowing across a natural forest and agricultural field. The general riparian vegetation zone is >50m and consists of herbaceous plants and trees. The banks and substrate are composed of soft clay and silt, with some fine sand. The banks increase in height in the downstream direction and have a steep gradient – commonly exhibiting fracture lines along the top of bank. Fallen trees and exposed tree roots are found across site, commonly congregated within the steep banks.

Comparison with the 2018 profile monitoring data provided by the City of Brantford shows minimal change in the channel gradient and pool spacing. In both the 2018 and 2022 monitoring survey, the pool spacing was farther apart than was covered by the length of the survey. The depth of the single pool on the tight meander in the survey shows approximately 0.5 m of change in pool depth. The channel profile results are summarized in **Table 3.13**.

Table 3.15: Jones 2 Comparison of Channel Profile

Profile Characteristics	2018	2022
Bankfull Gradient (%)	0.1	0.12
Channel Bed Gradient (%)	0.08	0.07
Maximum Low Flow Pool Depth US (m)	1.03	0.46
Maximum Low Flow Pool Depth DS (m)	1.03	0.52
Pool-pool Spacing (m)	> 55	> 55

The channel planform (**Table 3.16**) shows minor change, however the decrease in sinuosity and the increase in meander wavelength may have been a result of length underestimation in the original survey. All 2022 cross-sections were surveyed from the original 2018 survey nails and show minimal change in lateral channel position. The summarized values in **Table 3.16** are likely more similar than reported.

Table 3.16: Jones 2 Comparison for Channel Planform

Planform Characteristics	2018	2022
Sinuosity	1.95	1.62
Meander Wavelength (m)	20 - 30	30-40
Meander Amplitude (m)	30	30

The cross-section analysis of the 2022 monitoring survey shows a 10% average widening throughout the reach segment, and a 20% increase in overall channel depth. These changes result in a net decrease in the channel width to depth ratio. It also implies an increase in the cross-sectional area of the channel, which; in-turn increase the wetted perimeter and the hydraulic radius. The overall channel deepening while the pool is apparently shallowing suggests that the channel is experiencing an overall degradational process along with a subordinate process of channel widening. Further monitoring should extend to include both a downstream and upstream

pool to include appropriate pool spacing, and be monumented by bars farther away from the top of bank.

Table 3.17: Jones 2 Comparison of Channel Cross-sections

Bankfull Channel Characteristics	2018	2022	% Difference
Minimum Bank Height (m)	0.77	0.80	3.90
Maximum Bank Height (m)	1.54	1.69	9.74
Average Bank Height (m)	1.05	1.30	23.81
Minimum Width (m)	4.66	5.75	23.39
Maximum Width (m)	6.93	7.01	1.15
Average Width (m)	5.84	6.40	9.59
Minimum Depth (m)	1.21	1.64	35.54
Maximum Depth (m)	1.45	1.69	16.55
Average Depth (m)	1.34	1.66	23.88
Minimum Width:depth Ratio (m/m)	5.13	3.48	-32.16
Maximum Width:depth Ratio (m/m)	9.51	4.27	-55.10
Average Width:depth Ratio (m/m)	7.05	3.87	-45.11
Minimum Cross-Sectional Area (m ²)	3.91	4.50	15.09
Maximum Cross-Sectional Area (m ²)	5.95	6.39	7.39
Average Cross-Sectional Area (m ²)	4.89	5.82	19.02
Minimum Wetted Perimeter (m)	3.29	6.66	102.43
Maximum Wetted Perimeter (m)	7.02	7.67	9.26
Average Wetted Perimeter (m)	4.06	7.24	78.33
Minimum Hydraulic Radius (m)	0.56	0.68	21.43
Maximum Hydraulic Radius (m)	0.81	0.85	4.94
Average Hydraulic Radius (m)	0.73	0.80	9.59

*Red text indicates a negative value

Planform and profile drawings of the Jones 2 monitoring site are presented in **Figure 3.78**. The survey consists of four cross-sections along a 120 m segment of the Jones Creek tributary. Cross-sections are shown in **Figure 3.79**.

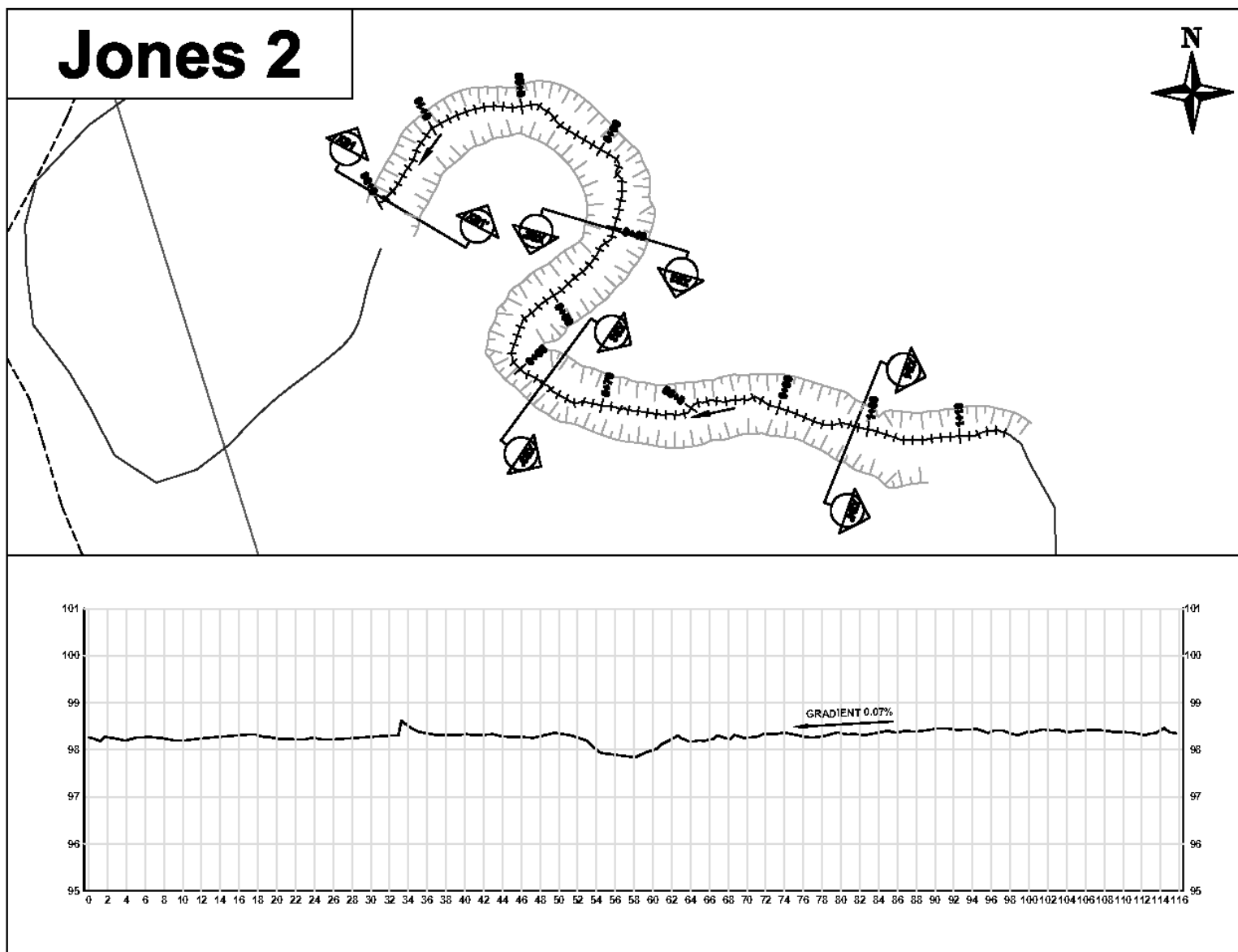


Figure 3.78: Plan and Profile of Monitoring Site Jones 2

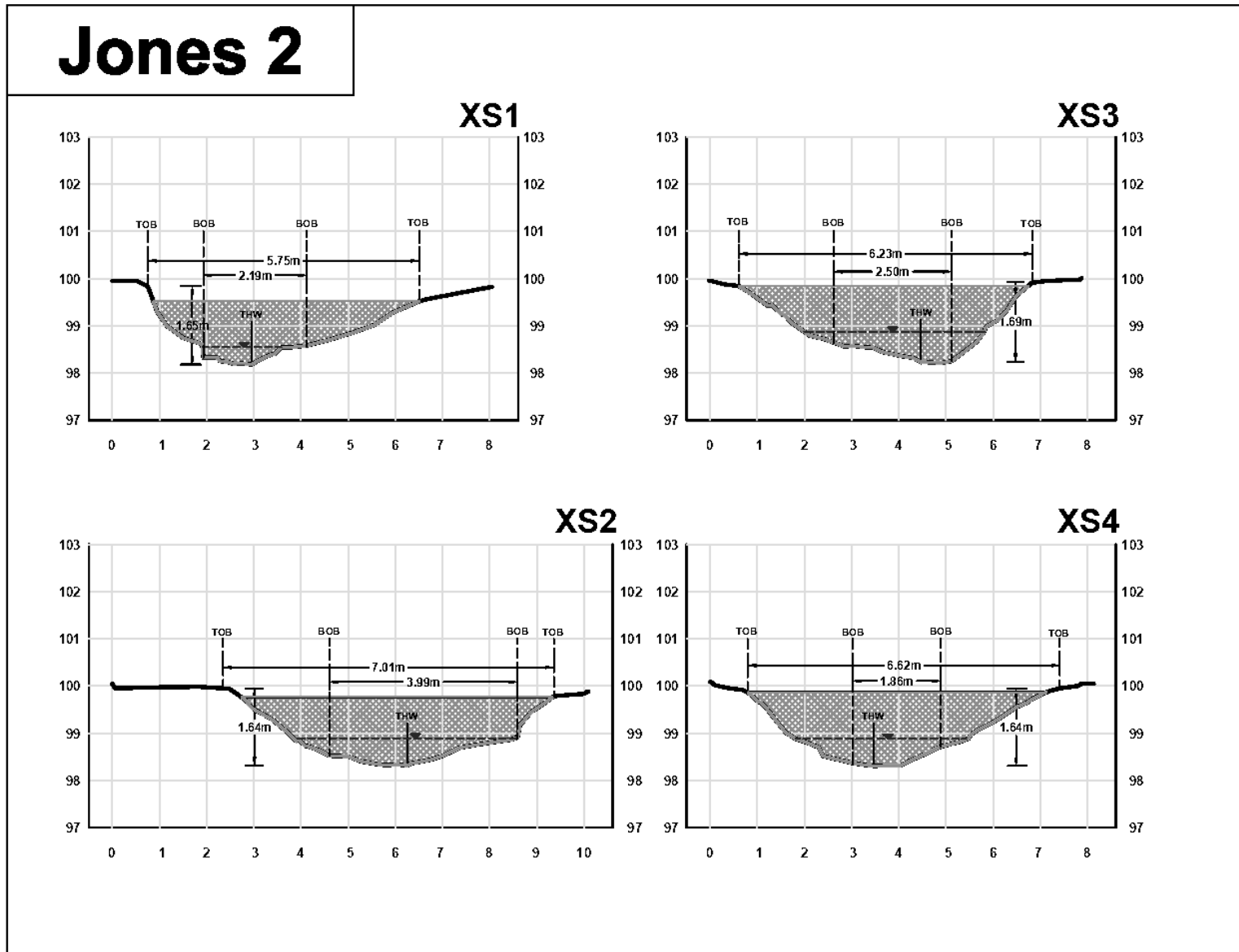


Figure 3.79: Cross Sections of Monitoring Site Jones 2

3.3.2.5 Assessment of Erosion Potential

An erosion allowance is typically applied in a development setting to provide a conservative buffer of safety to prevent risk to future infrastructure/development. A guideline table recommended for estimating the erosion allowance is presented as follows in **Table 3.18**.

The MNRF Guidelines “Geotechnical Principles for Stable Slopes” recommend an erosion setback where the watercourse is located within 15 m of the slope toe. The Guideline Table recommends different ranges of 100-year erosion setbacks based on the native soil comprising the slope toe, evidence of varying degree of erosion and watercourse characteristics. A 100-year erosion rate was estimated for each reach that was assessed during the field investigation using the guidelines outlined in **Table 3.18**. Assessment parameters and results are summarized in **Table 3.19**.

Table 3.18: MNRF Erosion Allowance Guidelines for Watercourses in Valley Settings

Minimum Toe Erosion Allowance - River within 15 m of Slope Toe *				
Type of Material Native Soil Structure	Evidence of Active Erosion** or Bankfull Flow Velocity > Competent Flow Velocity***	No evidence of Active Erosion** or Flow Velocity << Competent Flow Velocity***		
		Bankfull Width		
		<5m	5-30m	>30m
1. Hard Rock (granite)	0 - 2 m	0 m	0 m	1 m
2. Soft Rock (shale, limestone) Cobbles, Boulders	2 - 5 m	0 m	1 m	2 m
3. Stiff/Hard Cohesive Soil (clays, clayey silt) Coarse Granular (gravels) Tills	5 - 8 m	1 m	2 m	4 m
4. Soft/Firm Cohesive Soil Fine Granular (sand, silt) Fill	8 - 15 m	1 - 2 m	5 m	7 m

* If a valley floor is > 15 m width, still may require study or inclusion of a toe erosion allowance.

** Active Erosion is defined as: bank material is bare and exposed directly to stream flow under normal or flood flow conditions and, where undercutting, over steepening, slumping of a bank or high down stream sediment loading is occurring. An area may be exposed to river flow but may not display “active erosion” (i.e. is not bare or undercut) either as a result of well rooted vegetation or as a result of shifting of the channel or because flows are relatively low velocity. The toe erosion allowances presented in the right half of Table 2 are suggested for sites with this condition.

*** Competent Flow velocity; the flow velocity that the bed material in the stream can support without resulting in erosion or scour. Consideration must also be given to potential future meandering of the watercourse channel.

Source: Ontario Ministry of Natural Resources (2002), “Technical Guide River & Stream Systems: Erosion Hazard Limit, pp38

Table 3.19: Erosion Rates

Channel Reach	Evidence of Active Erosion	Bankfull Width (m)	Bankfull Depth (m)	Bank Material	Erosion Rate (m/100 year)
JC TRIB K-1A	Yes	4	0.9	Sand, Silt	15
LF TRIB A	Yes	8	2.5	Sand, Silt	15
LF TRIB A-C	Yes	10	1	Soft rock	5
LF TRIB B	Yes	11m	3m	Sand, Silt	15
JC TRIB K-1B	Yes	4	0.8	Sand, Silt	15
SC	Yes	5.5	0.7	Stiff clay	8
SC-A1	Yes	7	3	Stiff clay	8
SC-E	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB B-C	Yes	Unknown*	Unknown*	Unknown*	0
JC TRIB B-F	Yes	Unknown*	Unknown*	Unknown*	0
JC TRIB B-D	Yes	Unknown*	Unknown*	Unknown*	0
JC TRIB B-G	Yes	Unknown*	Unknown*	Unknown*	0
JC-I	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-U	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB K	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB B-H	Yes	Unknown*	Unknown*	Unknown*	0
JC TRIB B-I	Yes	Unknown*	Unknown*	Unknown*	0
JC TRIB B-J	Yes	Unknown*	Unknown*	Unknown*	0
JC-S	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-H	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-R	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-M	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-K	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-N	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB F	Yes	Unknown*	Unknown*	Unknown*	0
JC-G	Yes	Unknown*	Unknown*	Silt/Clay	8
LF-A	Yes	Unknown*	Unknown*	Silt/Clay	8
SC-B	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-F	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-B	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-D	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-A	Yes	Unknown*	Unknown*	Silt/Clay	8
LF-B	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-E	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB D	Yes	Unknown*	Unknown*	Unknown*	0
JC-C	Yes	Unknown*	Unknown*	Silt/Clay	8
JC TRIB B-A	Yes	Unknown*	Unknown*	Unknown*	0

Channel Reach	Evidence of Active Erosion	Bankfull Width (m)	Bankfull Depth (m)	Bank Material	Erosion Rate (m/100 year)
JC TRIB B-B	Yes	Unknown*	Unknown*	Unknown*	0
SC-C	Yes	Unknown*	Unknown*	Silt/Clay	15
SC-D	Yes	Unknown*	Unknown*	Silt/Clay	8
SC-A	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-J	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-L	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-P	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-Q	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-O	Yes	Unknown*	Unknown*	Silt/Clay	8
JC-T	Yes	Unknown*	Unknown*	Silt/Clay	8

* Values not reported in the Phase 1 Assessment

3.3.2.6 Long Term Stable Slope

Like many stream systems in southern Ontario, Fairchild Creek, Jones Creek and Phelps Creek are incised into the land surface—carved into a landscape of glacial sediments—with downstream reaches flowing through valley settings defined by slopes on one or both sides of the watercourse. The surface geology of the Study Area is dominated by glacial till and glacial lake sediments that were deposited under and in front of the Late Pleistocene continental ice sheet about 20 thousand years ago (Chapman and Putnam, 1984). The surface geology is a patchwork of sandy silt till from glaciolacustrine and glaciofluvial deposits during six glacial advances or fluctuations from the early and late Wisconsin glaciation (Cowan, 1972). The North Brantford and Tutela Heights watersheds are bound by the Fairchild Creek to the East, Phelps Creek to the south, and Jacobs Creek to the north, each extending well developed dendritic systems downstream towards the Grand River.

Collectively, these characteristics of the glacial surface geology play an important role in dictating the geomorphology and fluvial processes of the stream systems, representing the geologic template upon which the watercourses have evolved over time. Thus, the surface geology has strongly shaped the patterns of stream erosion and valley formation over centuries and millennia, resulting in modern day erosion hazards by stream channels within the floodplains and by hillslopes along the valley sides.

3.3.2.6.1 Erosion Hazards

While the erosion hazards for unconfined systems can be defined based on meander belt delineation or similar techniques, confined systems require greater effort to define erosion hazards potentially having to integrate fluvial erosion with geotechnical assessments for some combination of unconfined, confined, or partially confined reaches. As defined by MNR (2002), confined stream systems are characterized by the physical barriers of valley walls that limit the lateral movement of fluvial channels within the valley bottom. The location of the river or stream channel may be located at the base of the valley slope, in close proximity to the valley slope (i.e., within 15 m) or removed from the valley slope (i.e., a distance greater than 15 m). It should be noted the generic 15 m criteria to distinguish confined and unconfined reaches is based on provincial guidelines (MNR, 2002), but is not technically

supported in the broader scientific literature. Detailed erosion hazard assessments are needed to characterize site conditions on a reach basis to confirm where confined reaches require geotechnical slope stability assessments—priority areas are identified in the next section. Erosion hazard limits for confined stream systems are to include a stable slope allowance that accounts for future channel erosion, long-term stable slope formation, and an erosion access allowance (or other factor of safety). The relative definitions for confined and unconfined erosion hazards from MNR (2002) are provided in **Figure 3.80**.

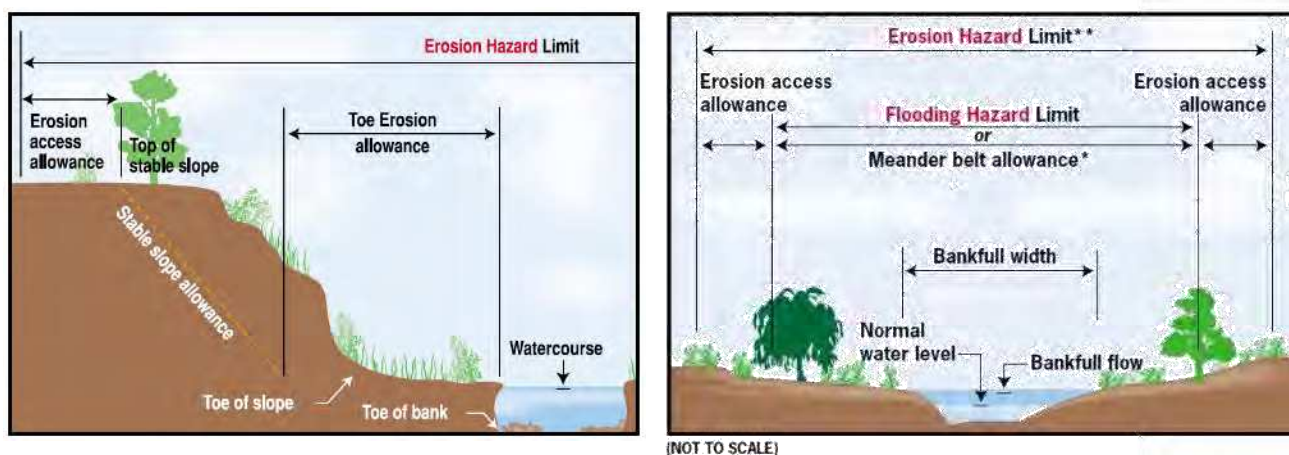


Figure 3.80: Erosion hazard limit in confined system (left) where toe of valley slope is less than 15m from watercourse (MNR, 2002); compared to erosion hazard limit for unconfined system (right).

3.3.2.6.2 Long Term Stable Slope

The long-term stable slope (LTSS) is a component of the erosion hazards assessment required to determine development setbacks and constraints, specifically around confined valley systems (MNR, 2002). Conservative estimates of the LTSS may be delineated as part of the Subwatershed Study planning stage using generic provincial guidelines (MNR, 2002), but ultimately the LTSS is to be confirmed and/or refined with detailed geotechnical studies, typically including detailed topographic surveys and borehole investigations in the field. Site specific geotechnical analysis will be need to be undertaken with each development application. For slope hazard areas where the LTSS is assessed, the erosion hazard limit will be required to include a “toe erosion allowance” associated with the creek channel and a “erosion access allowance” beyond the top of slope (**Figure 3.80**).

The first step of the process was to first delineate the “Top of Slope” and “Toe of Slope” for valley slopes greater than 15% - this was used to define the “Confined River System” (Note: “Top of Slope” in this case is generally equivalent to the “Top of Bank” surveys for defining development constraints).

Ultimately, detailed geotechnical studies for each development application are necessary to delineate the final erosion hazard limit around confined valley systems where the LTSS component is required. To highlight specific reaches for detailed geotechnical investigations of the LTSS, priority areas have been identified in **Table 3.23**. Photographs are provided in **Figure 3.81** to **Figure 3.84** to illustrate the contours of the surrounding area of the reaches and to provide a photographic depiction of the reaches. Based on the provincial guidelines (MNR, 2002), these priority areas generally include

reaches where the watercourse is within 15 m of the toe of slope for embankments with slopes steeper than 15% and heights greater or equal to 3 meters.



Figure 3.81: Channel Incision at Reach JC-H Tributary



Figure 3.82: Valley slope in Reach LF Trib A



Figure 3.83: Valley slope in Reach LF Trib A-H



Figure 3.84: Channel Incision at Reach LF Trib B

3.3.2.7 Conclusions

Based on the above geomorphic assessment, key items related to future development constraints and opportunities are summarized below:

- Of the 38 channelized reaches of watercourse in the subject area, 9 reaches were assessed to be in a state of geomorphic adjustment, 20 reaches were found to be in transition and 2 reaches were evaluated as being in regime. Restoration opportunities are possible in those reaches that are either in adjustment or in transition.
- Geomorphic monitoring has been completed for 2 of the 4 established monitoring locations. The omitted locations were due to lack of access on private property. In both monitoring locations an increase in channel cross-sectional area due to widening and degradational processes is observed. Any further geomorphic monitoring would benefit from expanding the number of monitoring locations, increasing the frequency of monitoring, and redesigning the spatial distribution of monitoring sites to capture significant trends in subwatershed dynamics which may be occurring, but are inconclusive from the current data.
- The erosion potential within Fairchild Creek, Jones Creek and Phelps Creek was determined to be as high as 15 m/100 years. Erosion potential will be accounted for during development planning through its integration into meander belt calculations. Meander belt assessments are required for all reaches in unconfined settings. Later sections will expand on erosion hazards and development constraints (see: Section 4.1.2).

- The long-term stable slope (LTSS) is a component of the erosion hazards assessment required to determine development setbacks and constraints, specifically around confined valley systems. The LTSS setback has been approximated by the slope hazard lines for this study; however, final LTSS setbacks should be confirmed based on detailed geotechnical field investigations after completion of the Subwatershed Study. Slope hazard delineation is presented in Section 4.1.2.
- Within the North Brantford and Tutela Heights subwatersheds, opportunities have been identified to impacts and/or restore stream forms and functions from both geomorphological and ecological perspectives. Those reaches assessed to be in geomorphic adjustment (**Figure 3.72** and **Figure 3.73**) have the opportunity to be enhanced by restoration efforts including, but not limited to:
 - a) Reestablishment of adequate riparian corridors and removal of invasive species within riparian corridors;
 - b) Inclusion of wider bridges and culverts to allow for natural meandering; and,
 - c) Reestablishment of natural planforms through channelized reaches.

3.3.3 Hydrology & Hydraulics

Hydrology is the science which deals with the interaction of water and land. Hydrology focuses on the processes by which precipitation is transformed into runoff to the receiving watercourses, returned to the atmosphere via evapotranspiration, or infiltrated into the shallow and deep groundwater systems. One of the most dramatic changes brought about by urbanization is the change in stream hydrology. For example, the replacement of vegetation and undisturbed terrain with impermeable surfaces (i.e. pavement, roof tops, graded surfaces and the provision of an underground storm drainage network) results in the greater interception of water that would naturally infiltrate into the ground and instead provides a direct and rapid transport of surface runoff to streams. As a result, groundwater recharge diminishes, which in turn could potentially affect baseflows within streams which rely on groundwater discharge. A more rapid rate of stormwater runoff from rainfall events can result in an increase in the total volume, peak flow, and frequency of runoff occurrences. Uncontrolled, these hydrologic changes can result in increases in flooding, channel erosion, sediment transport, and pollutant loadings. These changes can also cause deterioration in natural channel morphology, fish and wildlife habitats, recreational opportunity and aesthetics. It is important that the existing hydrologic characteristics of the Study Area and its watercourses be established. This information is critical in defining existing flood characteristics, defining regulatory floodplain limits, and providing key information on the selection and design of stormwater management facilities for future urban development lands.

River hydraulics is the science of flow conveyance through a watercourse. Hydraulic analysis uses the runoff output from hydrologic models along with channel and floodplain characteristics including river crossing details to establish flood elevations for specific return period events. The primary function of a floodplain is the conveyance of flood waters during extreme storm events and spring melts. It is dependent upon the shape of the channel and associated floodplain, the flow rate and the location of structures (buildings, roads, etc.). The GRCA regulates development applications within flood-

susceptible areas such as the floodplains of watercourse systems. Future urban development is not permitted within the Regulatory Floodplain limits. Hydrologic, hydraulic modeling and associated floodline mapping was undertaken for this study to identify areas susceptible to flooding under Regulatory Flood conditions. Within the Study Area, separate hydrologic and hydraulic models exist for Jones Creek, Fairchild Creek and Phelps Creek.

3.3.3.1 Relationship to Background Reports

The base hydrologic model discussed in this section was developed by GM BluePlan for use in the establishment of flows associated with specific storm events (1:2, 1:5, 1:10, 1:25, 1:50, and 1:100-year). Aquafor updated this model, as discussed in **Section 3.3.3.2**.

The hydraulic model discussed in this section was developed by Aquafor and was used to estimate water surface elevations and floodplain associated with specific flow events including the 1:2, 1:5, 1:10, 1:25, 1:50, 1:100-year and Regional flood scenarios. The hydraulic models of Jones Creek, Fairchild Creek and Phelps Creek were established using HEC-GeoRAS to assess the flood extents under existing (pre-development) conditions.

3.3.3.2 Hydrologic Model

The hydrologic model was received and used to simulate predevelopment conditions using PCSWMM. A total of five thousand seven hundred and forty-three (5743) subcatchments were delineated in the received model and three hundred and two (302) subcatchments were located in the Study Area. All the layers in the existing PCSWMM model, including junctions, conduits, subcatchments and outfalls, are using CGVD2013 vertical datum. The delineated subcatchments from the previous study are shown in **Figure 3.90**.

For the North Brantford Study Area, there was no minor system, but there were sewer systems and stormwater management facilities located upstream of the Study Area. For the Tutela Heights area, a sewer system and two stormwater management facilities are located in the Study Area. Most of the Study Area is undeveloped rural area, and open channels and watercourses play a large role in the system.

3.3.3.2.1 Hydrologic Model Update

The received model was not complete and needed updates and validation. The updates included:

- The invert elevations of stream channels and nodes were updated with the DEM (CGVD2013) data provided by the City of Brantford;
- The transects of channels were updated based on the DEM (CGVD2013) topography;
- Baseline flow for upstream nodes of Jones Creek was removed;
- The missing information for the SWM facility located in Phelps Creek subwatershed on Rue Chateaux Terrace was entered based on the design report provided by City;

- Flow length of all the rural area subcatchments was updated based on the measurement of each subcatchment;
- Slope percentage was assigned based on the provided DEM (CGVD2013) data calculated by the build-in function of PCSWMM;
- Manning's n value for impervious surface was assigned to 0.013 and pervious area was assigned to 0.3;
- Impervious percentage were adjusted based on current land use type;
- The maximum infiltration volume was assumed to be 45 mm for all subcatchments except for the Fairchild Creek upstream subcatchment at north.

The parameters of the subcatchments were to be calibrated in order to validate the hydrologic model results. The calibration will be discussed in the following paragraphs.

3.3.3.2.2 Streamflow and Precipitation Monitoring

Aquafor installed streamflow and precipitation monitors in spring 2022 in order to gather data in support of the setup and verification of hydrologic modeling for the Study Area streams. Three (3) new continuous flow monitoring locations were established in May 2022 throughout the study area. The locations of the flow monitoring locations are shown in **Appendix P** and general descriptions of the monitoring station locations are as follows:

- FM1: Located approximately 500m North of 174 Phelps Road in wetland channel. This location was established to monitor the general flow of the Phelps Creek system.
- FM2: Located just south of Governors Road just east of Golf Road. This location was established to monitor the flows of the upstream portion of the Jones Creek system.
- FM3: Located to the east of County Road 32 between Powerline Road and Governors Road. This location was established to monitor the flows of the main branch of the Jones Creek system.

Flow monitoring was implemented using a combination of discrete manual flow measurements and continuous water level measurements. A SonTek Acoustic Doppler Velocimeter (ADV) FlowTracker was used to undertake the discrete flow measurements, following the same flow measurement procedure that the Water Survey of Canada recommends (Water Survey of Canada, 2015). Field measurements were taken at appropriate intervals depending on the size of the watercourse.

Water velocity measurements were collected using a standard approach. For water levels less than 60 cm, velocity measurements were taken at 60% of the flow depth. For water levels greater than 60 cm, the mean of two (2) water velocity measurements were taken: one at 20% of the depth and the other at 80% of the depth. The water velocity and cross-sectional area for each increment were multiplied together to estimate the discharge (m^3/s) for each lateral increment along the channel cross-section.

The summation of these discharge values was used to produce a flow estimate for the cross-section during the time of sampling.

Hobo U20 water level loggers (pressure transducers) were utilized to record the varying water levels and temperature at each of the monitoring locations. The collection of the water level readings and single discrete flow measurements were used to develop relationships between flow rate and water level (i.e. rating curve) and ultimately convert the continuous water level data into continuous flow data.

Two (2) rainfall/precipitation monitoring gauges were also installed at the onset of the study period. One (1) gauge was placed in the northern Brantford area (located at the Walter Gretzky Municipal Golf Course) and one (1) gauge in the southern Tutela Heights area (located at the Lions Park Arena) and are shown in **Appendix P**. Each weather station was installed with a tipping bucket rain gauge equipped with data loggers, an air/relative humidity sensor with a radiation shield to protect it from the elements.

However, as 2022 was a very dry year, insufficient rain events occurred that were large enough to use for calibration and validation. As such, streamflows were obtained for 2017 through 2024 from the GRCA gauges at Highway 24 and Park Road on Jones Creek. Rainfall from GRCA's Brantford gauge were used for 2017 through 2019, and rainfall provided by GRCA using Hydromaster was used for 2020 through 2024. Hydromaster allowed for the rainfall from rain gauges outside the study area to be localized to the study area itself. This tool was only available from 2020 onwards. It was assumed that any corrections made to Jones Creek during calibration also applied to the other creeks in the Study Area. Data collected from the 2022 monitoring season from the streamflow and precipitation monitoring sites outlined above is available in **Appendix P**.

3.3.3.2.3 Model Calibration and Validation

The monitoring hydrographs and precipitation data were then reviewed further prior to attempting to use the data for model calibration. Precipitation events that exceed a depth of 25 mm can be utilized for the purpose of calibrating hydrological models. During the winter season, precipitation is considered unsuitable for calibration because of the frozen soil. Meanwhile, some summer events show very low flow rates and were considered unsuitable for calibration purposes. As a result, three precipitation events were carefully selected for the calibration of the model, and two precipitation events were used for validation. The details of calibration and validation process are described in Appendix S.

The model was calibrated with culverts removed in order that the constraints of the culvert structures were not taken into consideration, because the culverts can be upgraded in future. The model was calibrated by adjusting model parameters to produce results matching the measurements from the flow monitoring within reasonable accuracy in terms of peak flows and runoff volumes. Calibration relied on observed flow and precipitation monitoring data for input. Observed rainfall data were used to simulate the response of the model. The observed flow at the monitoring locations was then used to verify the flow predicted by the model for a range of rainfall events.

The calibration procedure was developed in order to enhance the ability of the model to represent

existing hydrologic and hydraulic conditions. Subsequent iterations of the model altered key parameters, such as infiltration parameters, subarea routing method and percentage routed, etc. Each iteration compared the flow volumes and peak flows of the model outputs to the monitored values. The calibration was considered complete once a reasonable agreement between the two was achieved.

Key steps of the model calibration methodology are described below:

- Subcatchment infiltration or surface depression were adjusted to a realistic degree for the storm system to achieve a reasonable match between measured and modelled values; and
- Emphasis was placed on minimizing the differences between the observed and simulated runoff volumes for the gauge on Park Road North. Following calibration of runoff volumes, the focus shifted to minimizing the differences between observed and simulated peak flow rates, and matching the general hydrograph timing.

The results of calibration for the Jones Creek at Park Road are shown in **Figure 3.85** and **Figure 3.86**.

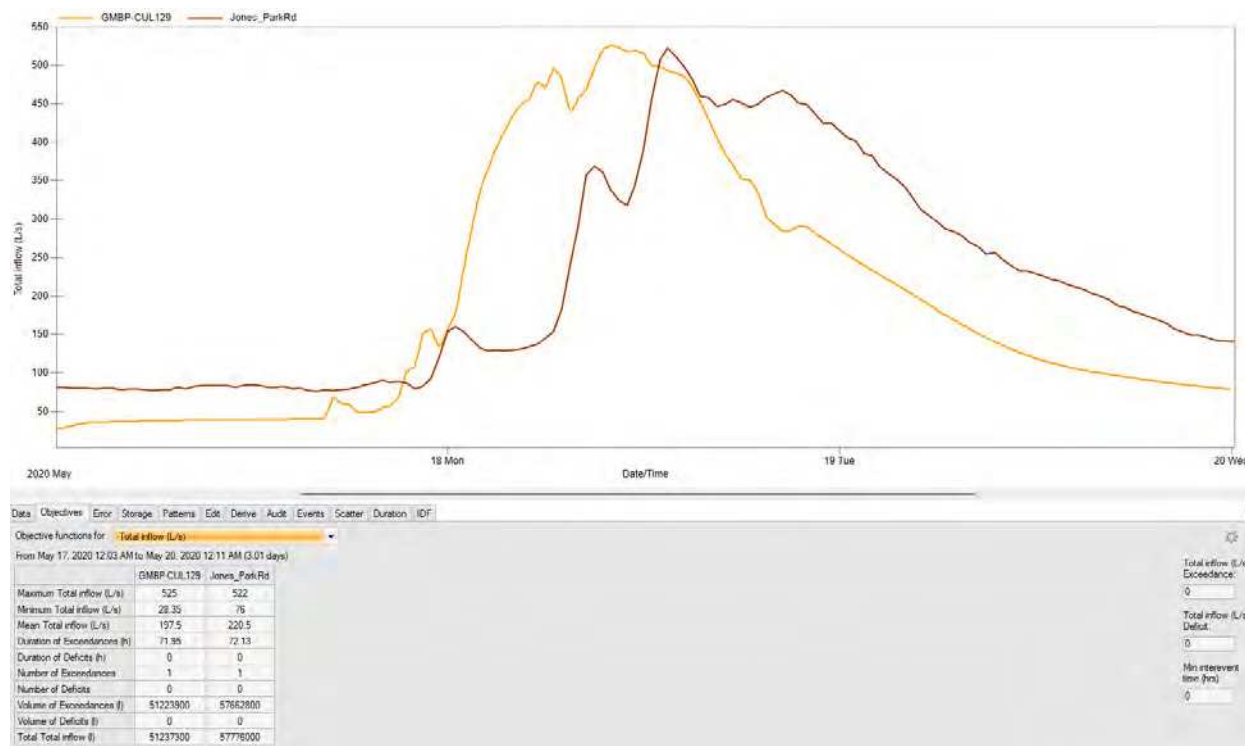


Figure 3.85: May 17, 2020 Calibration Result with Flow Record on Jones Creek at Park Road

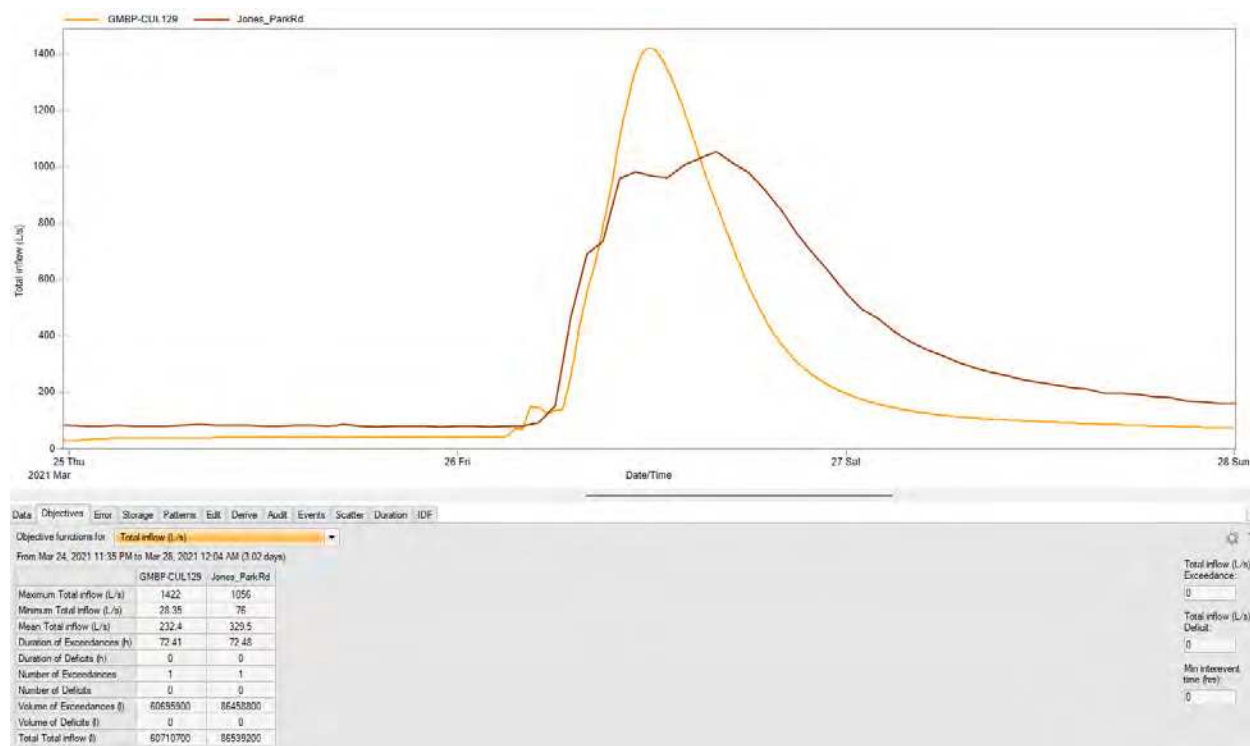


Figure 3.86: March 25, 2021 Calibration Result with Flow Record on Jones Creek at Park Road

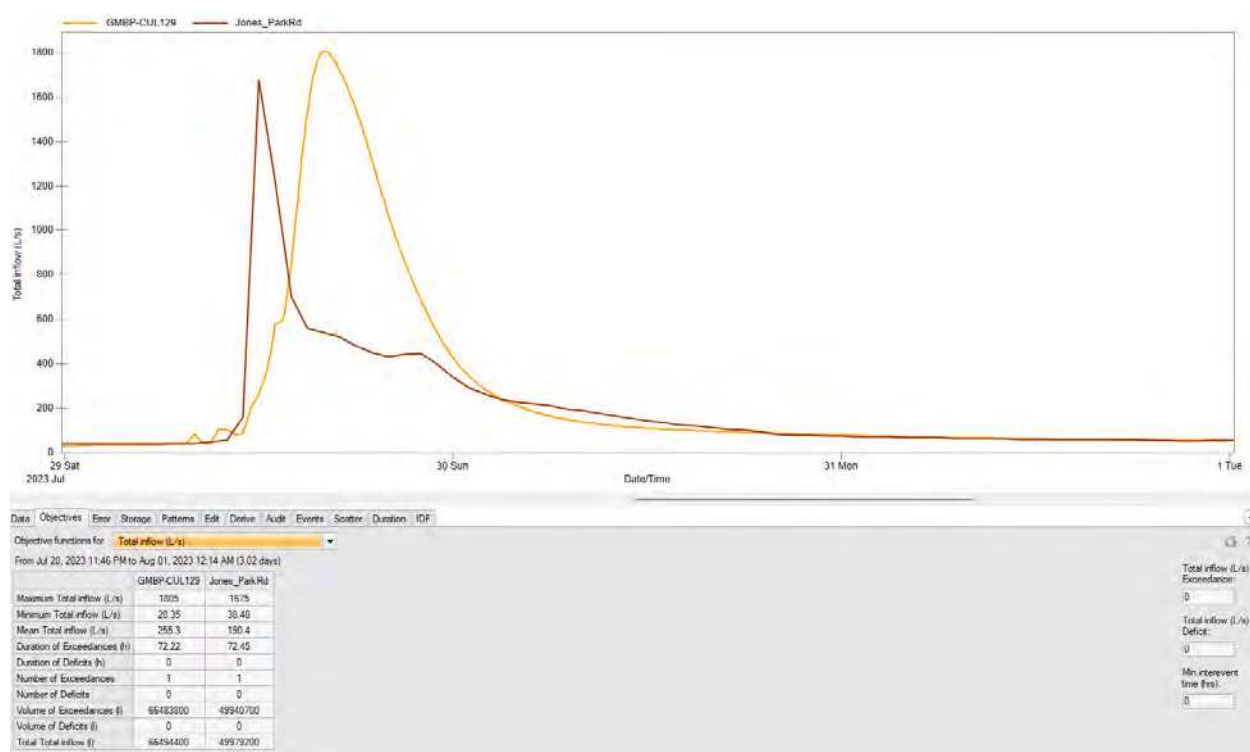


Figure 3.87: July 29, 2023 Calibration Result with Flow Record on Jones Creek at Park Road

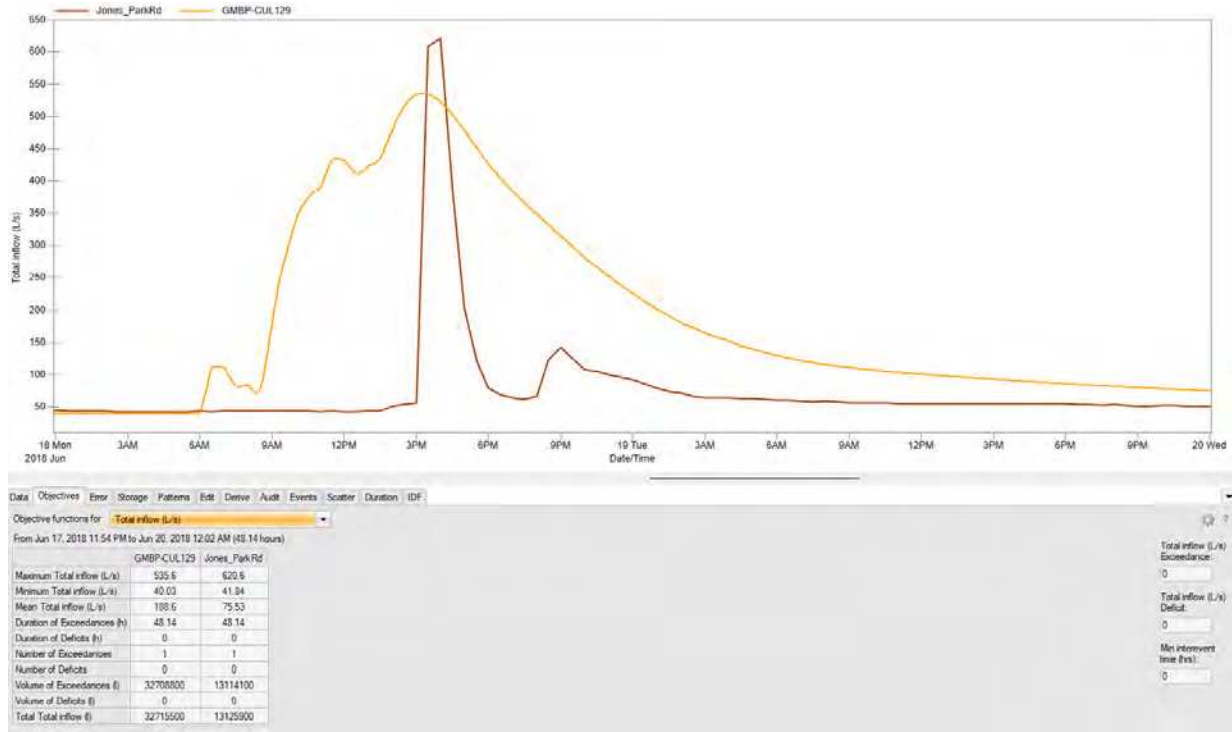


Figure 3.88: June 18, 2018 Validation Result with Flow Record on Jones Creek at Park Road

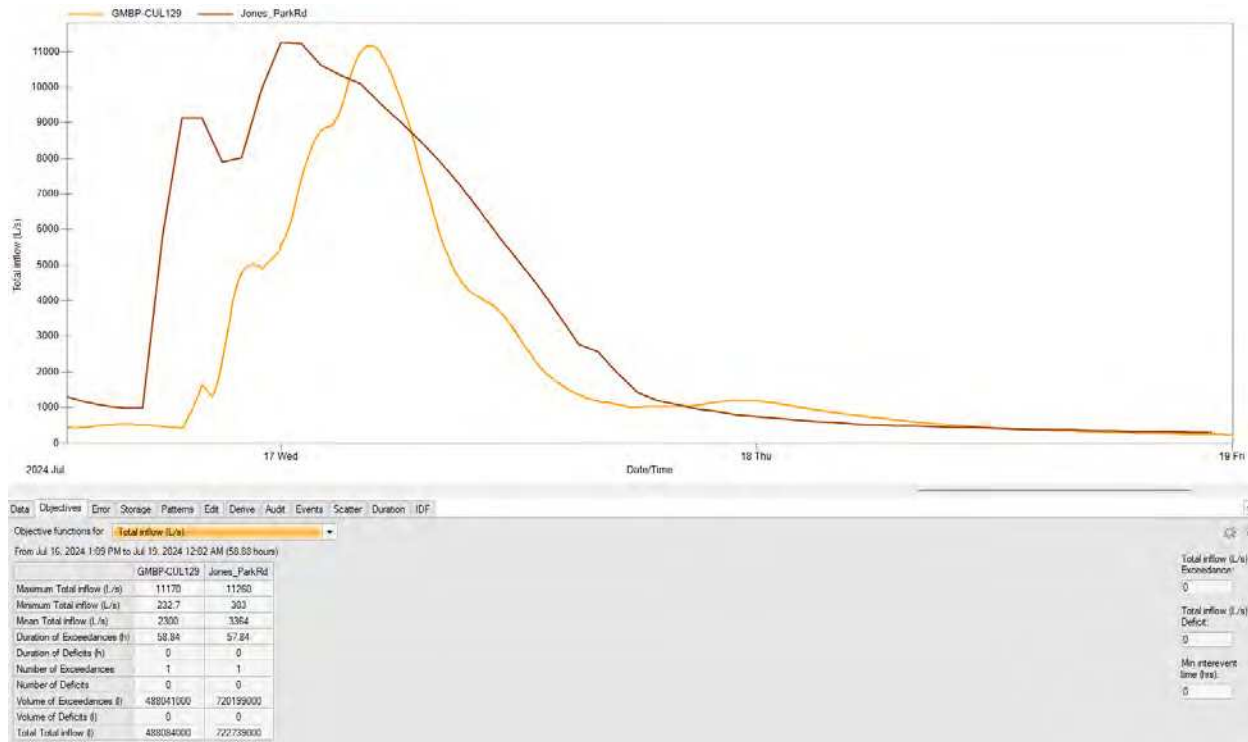


Figure 3.89: July 16, 2024 Validation Result with Flow Record on Jones Creek at Park Road

3.3.3.2.4 Flood Flow Estimates

The City of Brantford Storm Sewers Design and Construction Manual Linear Municipal Infrastructure Standard (May 2022) provided design storm IDF curves which were used to build the design storms. The culverts in the calibrated model were removed to define existing conditions. The model was run for the 12-hour SCS storm and the Regional Storm (Hurricane Hazel). The 12-hour SCS storm was modelled for 1:2, 1:5, 1:10, 1:25, 1:50, and 1:100-year return periods.

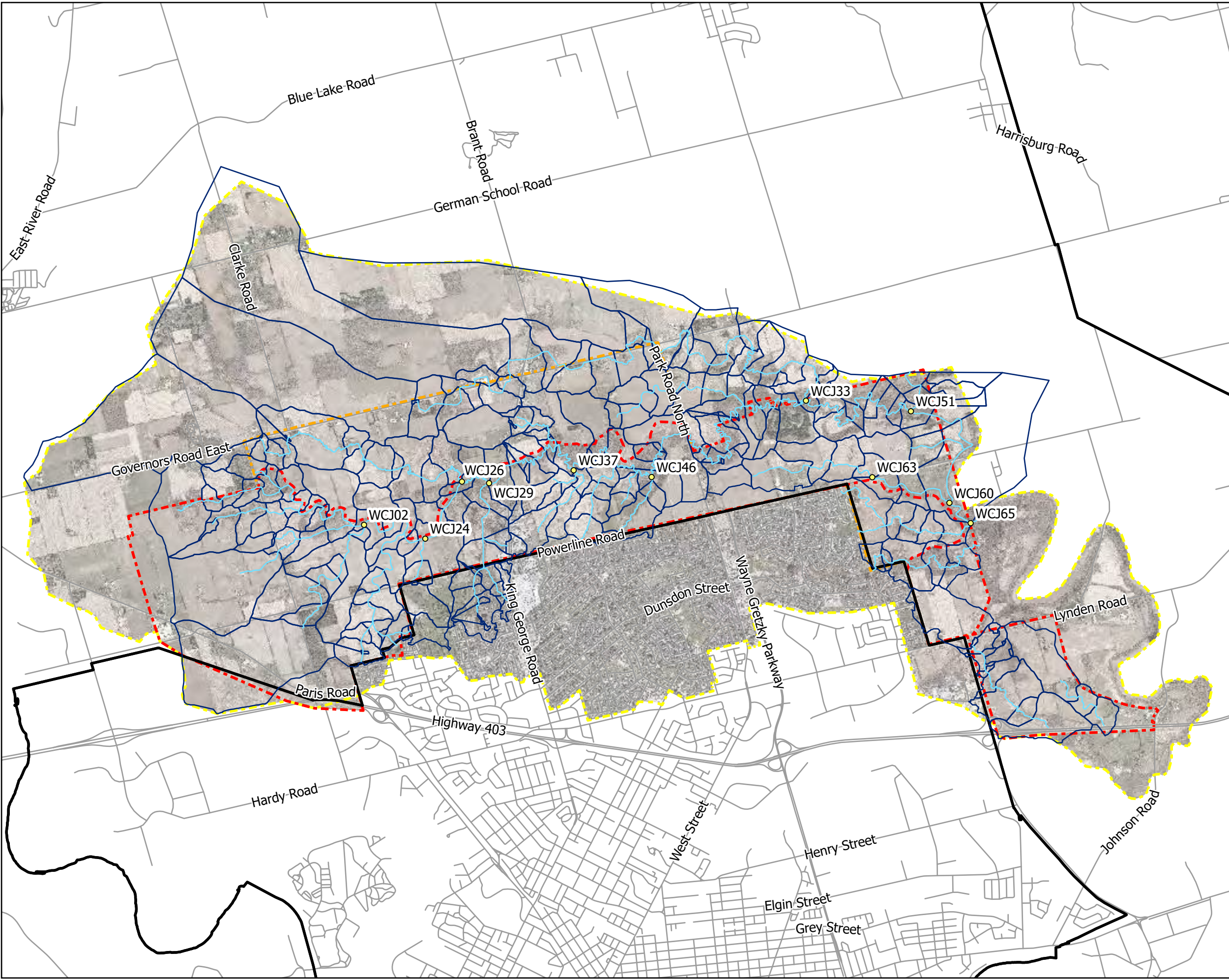
Hurricane Hazel was used to design the Regional storm event. The rainfall depth of Hurricane Hazel was based on Table D-2 of *MNR Technical Guild River and Stream Systems: Flooding Hazard Limit* (2002) with Reduction Factor applied based on Table D-3 of the *Technical Guild*. The contributing area of each flow node was sorted and the applicable reduction factor for each flow node was determined from Table D-3. The reduction factor was applied to the total rainfall depth at each subcatchment which directly contribute to the flow nodes. For example, an areal reduction factor of 89.4% was used for subcatchment S56, which directly contributes to flow node WCJ237 (contributing area of 322.4 km²). Design storm hyetographs are provided in **Appendix D**.

For the Regional storm event, the maximum infiltration volume for the large subcatchment north in the model was assumed to be 0 in order to generate a reasonable flow for Fairchild Creek, because there were no soil type and land use information or monitoring data to calibrate the model. For Phelps Creek, the 1:100-year event generally produces higher flows than Hurricane Hazel at the upstream channels. Table 3.20 summarizes the estimated flood flow rates of 2-year to 100-year and Regional events at key locations throughout the Jones Creek, Fairchild Creek and Phelps Creek. A full summary of flood flow rate table is provided in **Appendix D**.

Table 3.20: Summary of Estimated Flood Flows

Flow Location (Model Junction ID)	Flood Flow						
	2-year Flow (m ³ /s)	5-year Flow (m ³ /s)	10-year Flow (m ³ /s)	25-year Flow (m ³ /s)	50-year Flow (m ³ /s)	100-year Flow (m ³ /s)	Regional Flow (m ³ /s)
MTP90285	1.10	1.55	1.83	2.18	2.46	2.74	3.22
WCJ02	3.63	6.99	10.33	14.96	19.25	23.52	60.63
WCJ24	4.04	8.04	11.81	17.62	22.89	28.38	61.63
WCJ26	4.50	10.63	16.52	25.28	33.13	40.57	58.13
WCJ29	4.41	12.48	17.43	26.20	34.23	42.61	74.85
WCJ33	8.09	15.40	21.33	29.40	35.92	43.72	140.93
WCJ37	5.18	12.94	18.09	27.21	35.65	44.45	63.62
WCJ46	5.83	12.17	18.59	27.87	36.10	44.76	83.67
WCJ51	7.96	14.36	19.35	28.00	36.19	51.45	272.58
WCJ60	8.17	14.81	19.34	28.79	39.95	53.68	276.32
WCJ63	1.32	2.18	2.93	3.96	4.84	5.73	9.21
WCJ65	8.49	15.71	20.42	34.50	47.02	59.88	288.27
WCJ75	2.02	3.92	5.08	6.63	7.23	9.20	13.70
WCJ80	3.26	5.24	7.47	10.28	11.34	13.61	22.53

Flow Location (Model Junction ID)	Flood Flow						
	2-year Flow (m ³ /s)	5-year Flow (m ³ /s)	10-year Flow (m ³ /s)	25-year Flow (m ³ /s)	50-year Flow (m ³ /s)	100-year Flow (m ³ /s)	Regional Flow (m ³ /s)
WCJ81	6.39	7.26	8.98	11.74	13.51	15.92	26.32
WCJ83	5.95	9.10	11.60	14.93	17.98	21.21	35.48
WCJ84	5.77	9.49	12.73	16.20	19.53	23.22	39.83
WCJ88	0.30	0.51	0.72	0.98	1.18	1.36	1.92



Legend

- Flow Nodes
- ▭ Municipal Boundary
- Road Centreline
- River Reaches
- ▭ Subcatchment Boundary

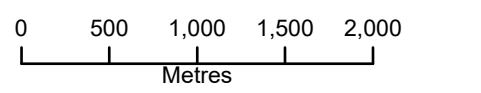
Subwatershed Study Area:

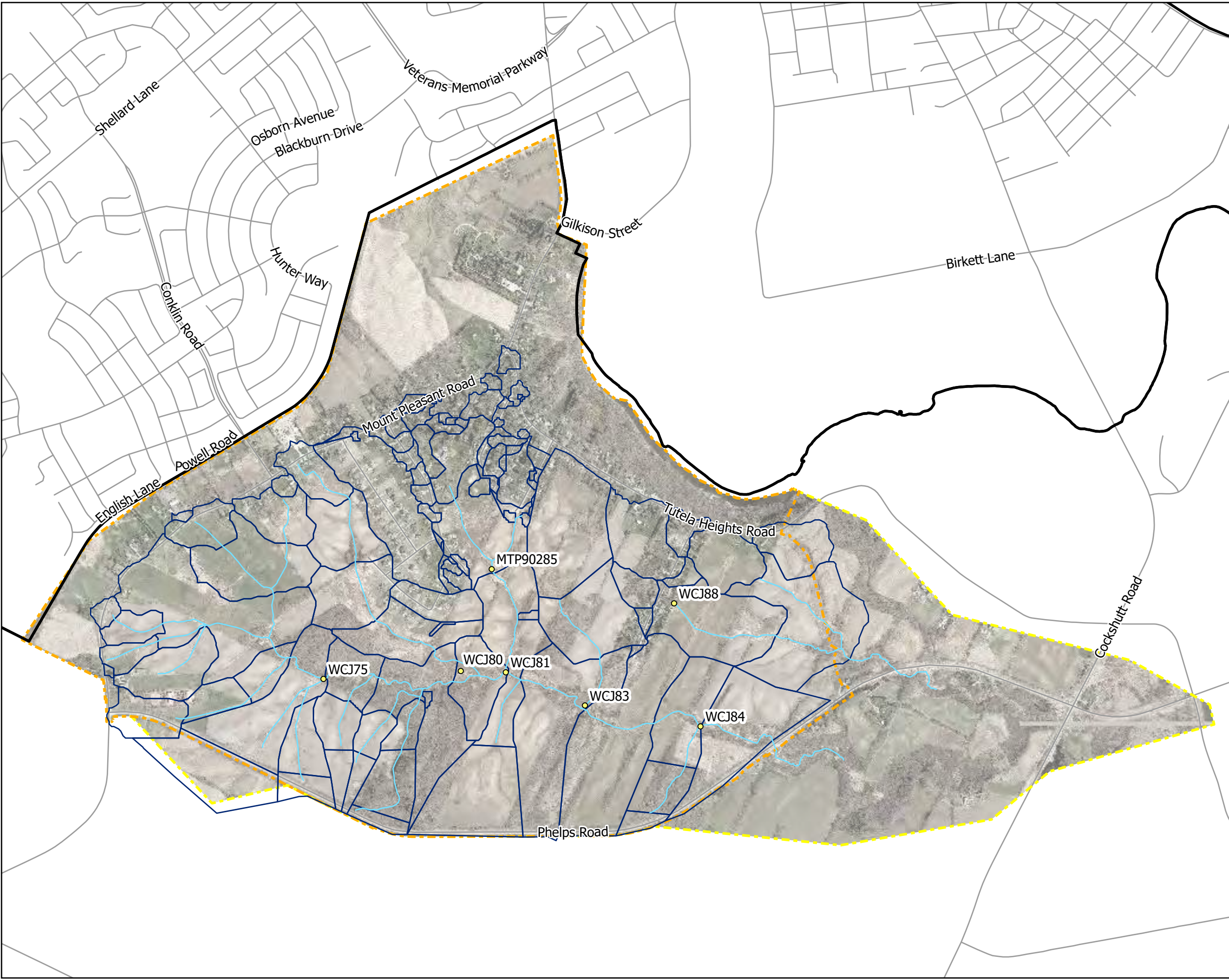
- ▭ Primary
- ▭ Secondary
- ▭ Tertiary

Figure 3.90

Subcatchment Delineation

Date: 2023-06-16
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: J.R.





Legend

- Flow Nodes
- ▭ Municipal Boundary
- Road Centreline
- River Reaches
- ▭ Subcatchment Boundary

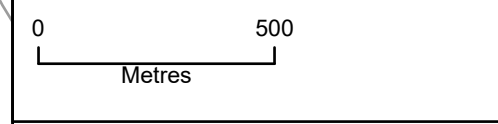
Subwatershed Study Area:

- ▭ Primary
- ▭ Secondary
- ▭ Tertiary

Figure 3.90

Subcatchment Delineation

Date: 2023-06-16
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: J.R.



Document Path: C:\Project\City of Brantford\GIS\Projects\Subcatchment\MapInfo\Subcatchment\Subcatchment\Subcatchment\Subcatchment\Subcatchment.aprx

3.3.3.3 Hydraulic Model

Hydraulic modeling and associated floodplain mapping were undertaken to define flood hazard lands along the major stream reaches within the North Brantford and Tutela Heights Study Area. Hydraulic analysis for the Study Area was undertaken using the GeoHEC-RAS hydraulic model. The HEC-RAS model engine was developed by the U.S. Army Corps of Engineers to compute water surface flood profiles using the standard step method and routines to analyze bridge and culvert road crossing structures.

3.3.3.3.1 Cross-Sections

A total of 855 cross sections were extracted using the DEM (CGVD2013) provided by the City of Brantford (2021) to define the channel geometry for the reaches as well as the floodplain geometry. Cross sections were spaced and extended perpendicular to the anticipated flow line, to ensure they contain the flood water to the left and right banks, across the entire floodplain. Left, right and channel flow length were calculated based on the polylines sketched to represent the left and right overbanks, and the flow lines representing the streams. Cross sections were spaced with less distance near the hydraulic structures. In defining the cross sections data, contraction and expansion coefficients are assigned based on the vicinity to the crossing structures, i.e., 0.1 for contraction and 0.3 for expansion for all cross sections for each crossing structure of the entire model, with the exception of two cross sections upstream and two cross section downstream of the structures for which coefficients of 0.3 and 0.5 are used. Contraction and expansion coefficients are used to evaluate transition loss due to changes of flow between cross sections.

3.3.3.3.2 Manning’s Coefficient

Manning’s roughness coefficients were assigned to each cross section based on conditions observed in available aerial photography. Jones Creek, Fairchild Creek and Phelps Creek within the Study Area flows through a mix of land uses which typically have different Manning roughness values. These values were shown in **Table 3.21**.

Table 3.21: Manning’s Values Used in HEC-RAS Model

Land use	Value
Open Area Agriculture Area	0.05
Wood Area	0.08
Road, Parking Lot and Driveway	0.015
Building and Obstruction	0.15
Waterbody and Main Channel	0.035

3.3.3.3.3 Conveyance Obstructions

Structures within the floodplain were modeled as conveyance obstructions to define areas of the cross section that are permanently blocked out. Obstructions decrease flow area and add wetted perimeter when water comes in contact with the obstruction. To enter obstructions to the model, multiple blocks with left and right stations and an elevation for each of the blocks were used.

3.3.3.3.4 Culvert/Bridge Structures

Each of the culverts and road crossings along the creeks were considered in the hydraulic model. A total of twenty-two (22) structures were modeled in the hydraulic model. Sixteen of the modeled structures were surveyed with CGVD2013 vertical datum by Aquafor, and six of the structures were modeled based on the inspection form provided by City. The roadway crossings of culverts/bridges were defined using the DEM. Inverts and obverts were collected as part of the topographic survey and other parameters such as material type, headwall structures and sediment blockages were also noted. For culverts, Manning values were assigned based on the material (0.013 for concrete and 0.024 for CSP). A structural summary of the all culverts is included within **Appendix E**. **Appendix E** also includes diagrams showing which points were surveyed on typical crossings.

3.3.3.3.5 Ineffective Flow Area

The ineffective flow areas were calculated for all structures. The ineffective flow area is applied to restrict the flow area to the width of the structure opening until the structure is overtopped and flow begins over the road structure. Normally ineffective flow area stations were calculated on each side of the structure opening based on 1:1 ratio upstream and 2:1 ratio downstream. The distance of the structure to upstream and downstream cross sections were used to estimate the horizontal stations for defining the ineffective flow areas. As for elevations, they were estimated in accordance with the HECRAS reference manual. The ineffective flow elevations were set to the lowest point of the top-of-road.

3.3.3.3.6 Model Calibration

The monitoring water depth and flow data were reviewed further prior to attempting to use the data for model calibration. During 2020 and 2021, there were five precipitation events that caused flood flows larger than 0.5 m³/s at the two monitoring locations (Jones Creek at Highway 24 and Jones Creek at Park Road North). All the five events were used to calibrate the hydraulic model. The calibration is limited because all the five precipitation events are much lower than 2-year storm event.

The model was calibrated by adjusting model parameters to produce results matching the measurements from the flow monitoring within reasonable accuracy in terms of water depth. Calibration relied on observed flow and water depth monitoring data with monitoring sensor elevation provided by GRCA for input. Observed flow data were used to simulate the response of the model and were entered upstream of the flow monitoring locations. The observed flow at the monitoring locations was then used to verify the water surface elevation by the model for the events. The calibration results are shown in **Table 3.22**.

Table 3.22 Hydraulic Model Calibration Results

Event Date	Monitoring Location	Monitored Flow (m ³ /s)	Monitored Depth (m)	Monitored Water Elevation (m)	Simulated Water Elevation (m)	Δ (simulated vs monitored)
May 17, 2020	XS 12343, Jones-8	0.50	0.941	216.21	215.86	-0.35
	XS 7257, Jones-3	0.52	0.651	207.36	207.4	0.04
September 7, 2021	XS 12343, Jones-8	0.43	0.914	216.18	215.83	-0.35
	XS 7257, Jones-3	0.55	0.663	207.37	207.41	0.04
September 13, 2021	XS 12343, Jones-8	0.63	0.989	216.26	215.89	-0.37
	XS 7257, Jones-3	1.33	0.903	207.61	207.6	-0.01
September 21, 2021	XS 12343, Jones-8	3.00	1.516	216.79	216.25	-0.54
	XS 7257, Jones-3	3.79	1.293	208.00	207.92	-0.08
October 3, 2021	XS 12343, Jones-8	1.14	1.144	216.41	216.02	-0.39
	XS 7257, Jones-3	1.30	0.896	207.70	207.59	-0.11

The water surface elevations at downstream match well with the monitoring data well. The results for the downstream flow gauge show that the difference between monitored records and simulated results is below 0.11 m with an average of 0.03 m. However, the upstream flow gauge results show a difference of around 0.4 m lower than the water elevation records. The potential reason could be that there is an issue with the upstream flow gauge data, because the upstream flow gauge generally recorded higher water depths than the downstream flow gauge, which is not reasonable. In summary, a limited calibration was undertaken. The results show a reasonable correlation between the monitored and simulated flows and depths.

3.3.3.3.7 Floodline Analysis

Flood flow estimates for the 2-year through 100-year design storm events and Regional event, as determined from the PCSWMM hydrologic model, were applied over the appropriate stream reaches in the GeoHEC-RAS model. The downstream boundary conditions were set to normal depth with slope calculated from DEM data. Model details, including flood profile plots, output tables, and floodline maps are provided in **Appendix F**. The model was run under a steady state analysis.

Model results for the 100-year and Regional storms were then plotted on topographic mapping generated from the DEM over the Study Area. The resulting floodplain hazard lands are illustrated in **Figure 3.91** and **Figure 3.92**. There is no spill of floodwaters in this model.

3.3.4 Sediment Quality

A sediment investigation evaluating stream bed sediment quality was undertaken to assist in assessing the aquatic life, fish habitat and general water quality of the watercourses in the Study Area. Pollutants can build up in stream bed sediment and can result in negative impacts to the overall aquatic health of the stream system.

3.3.4.1 Field Assessments and Methodology






Four (4) sampling sites throughout the Study Area were selected for sediment quality evaluation. Two (2) sites were placed at the upstream and downstream limits of Jones Creek in the Northern Brantford area while the other two (2) sites were placed at the upstream and downstream limits of Phelps Creek in the Tutela Heights area (**Figure 3.94**).

Where the stream was wadable, sediment samples were collected using a handheld auger which removed a small (approximately 10cm) core from the top of the streambed (**Figure 3.93**). One sampling site (Jones Creek Downstream) was deemed non-wadable and samples were collected using a Ponar Dredge grab sampler.



Figure 3.93: Sediment Sample at Phelps Creek Upstream

Legend

-  Municipal Boundary
-  Study Area
-  Road Centreline
-  Watercourse
-  Sediment Sampling Sites

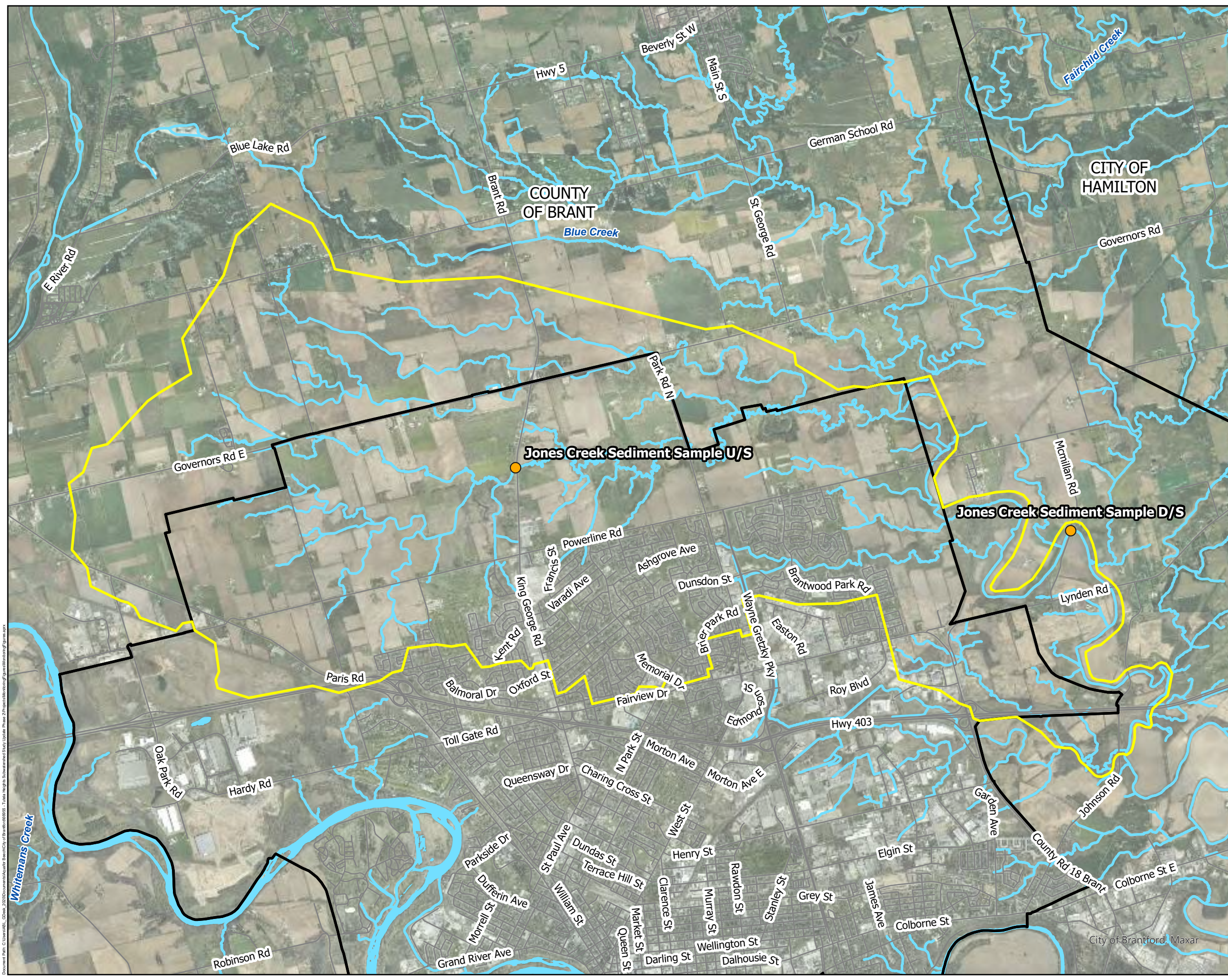
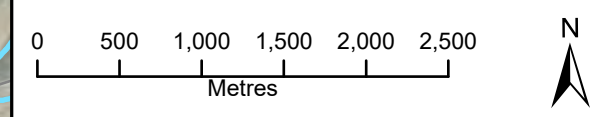


Figure 3.94






Sediment Sampling Locations

Date: 2022-11-09
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: A.V.



Document Path: C:\Users\A.V.\Desktop\2022\Documents\Aquafor Beech\City of Brantford\0304 - Table Heights Subwatershed Study Update Phase 2\ProjectMonitoring\GIS\Map\Figure 3.94 - Sediment Sampling Locations.aprx

Legend

-  Municipal Boundary
-  Study Area
-  Road Centreline
-  Watercourse
-  Sediment Sampling Sites

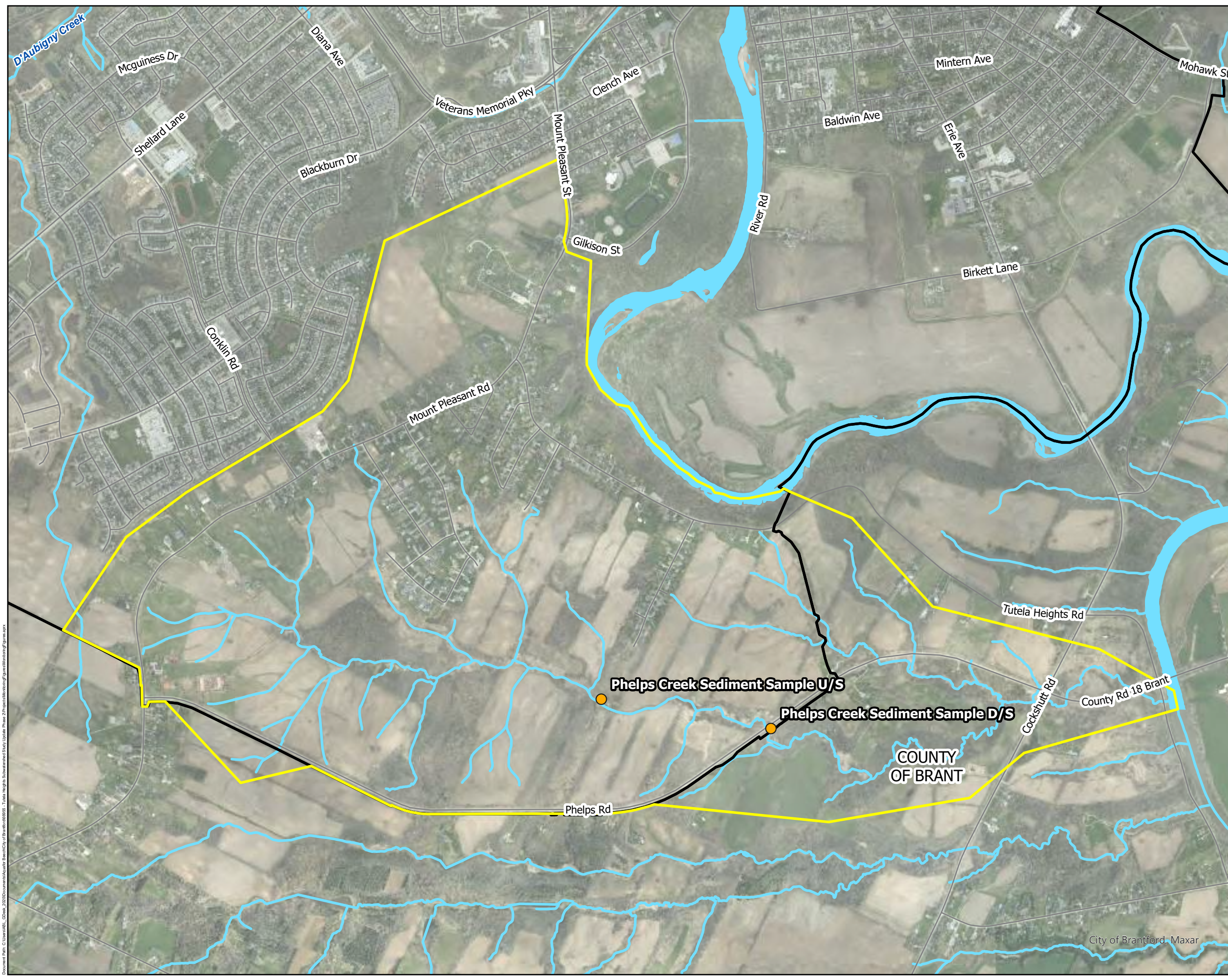
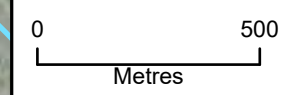


Figure 3.94

Sediment Sampling Locations

Date: 2022-11-09
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: A.V.



Document Path: C:\Users\A.V.\Desktop\2022\Documents\Aquafor Beech\City of Brantford\8859 - Tutela Heights Subwatershed Study Update Phase 2\ProjectMonitoring\GIS\MapInfo\Figure 3.94.mxd

3.3.4.2 Sediment Sampling Results

Results of the sediment quality samples were compared against the Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CSQGs). These guidelines are intended to protect all forms of freshwater and marine aquatic life during all aspects of their aquatic life cycles for an indefinite period of exposure to substances associated with bed sediments. The guidelines consist of threshold effect levels (also called ISQGs) and probable effect levels (PELs). The ISQGs and PELs are used to identify the following three ranges of chemical concentrations with regard to biological effects:

- Below the ISQG: the minimal effect range within which adverse effects rarely occur
- Between the ISQG and PEL: the possible effect range within which adverse effects occasionally occur
- Above the PEL: the probable effect range within which adverse effects frequently occur

Table 3.23 below outlines the sediment quality results for parameters which have an active CSQG.

Table 3.23: Sediment Quality Sampling Results (mg/kg)

Parameter	ISQG	PEL	Jones Creek Downstream	Jones Creek Upstream	Phelps Creek Downstream	Phelps Creek Upstream
Metals						
Arsenic	5.9	17	3.56	6.47	4.22	4.26
Cadmium	0.6	3.5	0.165	0.112	0.161	0.284
Chromium	37.3	90	16.9	18.5	19.4	24.4
Copper	35.7	19.7	18.6	25.0	16.3	22.4
Lead	35	91.3	9.22	8.69	10.7	17.6
Zinc	123	315	61.0	51.3	72.5	78.4
Polychlorinated biphenyls (PCBs)						
Total PCBs	0.0341	0.277	<0.030	<0.030	<0.030	<0.030
Polyaromatic Hydrocarbons (PAHs)						
acenaphthene	0.00671	0.0889	<0.050	<0.050	<0.050	<0.050
Acenaphthylene	0.00587	0.128	<0.050	<0.050	<0.050	<0.050
Anthracene	0.0469	0.245	<0.050	<0.050	<0.050	<0.050
benz(a)anthracene	0.0317	0.385	0.088	<0.050	<0.050	<0.050
benzo(a)pyrene	0.0319	0.782	0.154	<0.050	<0.050	<0.050
Chrysene	0.0571	0.862	0.172	<0.050	<0.050	<0.050
dibenz(a,h)anthracene	0.00622	0.135	<0.050	<0.050	<0.050	<0.050
Fluoranthene	0.111	2.355	0.311	<0.050	<0.050	<0.050
Fluorene	0.0212	0.144	<0.050	<0.050	<0.050	<0.050
methylnaphthalene, 2-	0.0202	0.201	<0.030	<0.030	<0.030	<0.030
Naphthalene	0.0346	0.391	<0.010	<0.010	<0.010	<0.010

Parameter	ISQG	PEL	Jones Creek Downstream	Jones Creek Upstream	Phelps Creek Downstream	Phelps Creek Upstream
Phenanthrene	0.0419	0.515	0.089	<0.050	<0.050	<0.050
Pyrene	0.053	0.875	0.239	<0.050	<0.050	<0.050

No Exceedances	Exceeds ISQG	Exceeds PEL
----------------	--------------	-------------

Overall, most of the parameters fell underneath the ISQG value for each parameter which only a few exceptions.

The arsenic levels from the Jones Creek Upstream sample were slightly above the ISQG value. Arsenic can enter the aquatic environment from both natural and anthropogenic sources through aerial deposition and runoff. Most anthropogenic emissions come from industrial processes as well as fertilizer.

The majority of exceedances were seen PAHs observed at the Jones Creek Downstream site. PAHs are released into the environment every year from a variety of natural (e.g. forest fires and volcanic activity) and anthropogenic (industrial activities, fossil fuel combustion, and waste incineration) sources. Though emissions of PAHs are almost exclusively atmospheric, they tend to become incorporated into sediment beds due to their poor solubility and nonvolatile nature.

3.3.4.3 Sediment Quality Conclusions and Recommendations

The sediment sampling program undertaken for this study provides a basic overview of the sediment quality within the Jones Creek and Phelps Creeks systems. Overall, the sediment quality results observed at the Phelps Creek monitoring sites fell below the ISQGs for all parameters and were similar to background concentrations observed across most Canadian stream systems. Further investigations are required to account for the high volume of PAH exceedances observed at the Jones Creek Downstream sample site. A more detailed sediment quality sampling program within the downstream Jones Creek area and its tributaries could help in uncovering any potential sources of pollution.

3.3.5 Water Quality

Water quality, including the pollutant levels found in surface runoff, can impact both human and ecological well-being. The modification of natural environments to agricultural and urban land uses can impact the landscape, vegetation, and ecological functions within a subwatershed, which in turn can contribute to increases in the levels of pollutants in the receiving watercourses. As such, water quality sampling was completed as part of the Subwatershed Study to help characterize baseline conditions prior to development.

3.3.5.1 Grab Sampling Field Assessments and Methodology

Twelve (12) water quality monitoring sites were selected at the onset of the study. Four (4) sites were placed at the boundary areas of the main watercourses Jones Creek and Silver Creek. Seven (7) sites were placed within key tributaries that enter Jones Creek and one (1) site was placed

within Phelps Creek. The sampling program included the collection of two (2) wet-weather flow samples (rainfall events greater than 15mm) at each site. The water quality monitoring sites are shown on Figure 3.95 and the general descriptions of the monitoring locations are as follows:

1. North Branch: Located at upstream boundary area on the south side of Governor's Road west of Golf Road.
2. South Branch: Located on the east side of the road just south of 460 Gulf Road.
3. Golf Course Tributary: Located on the east side of the road just North of 408 Gulf Road.
4. Lower Jones Creek (1): Located just south of 493 King George Road.
5. Lower Jones Creek (2): Located just east of 143 Powerline Road at Bridge Crossing of Jones Creek.
6. Upper Jones Creek: Located a culvert just off of Governor's Road to the east of County Rd 32.
7. Ravine Tributary: Located on the north side of Powerline Rd just east of Ivanhoe Road.
8. Tributary K: Located on the north side of Powerline Rd just west of Memorial Drive.
9. Karek Tributary North: Located just west of 194 Powerline Road.
10. Karek Tributary South: Located south of Powerline Road behind church located at 80 Coulbeck Road.
11. Silver Creek: Located just below pedestrian path that cuts between Ludlow Crescent and Hackney Ridge.
12. Phelps Creek: Located at the downstream limit of Phelps creek on the North side of Phelps Road west of Cockshutt Road.

There are a variety of pollutants as well as other physical, chemical and biological characteristics used to measure water quality. Some of the most common categories include:

- Solids (e.g., suspended solids, volatile solids, turbidity);
- Nutrients (e.g. phosphorus, nitrogen);
- Bacteria (e.g., coliforms);
- Metals (e.g., copper, zinc);
- Temperature;
- Chlorides; and
- Dissolved oxygen.

Provided below is an overview of these water quality parameters, their importance and influence in terms of aquatic and ecosystem health, and the potential impacts of urban development.

Solids and Turbidity

Suspended solids concentrations and turbidity both indicate the amount of solids suspended in the water, whether mineral (soil particles) or organic (algae). High concentrations of particulate matter can cause increased sedimentation and siltation in a stream, which in turn can degrade/impact important habitat areas for fish and other aquatic life. Elevated levels of suspended solids can also negatively affect water quality by absorbing light, thereby warming the water. Warm water holds less dissolved oxygen than cool water. The suspended particles also provide attachment places for other pollutants, such as metals and bacteria. High suspended solids or turbidity readings thus can be used as indicators of other potential pollutants.

Land use is generally the greatest factor influencing changes in TSS or turbidity in streams. Agricultural and urban land use results in an increase in disturbed areas, a decrease in vegetation, and an increase in the rate of runoff. These all cause increases in erosion, particulate matter, and nutrients, which promote increased algal growth. For example, loss of vegetation due to urbanization exposes more soil to erosion, allowing more runoff to form, and simultaneously reduces the subwatershed's ability to filter runoff before it reaches the stream.

Nutrients

Instream nutrients are essential for growth. The additional algae and other plant growth supported by nutrients may be beneficial up to a point but may easily become a nuisance or negatively impact aquatic species/habitat. The main nutrients of concern are phosphorus and nitrogen. Nutrient loading can result in increased algae growth. Excessive growths of attached algae can cause low dissolved oxygen (DO), unsightly conditions, odors, and poor habitat conditions for aquatic organisms. Pollution from urban development can impact instream nutrient concentrations in a number of ways. Municipal and industrial discharges usually contain nutrients, and overland flow from developed watersheds contains nutrients from lawn and garden fertilizers as well as the additional organic debris, which is washed from urban surfaces. Increased runoff from urban surfaces may result in increased rates of erosion, which can also be a significant source of nutrients to receiving streams, as nutrients are also naturally present in many soils in Ontario. Agricultural areas also contribute to nutrient increases through poor manure and fertilizing practices and increased erosion from plowed surfaces.

Pathogens (Bacteria)

Fecal coliform bacteria are microscopic organisms that live in the intestines of warm-blooded animals, as well as in the waste material, or feces, excreted from the intestinal tract. When fecal coliform bacteria are present in high numbers in a water sample, it means that the water has received fecal matter from one source or another. Although not necessarily agents of disease, fecal coliform bacteria may indicate the presence of disease-carrying organisms, which live in the same environment as the fecal coliform bacteria. Bacteria levels do not necessarily decrease as a subwatershed develops from rural to urban. Instead, urbanization usually generates new

sources of bacteria. Farm animal manure and septic systems are replaced by domestic pets and leaking sanitary sewers.

Metals

Urban transportation systems are a primary source of metals in stormwater runoff to urban streams and groundwater. All cars, even the cleanest vehicles, shed small amounts of metals, fluids, and other pollutants. Cadmium, copper, cobalt, iron, nickel, lead and zinc are deposited into the environment by vehicle exhaust, brake linings, and tire and engine wear. They accumulate on road surfaces and are then washed into storm drains with the next rainfall. Galvanized metal rooftops, gutters and downspouts, and moss killer are also a source of zinc in stormwater. Some copper comes from architectural uses and treated wood, and a primary source is brake pads. The erosion of soils can also be a significant natural source of metals within stormwater runoff.

The effects of a number of metals are reviewed below:

- Lead, which is often used as an indicator for other toxic pollutants in stormwater, can be harmful or deadly for human and aquatic life.
- Zinc, although not harmful to humans at concentrations normally found in stormwater, can be deadly for aquatic life.
- Cadmium can bioaccumulate in an ecosystem.
- Soil microorganisms are especially sensitive to it, and it is harmful to human health.
- Chromium damages fish gills and causes birth defects in animals. It is also dangerous to human health.
- Mercury is a neurotoxin that bioaccumulates.
- Low levels of copper inhibit the olfactory systems of salmonid fish, decreasing their ability to hide in response to warning signals.
- Some metals bind to soils and organic matter and are transported in sediment, while other metals dissolve in water. Rainwater is slightly acidic, which increases its ability to dissolve heavy metals and compounds the health and environmental effects of stormwater runoff from urban areas.

Temperature

Water temperature is important because it governs the kinds of aquatic life that can live in a stream. Fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred temperature range. If temperatures get too far above or below this preferred range, the number of individual species decreases until finally there are none.

Additional to point sources of heat pollution such as of heated municipal and industrial discharges, the process of subwatershed development also can affect temperatures in nearby

streams. Streambank vegetation is lost when land is cleared, thereby exposing the stream to increased warming by sunlight. A less obvious impact is that runoff water may be warmer, especially during the summer months when it flows over hot asphalt or concrete.

Chlorides






Chloride is a conservative pollutant, in that it is not degraded or removed from water by any natural process. High levels of chlorides can inhibit plant growth and impair reproduction. They also reduce the diversity of fish and other aquatic organisms in streams. Chloride is a general surrogate for development pressures, from road salting and septic systems.

Dissolved Oxygen (DO)

Like terrestrial animals, fish and other aquatic organisms need oxygen to live. As water moves past their gills (or other breathing apparatus), microscopic bubbles of oxygen gas in the water, called dissolved oxygen (DO), are transferred from the water to their blood. In addition to being required by aquatic organisms for respiration, oxygen also is used for decomposition of organic matter and other biological and chemical processes.

Stormwater runoff delivers oxygen-demanding substances to streams. When a subwatershed becomes developed, greater quantities of pollutants are released and the total volume of runoff increases. Most conventional pollutants (sediments, nutrients, organic matter) require oxygen for decomposition or for chemical reactions. Consequently, instream DO concentrations often decrease in a developed or developing subwatershed.

Legend

-  Municipal Boundary
-  Study Area
-  Road Centreline
-  Watercourse
-  Water Quality Monitoring

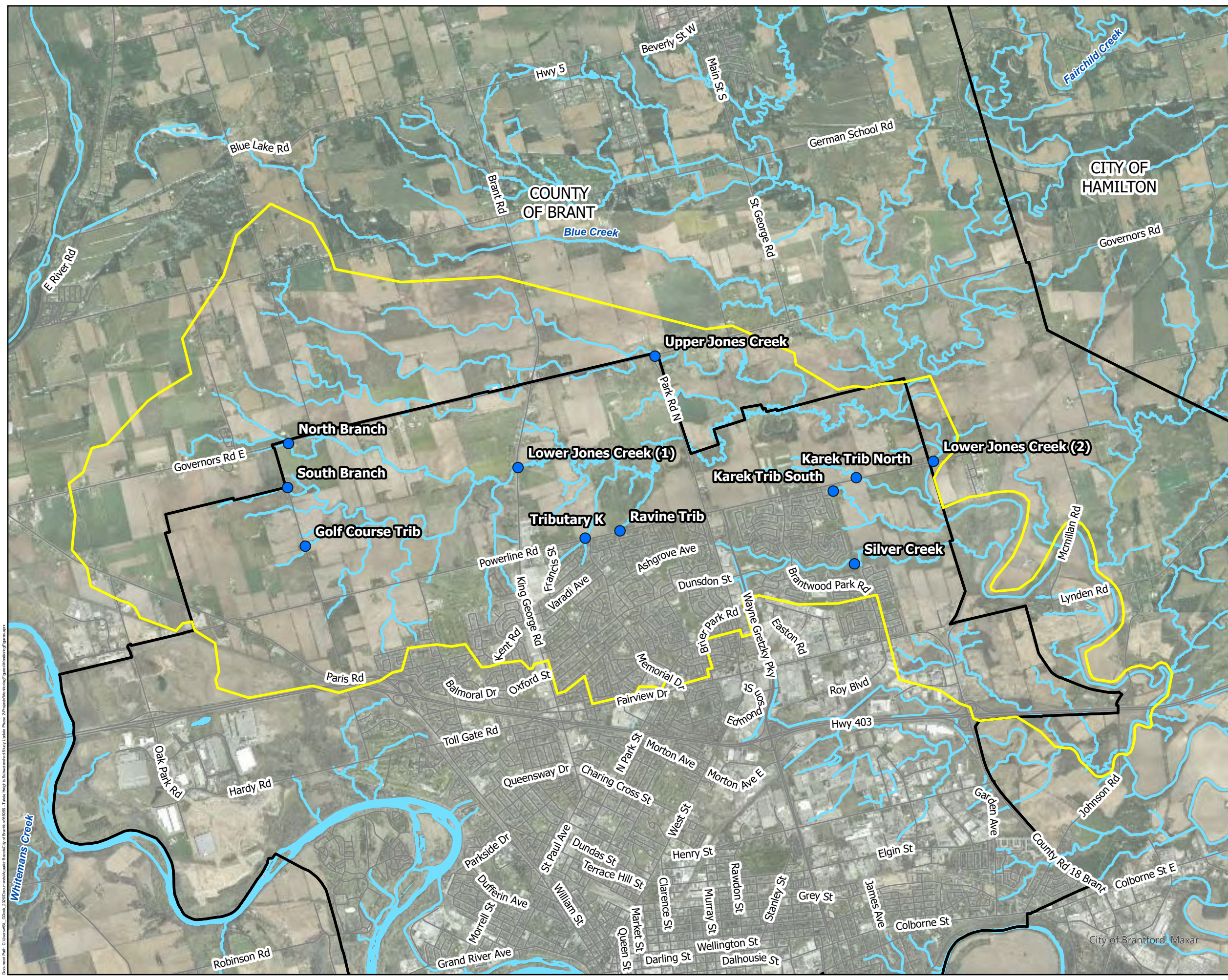
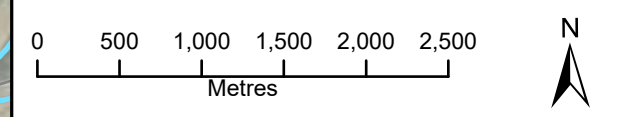


Figure 3.95

Water Quality Monitoring Locations

Date: 2022-11-09
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: A.V.



Document Path: C:\Users\A.V.\Desktop\2022\Documents\Aquafor Beech\City of Brantford\0305 - Tables\Highly Submersed Study Update Phase 2\ProjectMonitoringPrograms.mxd

Legend

- Municipal Boundary
- Study Area
- Road Centreline
- Watercourse
- Water Quality Monitoring

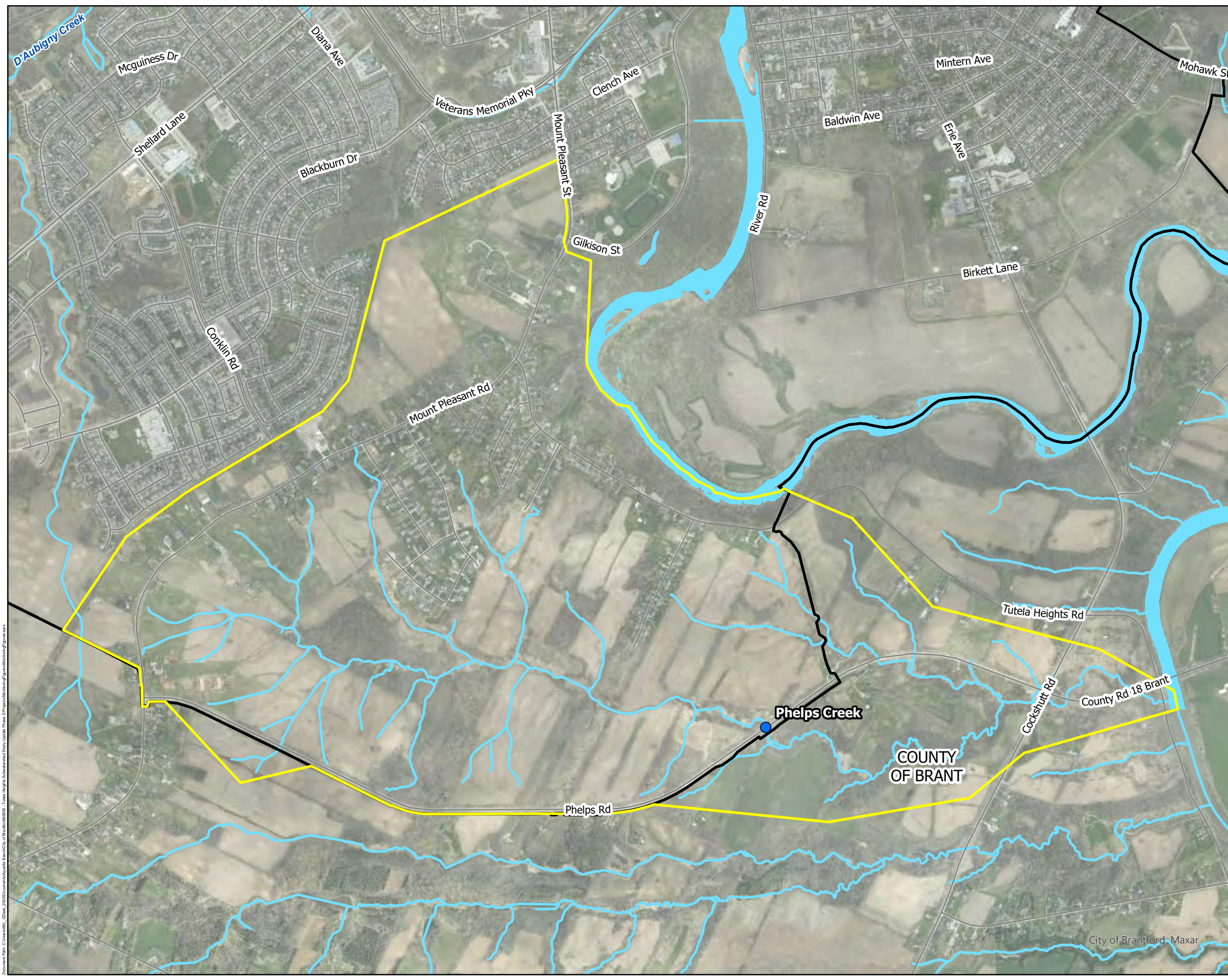
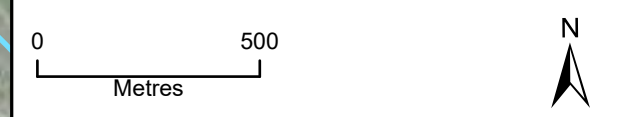


Figure 3.95

Water Quality Monitoring Locations

Date: 2022-11-09
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: A.V.



Document Path: C:\Users\A.V.\Desktop\2022\Documents\Aquafor Beech\City of Brantford\8859 - Tutela Heights Subwatershed Study Update Phase 2\ProjectMonitoring\GIS\MapDocs\fig3.95.mxd

Sampling Methodology

The water quality sampling procedures for this study were undertaken in accordance with the Protocols Manual for Water Quality Sampling in Canada (CCME, 2011). The following items were used during grab sampling and field measurements:

- Equipment: Laboratory sampling bottles (with ice and coolers, YSI Professional Plus Multimeter)
- Reagents and Chemicals: Distilled Water was used to triple-rinse sampling materials

Individual grab samples were collected by filling a typical sampling device (i.e. a plastic beaker) and distributing the water to each of the sampling bottles to be submitted for analysis. The sample bottles were filled with sufficient volume to eliminate air bubbles while being careful not to overfill thereby displacing any bottle preservatives. The sampling device was filled facing upstream directly with stream water which ensured that any flow disruptions made by the sampler did not negatively impact the integrity of the water samples. Prior to sample collection, the use of the “triple rinse” technique was used to neutralize the sampling device from one monitoring station to the next.

At the same time as the discrete grab samples, field measurements were taken using the YSI Professional Plus multimeter. This device was calibrated prior to its use in the field and was used to record the following parameters: pH, dissolved oxygen (DO), temperature and conductivity.

Table 3.24 lists the parameters that were analyzed and the sampling procedures utilized at the time of sampling.

Table 3.24: Water Quality Parameters and Sampling Procedures

Parameters	Sampling Procedure/Type	Details
Physical Tests	Grab	hardness, total suspended solids, turbidity
Bacterial	Grab	E. Coli and total coliforms
Anions and Nutrients	Grab	Bromide, Chloride, Fluoride, Nitrate, Nitrite, Total Kjeldahl Nitrogen, Total Phosphorus, Sulfate
Metals	Grab	Incl. Salts and Metals (Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Fe, Cu, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sn, Sr, Ti, U, V and Zn)
Organochlorine Pesticides	Grab	Organochlorines (DDT & metabolites), Carbamates (Aldicarb & Carbaryl), and organophosphates (Dichlorvos & Malathion)
pH	Field Measurement	YSI Professional Plus

Parameters	Sampling Procedure/Type	Details
DO	Field Measurement	YSI Professional Plus
Temperature	Field Measurement	YSI Professional Plus
Conductivity	Field Measurement	YSI Professional Plus

3.3.5.2 Continuous Water Temperature Monitoring

In addition to grab sampling, Aquafor also completed continuous water temperature monitoring at three (3) stations throughout the monitoring period. The water temperature monitoring sites are shown on **Figure 3.95** and the general descriptions of the monitoring locations are as follows:

1. TM1: Located in channel approximately 500m north-west of 174 Phelps Road
2. TM2: Located in channel beside 495 Governors Road East on the south side of the road
3. TM3: Located in channel on east side of Park Road approximately 1km north of Powerline Road

Each of these sites was equipped with a HOBO U20 logger which continuously recorded water depth and temperature at a 15-minute interval.

3.3.5.3 Water Quality Sampling Results

The following section summarizes the water quality monitoring results. The first set of water quality samples were sampled on June 7, 2022 during a rainfall event that totaled approximately 20mm. **Table 3.25** outlines the results for each of the monitoring sites that were sampled. Two (2) sites, the South Branch Location and the Ravine Tributary Location were both dry during this rainfall event and were unable to be sampled. Unfortunately, due to extremely low rainfall totals this fall, a second sample has not yet been able to be collected, as a minimum of 15mm of precipitation is needed for the sampling to occur. Aquafor continues to monitor rainfall forecasts and will collect this second sample if possible.

Water Quality results were compared to the following agency guidelines where applicable:

- PWQO: Provincial Water Quality Objectives
- CCME: Canadian Council of Ministers for the Environment
- CWQG: Canadian Water Quality Guidelines for the Protection of Aquatic Life

The Provincial Water Quality Objectives are numerical and narrative criteria which serve as chemical and physical indications representing a satisfactory level for surface waters of the province. The PWQO are set at a level of water quality which is protective to all forms of aquatic life and all aspects of aquatic life cycles during indefinite exposure to the water. These objectives cover a large range of parameters including physical parameters, nutrients, metals, PAHs, and other chemicals.

The CCME and CWQGs are intended to protect all forms of aquatic life and all aspects of aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term

from anthropogenic stressors such as chemical inputs or changes to physical components. They provide the science-based benchmark for a national consistent level of protection for aquatic life in Canada. Standards and guidelines from these sources were used on a select few parameters where there no PWQO was available.

Table 3.25: Water Quality Sampling Results for June 7, 2022

Parameters	Lowest Detection Limit	Units	Guideline	KAREK NORTH	KAREK SOUTH	SILVER CREEK	UPPER JONES	PHELPHS CREEK	TRIBUTARY K	LOWER JONES (1)	LOWER JONES (2)	GOLF TRIB	NORTH BRONCH
Physical Tests (Water)													
Conductivity	1.0	umhos/cm	N/V	1610	776	179	763	837	497	809	713	685	695
Hardness (as CaCO3)	1.3	mg/L	N/V	498	158	113	263	346	123	284	313	304	336
pH	0.10	pH units	6.5-8.5 (PWQO)	8.01	7.91	8.21	8.23	8.04	7.89	8.22	8.41	8.31	8.34
Total Suspended Solids	3.0	mg/L	25 (CCME)	22.2	19.4	295	34.6	28.2	17.8	127	54.5	20.4	29.6
Total Dissolved Solids	13	mg/L	N/V	944	388	115	413	469	250	444	392	414	399
Turbidity	0.10	NTU	N/V	21.0	26.1	211	33.8	12.8	11.3	64.3	40.6	5.85	17.9
Anions and Nutrients (Water)													
Bromide (Br)	0.10	mg/L	N/V	<0.50	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Chloride (Cl)	0.50	mg/L	640 (CWQG)	280	148	17.2	93.1	63.3	84.4	97.5	54.5	47.1	34.0
Fluoride (F)	0.020	mg/L	0.12 (CWQG)	0.11	0.069	0.025	0.106	0.116	0.041	0.097	0.136	0.122	0.087
Nitrate and Nitrite as N	0.022	mg/L	N/V	0.29	0.501	0.308	1.045	0.056	0.637	2.641	1.447	0.188	4.905
Nitrate (as N)	0.020	mg/L	550 (CWQG)	0.29	0.488	0.295	1.01	0.056	0.622	2.62	1.40	0.188	4.89
Nitrite (as N)	0.010	mg/L	N/V	<0.050	0.013	0.013	0.035	<0.010	0.015	0.021	0.047	<0.010	0.015
Total Kjeldahl Nitrogen	0.050	mg/L	N/V	0.934	0.842	0.952	0.823	0.676	0.341	1.16	0.862	1.01	0.946
Phosphorus, Total	0.0030	mg/L	0.03 (PWQO)	0.121	0.168	0.399	0.163	0.114	0.0684	0.225	0.109	0.326	0.101
Sulfate (SO4)	0.30	mg/L	N/V	9.2	12.5	3.51	29.9	23.9	12.3	24.6	39.3	34.1	32.9
Bacteriological Tests (Water)													
E. Coli	10	CFU/100mL	100 (PWQO)	260	3900	8700	4100	3700	4600	6500	1500	3900	4400
Total Coliforms	100	CFU/100mL	1000 (PWQO)	14000	42000	32000	25000	4200	23000	22000	3900	31000	34000
Metals (Water)													
Sodium Adsorption Ratio	0.10	SAR	N/V	2.63	3.19	0.51	1.54	0.93	1.91	1.46	0.74	0.4	0.33
Total Metals (Water)													
Calcium (Ca)-Total	0.50	mg/L	N/V	157	46.2	34.9	72.8	105	38.0	73.3	76.8	95.4	82.9
Magnesium (Mg)-Total	0.050	mg/L	N/V	26.1	10.3	6.30	19.8	20.5	6.78	24.6	29.5	15.9	31.3
Potassium (K)-Total	0.050	mg/L	N/V	3.15	2.05	2.40	2.89	4.41	1.44	5.10	2.79	5.13	4.27
Sodium (Na)-Total	0.50	mg/L	N/V	135	92.2	12.6	57.3	39.6	48.5	56.5	30.0	15.9	13.9
Organochlorine Pesticides (Water)													
Aldrin	0.0080	ug/L	0.001 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
alpha-BHC	0.0080	ug/L	N/V	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
beta-BHC	0.0080	ug/L	N/V	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
gamma-hexachlorocyclohexane	0.0080	ug/L	N/V	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
delta-BHC	0.0080	ug/L	N/V	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
a-chlordane	0.0080	ug/L	0.06 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
g-chlordane	0.0080	ug/L	0.06 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
o,p- DDD	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
pp- DDD	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
o,p- DDE	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
pp- DDE	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
op- DDT	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
pp- DDT	0.0040	ug/L	0.003 (PWQO)	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040	<0.0040
Dieldrin	0.0080	ug/L	0.001 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Endosulfan I	0.0070	ug/L	0.003 (PWQO)	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070
Endosulfan II	0.0070	ug/L	0.003 (PWQO)	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070
Endosulfan Sulfate	0.0070	ug/L	N/V	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070	<0.0070
Endrin	0.010	ug/L	0.002 (PWQO)	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Endrin Aldehyde	0.010	ug/L	N/V	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Heptachlor	0.0080	ug/L	0.001 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Heptachlor Epoxide	0.0080	ug/L	0.001 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Hexachlorobenzene	0.0080	ug/L	0.0065 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Hexachlorobutadiene	0.0080	ug/L	0.009 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Hexachloroethane	0.0080	ug/L	1.0 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Methoxychlor	0.0080	ug/L	0.04 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Mirex	0.0080	ug/L	0.001 (PWQO)	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
trans-Nonachlor	0.010	ug/L	N/V	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Oxychlorane	0.0080	ug/L	N/V	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080	<0.0080
Pentachloronitrobenzene	0.010	ug/L	N/V	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Decachlorobiphenyl		%	N/V	101.8	102.7	85.8	103.2	98.9	89.7	92.1	97.1	95.5	98.4
Tetrachloro-m-xylene		%	N/V	110.3	111.2	86.6	101.8	94.6	93.7	103	97.1	108	97.6

Overall, there were not many exceedances observed across the water samples collected throughout the Study Area. The total suspended solids concentrations were above the guideline at six of twelve sites, however, most of the exceedances were only slightly above the guideline. The highest TSS values were seen in the bigger watercourses Silver Creek and Lower Jones Creek (1). Lower Jones Creek (2) and the Golf Tributary monitoring sites had elevated Fluoride concentrations which exceeded the CWQGs, however these exceedances were also very minor.

There were three parameters for which exceedances were observed at all 12 locations sampled: total phosphorus, *E. coli*, and total coliforms. The exceedances of the bacteriological parameters ranged from 2.6 to 87 times greater than the PWQO guidelines. Although these numbers do appear high, elevated concentrations are common in areas with large agricultural inputs. Furthermore, the PWQO for these bacteriological parameters is based on public health and safety purposes for water being used for recreational activities (i.e. swimming and other activities). The total phosphorus concentrations ranged from 2 to 10 times greater than the PWQO guideline. Phosphorus is a common constituent in many agricultural fertilizers, manure, and organic waste and is also commonly observed to be elevated in areas with large agricultural inputs.

3.3.5.4 Continuous Water Temperature Monitoring Results

A method developed by Stoneman and Jones (1996) and revised by Chu (2009) was utilized to classify sites into coldwater, coolwater, or warmwater habitats based on their maximum air and water temperatures during the summer months. The methodology uses single measurements of daily maximum air temperature (> 24.5°C) and water temperatures between 16:00 and 18:00 hrs, between July 1 and August 31 plotted on a nomograph to approximate the thermal classification of each site (Chu, 2009). **Figure 3.96** and **Figure 3.97** demonstrates the 2022 nomographs and corresponding thermal regimes for TM2 and TM3. The above methodology could not be applied to site TM1 due to the dry conditions experienced at this site throughout July and August.

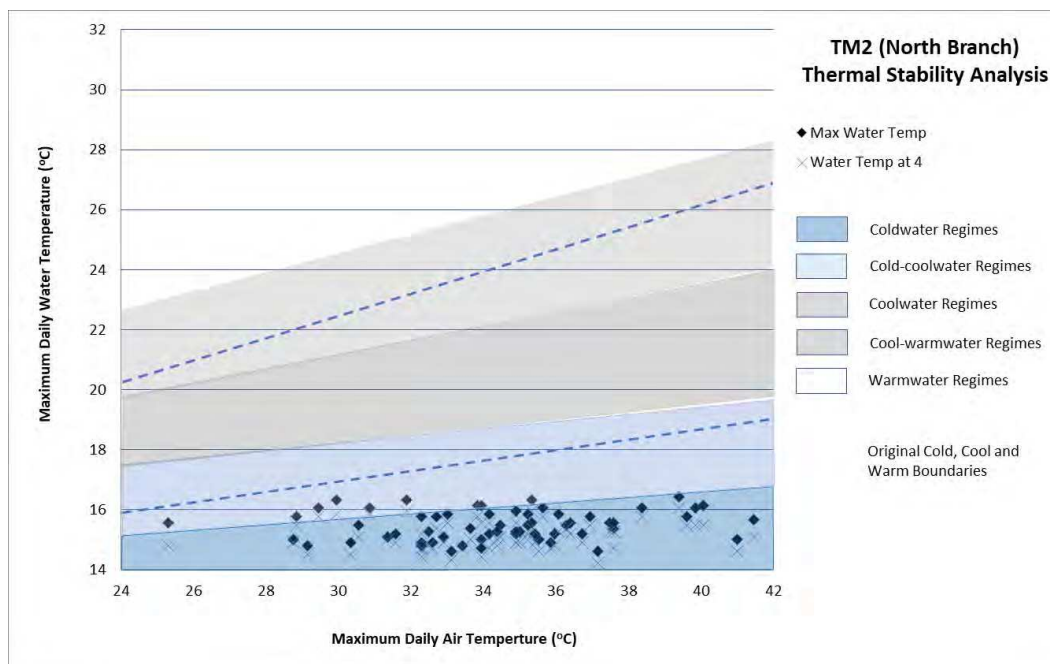


Figure 3.96: TM2(North Branch) Thermal Regime

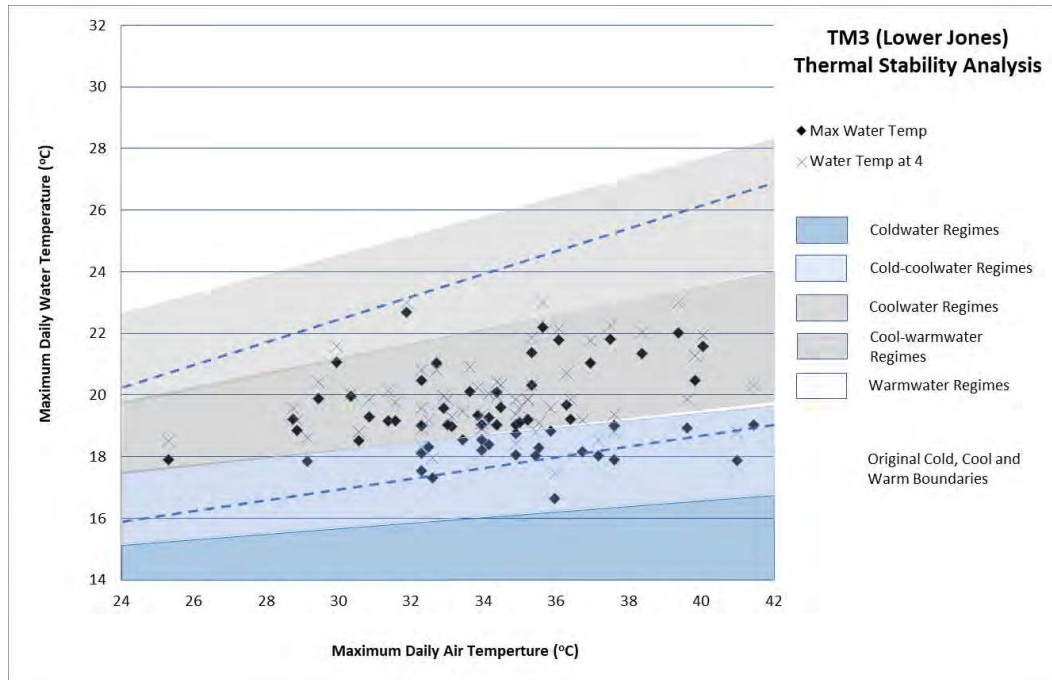


Figure 3.97: TM3 (Lower Jones) Thermal Regime

In 2022, site TM2 exhibited water temperatures that categorize it as a coldwater system and TM3 exhibited water temperatures that categorize it as a coolwater system. These categorizations are consistent with the observations taken during the aquatic habitat assessments (see **Section 3.4.3**).

3.3.5.5 Water Quality Conclusions and Recommendations

The water quality data collected so far in this study is limited due to the small and infrequent rain events during 2022, and as such can only partially inform baseline conditions within the Study Area. Wet weather samples can be highly variable based on the magnitude and distribution of the rainfall event, number of dry days preceding the events, and the timing of the sample collection in comparison to the rising limb of the hydrograph. Further water quality sampling is recommended to firmly establish accurate baseline conditions including dry weather sampling. It is also recommended that Stage 3 of the Subwatershed Study outline a monitoring plan to monitor the impacts of development on water quality.

3.4 Ecological Resources

Natural heritage features within the North Brantford and Tutela Heights subwatershed Study Areas were characterized using a combination of primary and secondary information sources. The main background resource used by Aquafor was the 2020 Comprehensive EIS by Plan B Natural Heritage; this study provided the framework upon which Aquafor assessed for data gaps and targeted its own field investigations and analysis to provide the greatest benefit moving forward (e.g., avoiding redundant survey locations). The following subsections provide an overview of background data (**Section 3.4.1**), and detailed discussion of Aquatic Resources (**Section 3.4.3**) and Terrestrial Resources (**Section 3.4.4**). Further assessment was carried out to address Species at Risk (**Section 3.4.5**) and Significant Wildlife Habitat (**Section 3.4.6**). In all cases, it is acknowledged that

the future results of a scoped, site-specific EIS or similar study as approved by the City and/or GRCA may be used to refine or amend the information presented herein, as such site-specific studies are often able to address the characterization and assessment of a site on a finer scale than a Subwatershed Study. This SWS is intended to provide guidance and information towards the completion of future EISes and similar studies prepared at the development proposal stage.

The implications of this SWS’s ecological data regarding Key Hydrologic Features and Key Natural Heritage Features (per the City’s OP) are discussed in **Section 4.2**, and developmental constraints and opportunities are discussed in **Section 4.4**.

3.4.1 Background Information Sources

Background information was obtained from a variety of sources to provide context of the ecological setting and sensitivity of the Study Area and surrounding lands. Background information sources include:

- Comprehensive Environmental Impact Statement - North Brantford and Tutela Heights, City of Brantford (Plan B Natural Heritage, November 2020);
- Current and historical air photos;
- City of Brantford Official Plan (Consolidated September 2022);
- The provincial Natural Heritage Information Centre (NHIC) ‘Make A Map: Natural Heritage Areas’ mapping website and associated database records of significant species and natural areas;
- Provincial species atlases (Ontario Reptile and Amphibian Atlas, Ontario Breeding Bird Atlas, Ontario Butterfly Atlas);
- Community science bird observation records obtained from the eBird.org website;
- Community science ‘research grade’ observation records of all taxa obtained from the iNaturalist.org website;

3.4.2 Overview of Ecological Field Studies

In addition to the use of the background resources listed above, existing conditions in the subwatershed Study Area were characterized through targeted field investigations where site access permissions allowed. **Table 3.26** details the survey types conducted, provides an overview of the methodologies used, and lists the dates for the natural heritage field investigations completed in 2022. More information on each survey type is provided in the indicated subsections.

Table 3.26: Summary of Ecological Field Surveys

Survey Type	Methodology	Dates
Aquatic Ecology		

Survey Type	Methodology	Dates
Aquatic Habitat Assessment (Section 3.4.3.1)	Aquatic habitat was assessed using Ontario Stream Assessment Protocol (OSAP) Version 10 (2017): Section 1: Module 1 (Defining Site Boundaries and Key Identifiers); Module 2 (Screening Level Site Documentation), and; Module 3 (Assessment Procedures for Site Features Documentation) Section 4: Module 2 (Point-Transect Sampling for Channel Structure, Substrate and Bank Conditions), and; Module 3 (Bankfull Profiles and Channel Entrenchment)	August 10 & 11, 2022
Benthic Invertebrates (Section 3.4.3.2)	Benthic macroinvertebrates were collected using the traveling kick-and-sweep method in accordance with the OSAP (Stanfield, 2017).	July 26 & 27, 2022
Fish Communities (Section 3.4.3.3)	Fish communities were sampled using OSAP Version 10 (2017): Section 3: Module 1 (Fish Community Sampling using Standard, Single Pass Electrofishing Techniques)	July 26 & 27, 2022
Terrestrial Ecology		
Vegetation Community Classification (Section 3.4.4.1)	Vegetation community surveys were completed in accordance with the Ecological Land Classification (ELC) system for Southern Ontario (Lee et al., 1998). Survey locations were scoped based on site access and areas of conflicting or incomplete background data.	Aug. 10, 17, & 19; Sept. 7, 9, 22, 26, & 30; Oct. 7, 2022
Botanical Inventories (Section 3.4.4.2)	Botanical inventory was conducted concurrently with Ecological Land Classification surveys, using an area search methodology.	Aug. 10, 17, & 19; Sept. 7, 9, 22, 26, & 30; Oct. 7, 2022
Breeding Bird Surveys (Section 3.4.4.4)	Breeding birds were surveyed during the peak nesting season (end of May to early July) over the course of two separate surveys beginning at dawn and extending no later than midday. Both area search and point count methodologies were employed as appropriate to supplement existing background data.	June 1 & 14, 2022
Amphibian Calling Surveys (Section 3.4.4.5)	Amphibian calling surveys were conducted at selected roadside survey locations in accordance with the methodology of the Marsh Monitoring Program (Bird Studies Canada, 2009).	April 22, May 25, & June 23, 2022
Other Wildlife (Section 3.4.4.6)	Incidental observations of wildlife were recorded during all other field surveys.	All dates listed for other survey types

Land access permission was not received for all properties within the Study Area, as previously detailed in **Section 3.1**. Features on lands not accessed during this study were evaluated from adjacent lands, if possible, and through air photo interpretation and background information

review, including the detailed work compiled by Plan B Natural Heritage in the previous Comprehensive EIS (2020).

3.4.3 Aquatic Resources

Aquatic resources play an important role in a natural heritage system and both human health and ecosystem health are largely dependent on stable aquatic resources. It is the role of the municipal OP to support the protection of *all significant natural heritage features and their associated ecological and hydrological functions* (City of Brantford, 2022). The OP identifies key hydrologic features and fish habitat as key natural heritage features or key hydrologic features to be considered for protection. Fish Habitat, as defined under the Provincial Policy Statement (2020) and the *Fisheries Act* (2020), defines Fish Habitat as, “spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes” (Government of Ontario, 2020). Understanding these resources provides a better idea of overall ecosystem health and aids decision makers when applying the OP to the protection of both aquatic resources and the overall NHS. The following sections discuss these resources in three parts: aquatic habitat; fish communities; and benthic macroinvertebrate communities.

3.4.3.1 Aquatic Habitat

Aquatic habitat characteristics, as described in the following section, are major determinants for biotic composition. Biotic composition is an indicator of aquatic ecosystem health. Understanding aquatic habitat can therefore determine relationships with biotic composition, providing a better understanding of subwatershed health and integrity. While aquatic habitat changes constantly, anthropogenic disturbance can impact habitat, stressing the relationship with aquatic habitat and biological/chemical indicators. The habitat characteristics investigated within the North Brantford and Tutela Heights Study Areas include:

- Bank characteristics;
- Stream width (wetted and bankfull);
- Instream cover (e.g., woody debris, undercut banks, boulders, vegetation);
- Riparian cover (vegetation composition, quality and width); and
- Physical barriers to fish movement (e.g., woody or debris jams, knickpoints, etc.).

Throughout the monitoring period, sites within the Study Area contained flow only immediately after the spring freshet and remained dry for most of the year. OSAP requires that the Study Area contain flow at the time of assessment. While the general flow regime of many of the watercourses in the Study Area(s) is seemingly perennial and/or intermittent in nature, drier than normal weather restricted Aquafor Beech Limited biologists from carrying out OSAP investigations in a number of the watercourses throughout 2022, as summarized below.

3.4.3.1.1 Methodology

Aquatic habitat assessment methodology is detailed in the following section.

In summary:

- OSAP Version 10 (Stanfield, 2017) was used for habitat assessments by certified Aquafor Beech Limited biologists;
- Site limits were located using OSAP Section 1: Modules 1 and 2 (Defining Site Boundaries and Key Identifiers; Screening Level Site Documentation);
- Habitat features including barriers to fish movement and other channel disturbances were recorded using OSAP Section 1: Module 3 (Assessment Procedures for Site Features Documentation);
- Depth, wetted width, habitat type, instream cover, instream vegetation, riparian vegetation, width/depth ratio, bank stability, substrate, and entrenchment was assessed using OSAP Section 4: Modules 2 and 3 (Point-Transect Sampling for Channel Structure, Substrate and Bank Conditions; Bankfull Profiles and Channel Entrenchment);

Proof of staff's OSAP certification is provided in **Appendix G**. OSAP data was summarized using the Flowing Waters Information System (FWIS) and is outlined in **Table 3.27** and **Table 3.28**. Aquafor Beech Limited biologists received FWIS training (conducted by Les Stanfield). All 2022 field sheets are located in **Appendix H** and FWIS data summaries are located in **Appendix I**. Aquatic sampling sites are illustrated in **Figure 3.98**, below with photographs of sampling sites shown in **Figure 3.99** through **Figure 3.103**.

Table 3.27: Channel Morphology Diagnostic Indicators

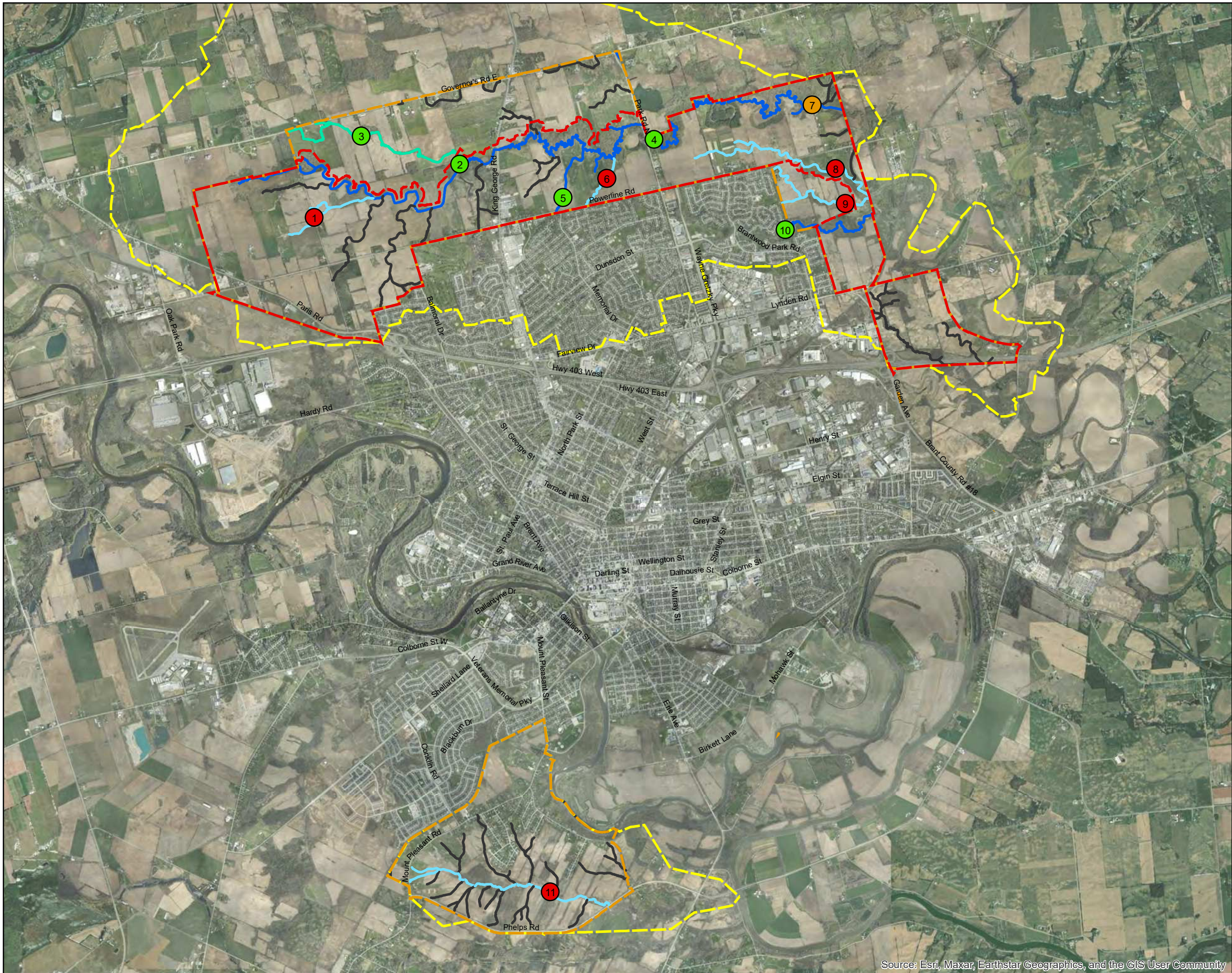
Diagnostic Indicator	Golf Course Tributary	South Branch	North Branch	Lower Jones	Tributary K	Ravine Tributary	Karek Tributary N	Karek Tributary S	Silver Creek	Phelps Creek
Proportion Stable Banks	N/A	0.39	0.97	0.36	0.47	N/A	N/A	N/A	0.34	N/A
Average Wetted Width (m)		2.08	2.16	2.20	1.25				3.05	
Minimum Wetted Width (m)		1.40	1.60	1.70	0.40				1.30	
Maximum Wetted Width (m)		3.00	1.60	3.70	1.90				4.00	
Average Depth (mm)		125.56	265.08	164.25	77.63				160.40	
Maximum Depth (mm)		280.00	530.00	420.00	185.00				330.00	
Width/Depth Ratio		16.57	8.14	13.39	16.04				18.99	
Count of Point Particles		45.00	60.00	60.00	40.00				45.00	
Mean Point Particles (mm)		0.05	60.00	6.79	36.39				0.06	
SD Point Particles (mm)		0.01	0.02	50.98	77.81				0.04	
Count of Max Particles		45.00	60.00	60.00	40.00				45.00	
Mean Max (mm)		0.10	1.67	9.75	109.13				18.16	
SD Max (mm)		0.01	60.00	52.16	96.51				40.45	
D16 Point (mm)		0.05	0.05	0.01	0.01				0.01	
D50 Point (mm)		0.05	0.05	0.05	0.01				0.05	
D84 Point (mm)		0.05	0.05	0.05	63.80				0.10	
D16 Maximum (mm)		0.10	0.10	0.10	0.01				0.10	
D50 Maximum (mm)		0.10	0.10	0.10	115.00				0.10	
D84 Maximum (mm)		0.10	0.10	0.10	197.60				25.00	
Sorting Index (Point)		1.00	1.00	2.77	2900.50				3.27	
Sorting Index (Maximum)	1.00	1.00	1.00	5228.13	125.50					

Table 3.28: OSAP Channel Structure Summaries

Habitat Characteristics	General Flow Regime	Site Location	Site Characteristics	Habitat Description	Substrate Composition	Bank Stability	Instream and Riparian Vegetation	Fish Barriers and Other Disturbances
Golf Course Tributary	Intermittent	The Golf Course Tributary was found within the watercourse that intercepts Golf Road, north of Powerline Road and south of Governor’s Road. The site is on private property surrounded by a thin riparian corridor and a cropland beyond. It was found within the catchment of the Jones Creek South Branch with a number of other contributing features between this tributary and the sampling location located on the South Branch. The site was dry at the time of assessment with no indication of ground water contribution. OSAP could not be performed due to the intermittent flow regime, however habitat will be discussed in the following section.						
Jones Creek South Branch	Permanent	The Jones Creek South Branch monitoring location was at the furthest downstream extent of the watercourse, immediately upstream of it’s confluence with the North Branch to become Lower Jones Creek, where flow was observed throughout the year and where results would provide insight to upstream features, such as the Golf Course Tributary.	Site length was 43.3 m. Minimum wetted width at the time of sampling was 14. m, and the average wetted width was 2.08 m. The average depth was 125.56 mm and the maximum depth sampled was 280 mm. Minimal stream velocity was observed throughout this study reach, with sedimentation present throughout. An abundance of anurans suggested that this watercourse did not convey strong water velocities through the summer months and did not support significant groundwater contributions.	This site was essentially a long, equally deep glide with a riffle located at the upstream extent, outside of the study reach. Pools were observed where tree roots would interfere with high flow events or at meander bends. Instream cover was low, consisting of almost woody material. Vegetation was also low, consisting of emergent macrophytes and wetland plants at the upstream extent. Canopy cover was abundant, providing the watercourse with 100% shade.	This site entirely consisted of silt and sand. The mean point particle was 0.05 mm (silt) and the mean maximum particle was 0.1 mm (sand). The substrate was very well sorted (sorting index of 1) and was defined by FWIS as “low quality sand bed”.	Both banks consisted almost entirely of silts, stabilized by in areas by established deciduous trees. Despite only 39% proportional stable banks, only 1 undercut was observed on sampled transects (180 mm).	Instream vegetation was absent through the majority of the site, with some emergent macrophytes represented by wetland vegetation (Broadleaf arrowhead) present at the upstream extent. Riparian vegetation was abundant beyond the top of bank, consisting of well-established forest floor vegetation and mixed deciduous forest. Between the top of bank and the wetted channel, little to no vegetation was present, contributing to low bank stability.	Few road crossings are upstream of this site, save Golf Road at the upstream extent. Between this crossing and the site, landuse is predominately agricultural with small forest parcels throughout. Adjacent land use consists of agriculture with few residents. No fish barriers were observed with fish observed throughout.
Jones Creek North Branch	Permanent	The Jones Creek North Branch monitoring location was the approximately 1.5 km downstream of the Governors Road E right-of-way (ROW).	Site length was 42 m. Minimum wetted width at the time of sampling was less than 1.6 m, and the average wetted width was 2.08 m. The average depth was 265.08 mm and the maximum depth sampled was 530 mm. An abundance of coldwater indicators were observed throughout with watercress present along the entire reach. Brook trout was observed at the Governors Road ROW with landowners sharing evidence of year-round trout species and coldwater characteristics.	This site was evenly distributed among riffles and runs, with little pools available for fish refuge throughout. Downcutting was not present due to stable banks and abundant vegetation. Cover was largely provided by overhanging terrestrial vegetation and instream macrophytes. Canopy cover was non-existent, provided only by overhanging grasses.	This site mainly consisted of silt and sand with some cobbles, with a mean point particle of 0.05 mm (silt) and a mean maximum particle size of 1.67 mm that would not contribute to instream cover. The substrate was very well sorted (sorting index of 1) and was defined by FWIS as “low quality sand bed”.	Both banks consisted almost entirely of silt but were stabilized by well-established terrestrial grasses and meadow species. Both banks demonstrated high stability, with one undercut observed on the left bank (210 mm) but 97% proportion of stable banks, the highest in the Study Area(s).	Instream vegetation was abundant, consistent of rooted macrophytes including watercress, indicating groundwater contributions throughout. Riparian vegetation consisted of terrestrial grasses and meadow species up to 10 m and cropland/pastureland up to beyond. small trees were spread throughout that did not provide the site with any canopy cover.	The monitoring site is approximately 1.5 km downstream of the Governors Road E ROW. This is likely the largest source of nutrients/pollutants, along with adjacent and upstream agriculture. Ongoing ditching and grading adjacent to Governors Road E extending into the watercourse potential contributor of sedimentation (Figure 3.104)

Habitat Characteristics	General Flow Regime	Site Location	Site Characteristics	Habitat Description	Substrate Composition	Bank Stability	Instream and Riparian Vegetation	Fish Barriers and Other Disturbances
Lower Jones Creek	Permanent	The Lower Jones Creek monitoring Site was located approximately 450 m downstream of the Park Road ROW, downstream of the confluence between the North and South branches of Jones Creek, as well as the contributing Tributary K and Ravine Tributary, but upstream of the Upper Jones Creek confluence which was outside of the Study Area.	Site length was 40.7 m. Minimum wetted width was 1.7 m and the average wetted width was 2.2 m. The average depth was 164.25 mm and the maximum depth sampled was 3.7 m. Sedimentation was present throughout with evidence of bank instability and downcutting. An abundance of anurans in low velocity areas suggested that this watercourse did not convey strong water velocities through the summer months, potentially due to upstream woody debris jams or stream gradient, and did not support significant groundwater contributions.	This site was delineated by two clear riffles, with the majority of the site between the two crossovers contributed by medium depth runs and a very deep pool at a meander bend. Woody material was abundant, which provided the majority of instream cover as vegetation was absent. Canopy cover from the well-established deciduous forest provided the channel with 100% shade.	Substrate was fairly well sorted at this site (sorting index of 2.77). It consisted of sands, gravels and cobble with the mean point particle of 6.79 mm and the mean maximum particle size being 9.75 mm. Some consolidated clay areas were observed, primarily near the downstream extent. The substrate was ranked and described as “low quality sand bed” by FWIS.	Both banks showed signs of instability with 36% proportionate stable banks. Signs of downcutting was present throughout, along with minimal bank vegetation below the top of bank. Large trees had become uprooted supporting bank instability. Despite this, only one undercut was observed on the right bank (110 mm) while three were observed on the left (160 – 930 mm).	Instream vegetation was non-existent, likely due to substrate composition and variable flow. Riparian vegetation consisted of a well-established mixed forest that provided the site with abundant canopy cover. Bank vegetation was very limited as bank instability did not support rooted vegetation.	Upstream and adjacent agriculture lands likely contribute to nutrient and pollution loading within the site, along with the upstream Park Road ROW. No fish barriers were observed within the site, although a large woody material jam was observed at the upstream extent. Fish were observed throughout the site.
Tributary K	Permanent	The Tributary K monitoring site was located immediately downstream (north) of Powerline Road and Memorial Drive. This tributary contributed to the drainage area of Lower Jones Creek, upstream of the Lower Jones Creek monitoring site.	Site length was 42.1 m. Minimum width was less than 1 m and the average wetted width was 1.25 m. Average depth was 77.63 mm and maximum depth was 185 mm. This site was located near the top of the watercourse, immediately downstream of a large CSP culvert servicing the Powerline Road ROW which was perched and represented a major barrier to potential fish movement. A large plunge pool was observed below the CSP along with failing concrete blocks from historic bank stabilization efforts.	The habitat at this site was well distributed between riffles and runs, with some pool habitat throughout. Instream cover was provided largely by cobbles and roots from the mixed deciduous forest on either bank. Canopy cover, although narrow, was well-established and provided much of the channel with shade.	Substrate was largely consolidated clay with cobbles observed throughout the reach. The mean point particle was 36.39 and the mean maximum particle size was 109.13 mm. Substrate was very poorly sorted (sorting index of 2900.5) and was described by FWIS as “low quality cobble bed”.	Both banks showed signs of instability with a large amount of downcutting below the top of bank but outside of the wetted width. Many of the banks were greater than 2 m in height, with three undercuts observed throughout the reach (85 – 210 mm).	Instream vegetation was non-existent, likely due to the clay bound bed and coarser cobble. Riparian vegetation was narrow, though the well-established deciduous forest up to 10 m beyond the channel provided the watercourse with abundant canopy cover. Beyond the narrow riparian corridor, the watercourse was bound by cropland.	Powerline Road and the upstream residential development, along with adjacent agriculture, could contribute large sources of nutrients and/or pollutants. A fish barrier was also observed at the Powerline Road crossing. Fish were observed downstream of this barrier.
Ravine Tributary	Intermittent	The Ravine Tributary was found immediately north of Powerline Road east of Tributary K and west of Park Road, approximately 1 km upstream of the confluence with Lower Jones Creek. The site was on City-owned property surrounded by a thin riparian corridor and a cropland beyond. A private parcel was located at the upstream end where a private laneway is serviced by a CSP culvert. The site was dry at the time of assessment with no indication of ground water contribution. OSAP could not be performed due to the intermittent flow regime, however habitat will be discussed in the following section.						
Karek Tributary North	Intermittent	The North Karek Tributary was found intercepting the right-of-way for Karek Road, an unserviced laneway with a private parcel at the north end immediately south of Powerline Road. Of the two Karek Tributaries, this channel was closest to Powerline Road. The channel was bordered by a meadow and forest, with cropland to the south. The flow regime however was observed as intermittent and was dry throughout the majority of the season. OSAP could therefore not be performed. Habitat will be discussed in the following section.						

Habitat Characteristics	General Flow Regime	Site Location	Site Characteristics	Habitat Description	Substrate Composition	Bank Stability	Instream and Riparian Vegetation	Fish Barriers and Other Disturbances
Karek Tributary South	Intermittent	The South Karek Tributary was found intercepting the right-of-way for Karek Road, an unserviced laneway with a private parcel at the north end immediately south of Powerline Road. Of the two Karek Tributaries, this channel was furthest from Powerline Road. The channel had a narrower, less naturalized corridor of meadow and forest, with cropland encroaching to the north and south. The flow regime however was observed as intermittent and was dry throughout the majority of the season. OSAP could therefore not be performed. Habitat will be discussed in the following section.						
Silver Creek	Permanent	The Silver Creek monitoring site was consistent with the GRCA monitoring site to align with past fish and benthic community monitoring. The site was located upstream of the pedestrian crossing between Ludlow Crescent and Hackney Ridge.	Site length was 55.8 m. Minimum width was less than 1.3 m and the average wetted width was 3.05 m. Average depth was 160.40 mm and maximum depth was 330 mm. This site was located midway through the watercourse drainage area, approximately 3 km upstream of the discharge to Lower Jones Creek and within a residential development.	This site was contributed largely by slow moving medium depth runs and was historically straightened to accommodate the residential development, pedestrian bridge, storm sewer outfall at the downstream extent, and adjacent park. One transect fell on an island at the upstream extent suggesting aggradation in the system. Instream vegetation was limited with very little instream cover or woody material.	Substrate was largely silt and sand, with some cobbles observed throughout the reach along with some areas of consolidated clay. The mean point particle was 0.06 (silt) and the mean maximum particle size was 18.16 mm. Substrate was fairly well sorted (sorting index of 3.27). The substrate was ranked and described as “low quality sand bed” by FWIS.	Both banks showed signs of instability, with evidence of downcutting throughout the entire reach and only 34% of proportionate stable banks. Many of the banks were greater than 2 m in height supporting large scale downcutting.	Instream vegetation was non-existent throughout the majority of the reach. Riparian vegetation was inconsistent, comprised of meadow and grasses for the majority before transitioning to deciduous forest near the upstream extent. Canopy cover was limited throughout the reach. The riparian corridor itself was limited by the residential area on either bank beyond 30-50 m.	Brantwood Park Road was the nearest upstream ROW with Wayne Gretzky Parkway near the upstream extent of the watercourse, both of which likely contribute large sources of nutrients and/or pollutants. Residential areas and stormwater contributions likely also contribute to the watercourse. No fish barriers were observed with GRCA monitoring data suggesting permanent fish presence throughout. Fish were also observed downstream of the pedestrian bridge and riffle/grade control, in a large pool adjacent to a storm sewer outfall.
Phelps Creek	Intermittent	Phelps Creek was the only watercourse within the Tutela Heights Study Area, with the site located on a private parcel approximately 1 km upstream of Phelps Road. An unserviced laneway provides access to the watercourse, with evidence of ATV use and crossing of the watercourse at the study site. Water was observed in the poorly defined channel in the early months following the spring freshet, through little to no velocity was demonstrated through the heavily vegetated watercourse. The flow regime however was observed as intermittent and was dry throughout the majority of the season, with algae and duckweed observed on the dry streambed, suggesting this watercourse supports a wetland habitat. OSAP could therefore not be performed. Habitat will be discussed in the following section.						



Legend

- Aquatic Station
- N/A
- Dry
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Evaluated Watercourse: Intermittent Habitat
- Evaluated Watercourse: Permanent Coldwater Habitat
- Evaluated Watercourse: Permanent Cool-Warm Water Habitat
- Unevaluated Watercourse

Aquatic Stations

1. Golf Course Tributary (Dry)
2. South Branch
3. North Branch
4. Lower Jones Creek (1)
5. Tributary K
6. Ravine Tributary (Dry)
7. Lower Jones Creek (2) (NA)
8. Kerek Tributary North (Dry)
9. Kerek Tributary South (Dry)
10. Silver Creek (OSAP only)
11. Phelps Creek (Dry)

Figure 3.98

Aquatic Monitoring Locations

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO

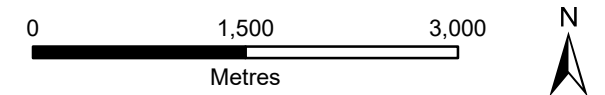




Figure 3.99: Jones Creek South Branch: Downstream Looking Upstream



Figure 3.100: Jones Creek North Branch: Downstream Looking Upstream



Figure 3.101: Lower Jones Creek: Downstream Looking Upstream



Figure 3.102: Tributary K: Downstream Looking Upstream



**Figure 3.103: Silver Creek: Downstream
Looking Upstream**

3.4.3.1.2 Results

Golf Course Tributary

The Golf Course Tributary was dry shortly after the freshet and remained intermittent throughout the monitoring period. This tributary contributes to the South Branch of Jones Creek which contributes to direct fish habitat. No fish were observed within the Golf Course Tributary; however, the watercourse was well-defined at Golf Road and appeared to contribute to downstream catchments. Although no fish were observed within the watercourse, the watercourse should still be considered fish habitat despite the intermittent nature of the watercourse. This watercourse was well-defined and would convey sediment and food supply as well as flow during runoff events, indirectly contributing to the downstream catchments. Further downstream, outside of property permissions, the watercourse could directly contribute to fish habitat and should be confirmed prior to any site alteration or development adjacent to this watercourse.

Jones Creek South Branch

The South Branch of Jones Creek varied greatly from the North Branch discussed below. The South Branch, which spans from upstream of Golf Road to the confluence with the North Branch and the main Lower Jones Creek upstream of Highway 24, includes multiple contributing tributaries that were observed as dry through much of the monitoring period, including the Golf Course Tributary discussed above. The South Branch itself, carried little stream velocity when compared to the North Branch observed immediately downstream of the monitoring site. That said, the South Branch maintained permanent flow throughout the monitoring period, providing direct habitat to a variety of fish and anurans. Cover was provided largely by woody material and rooted wetland vegetation at the upstream extent, as substrate was entirely contributed by silt and sand, suggesting aggradation within the system. Banks did not demonstrate active erosion but were not stabilized by vegetation or larger substrate, indicating that larger flows may contribute to sediment aggradation. Canopy cover was abundant at the monitoring site, with both banks dominated by well-established deciduous forest and understory. Further upstream where land use is largely agriculture, the stream received little to no shading and is subject to solar warming. No barriers to fish migration were observed.

Jones Creek North Branch

The North Branch of Jones Creek monitoring site was downstream of the Governors Road E ROW and upstream of confluence with the North Branch and the main Lower Jones Creek upstream of Highway 24. No noticeable contributing features were upstream of the monitoring site. This watercourse is a largely intact coldwater system, with active habitat for coldwater species such as Brook trout, which were observed upstream of the monitoring site at the Governors Road E ROW. Watercress was observed throughout the monitoring site, with continuous water temperatures supporting the coldwater thermal regime, despite a lack of canopy cover or robust riparian coverage on either bank. This suggests an abundance of groundwater contribution within the North Branch. In-stream cover was abundant, provided by rooted macrophytes and overhanging grasses. Substrate was well sorted, consisting of sand likely allowing for greater groundwater contributions. Banks were stable, with meadow species providing stabilization and flow dissipation. Little evidence of erosion or flow fluctuations were observed through the site. Despite

the encroaching agriculture on either bank and a lack of established canopy cover, this watercourse appeared to provide high quality, coldwater habitat to a variety of fish species. Ongoing ditch clearance and grading was observed adjacent to Governors Road E, extending into the watercourse during a site visit on October 19, 2022 (**Figure 3.104**).



Figure 3.104: Ditching and Sediment Fencing Adjacent to Watercourse

Lower Jones Creek

The Lower Jones Creek was located immediately downstream of Park Road and was selected to provide a holistic view of the Study Area downstream of contributing features within the Study Area, such as the Jones Creek North and South Branches, Tributary K, Ravine Tributary, along with all other drainage features in the proposed development area, but upstream of catchments outside of the Study Area, such as Upper Jones Creek. This portion of the watercourse was representative of an impacted stream, with signs of sediment aggradation, bank instability and downcutting. Riparian vegetation below the top of bank was absent, contributing to bank instability. Instream vegetation was also absent, with instream cover provided by woody material and canopy cover provided by the established deciduous forest outside of the channel width. Substrate was well-sorted but consisting of low-quality sand and silt, with some areas of consolidated clay near the downstream extent. This habitat was consistent with other observations along the Lower Jones Creek throughout the Study Area, and represents a departure from the North Branch discussed above as more agriculturally bound features contribute the catchment.

Tributary K

Tributary K was located upstream of the Park Road ROW and the Lower Jones Creek monitoring site. This watercourse represents a smaller catchment in the Study Area but retained permanent flow throughout the study period. Instream habitat was well-distributed between pools, riffles and runs, with one large pool observed upstream of the monitoring site immediately downstream of the Powerline Road ROW and the large, perched CSP culvert that services it. Failed and failing bank stabilization material was observed within the pool. Throughout the naturalized portion of the watercourse, evidence of downcutting was abundant as many of the banks were in

exceedance of 2 m and therefore outside of the width/depth ratio for OSAP. Substrate was very poorly sorted, with areas of consolidated clay along runs and outside bends, depositions of sand and cobbles in pools, and larger cobbles consisting of angular stones in riffles. Instream vegetation was non-existent and riparian vegetation was limited to the narrow corridor bound by agricultural land on either bank. The upstream perched culvert was the only barrier to fish movement observed, despite a relatively steep stream gradient and multiple knickpoints, as fish were sampled throughout the site. Upstream of the ROW, land use is largely residential and parkland where the baseflow appears to originate from.

Ravine Tributary

The Ravine Tributary, approximately 500 m east of Tributary K along Powerline Road, was observed to run dry shortly after the freshet early in the year and remain dry for the monitoring period. Any flow is likely conveyed along the Powerline Road ROW or from adjacent agricultural land during spring melt and runoff events. Habitat immediately downstream of Powerline Road represented a shallow, well-vegetated swale that likely doesn't experience high flow returns, while habitat further downstream showed signs of downcutting and erosion, suggesting greater capacity for high return events as the catchment proceeded to Lower Jones Creek approximately 1 km downstream. Riparian vegetation was much greater than other agriculturally bound catchments in the Study Area, with 100% of the stream shaded by mixed deciduous canopy cover. Although no fish were observed within the watercourse, the watercourse should still be considered habitat despite its intermittent nature. This watercourse was well-defined and would convey sediment and food supply as well as flow during runoff events, indirectly contributing to the downstream catchments. Further downstream, outside of property permissions, the watercourse could directly contribute to fish habitat and should be confirmed prior to any land use development adjacent to this watercourse.

Karek Tributaries

The Karek North and South Tributaries were observed near the eastern extents of the Study Area, draining from west to east into Fairchild Creek south of Powerline Road. The North Tributary drained the agricultural land to the north of Powerline Road, while the South Tributary drained the residential areas to the north eastern urban boundary. Both tributaries flowed through the agricultural land south of Powerline Road before emptying into Fairchild Creek. Both tributaries were observed to convey flow following the spring freshet but remained dry for the entirety of the monitoring period. Both channels were defined largely by vegetation, as agricultural practices left the riparian corridor naturalized to meadow species and scrubland immediately adjacent to the watercourses. Little shading was provided to both watercourses outside of the overhanging grasses, and, since the watercourses were dry at the time of assessments, substrate composition and instream vegetation was unobservable as the site was dry and watercourse delineation was therefore not repeatable as OSAP intends. Although no fish were observed within the watercourses, both the north and south watercourse should still be considered habitat despite the intermittent nature.

Silver Creek

The Silver Creek monitoring site was selected to align with GRCA monitoring, in order for background fish and benthic communities to be used for this study. This site was located

immediately upstream of the pedestrian bridge between Ludlow Crescent to the north and Hackney Ridge to the south. The site maintained flow for the entirety of the monitoring period with baseflow originating from two features upstream of Brantwood Park and Wayne Gretzky Parkway and terminating at Fairchild Creek downstream of the railway crossing. The monitoring site was bound by parkland on either bank up to 50 m and residential areas beyond. Throughout the naturalized portion of the watercourse, upstream of the pedestrian bridge, evidence of downcutting was abundant as many of the banks were in exceedance of 2 m and therefore outside of the width/depth ratio for OSAP. It appeared as though the monitoring site had been subject to historic straightening, with little instream habitat or morphological variation. Depth and width were uniform throughout, with well-sorted, poor quality sand substrate contributing to the streambed. No instream vegetation was observed, with some overhanging grasses contributing to cover near the downstream extent, and deciduous forest contributing to canopy cover upstream of the park. Downstream of the pedestrian bridge, a large sewer outfall was observed flanked by armouring and boulders for bank stabilization. A large pool was observed at the outfall with abundant fish present. No fish were observed above the pedestrian bridge or within the monitoring reach.

Phelps Creek

The Phelps Creek monitoring site was the only aquatic monitoring site in the Tutela Heights Study Area. With the watercourse flowing west to east from Mount Pleasant Road to Phelps Road and conveying flow from largely agricultural land, the monitoring site and watercourse as a whole was observed with water only after the spring freshet. A number of contributing features were mapped upstream of the monitoring site at 191 Phelps Road, however none maintained consistent flow after the freshet. The monitoring site itself was found at the end of an ATV trail, with evidence of active crossing of the watercourse itself. Since the watercourses were dry at the time of assessments, substrate composition and instream vegetation were unobservable as the site was dry and watercourse delineation was therefore not repeatable as OSAP intends. However, vegetation surrounding the watercourse was largely wetland vegetation, with Lesser duckweed left after the water levels had receded. The watercourse itself was poorly defined, with silt contributing to the streambed, suggesting this monitoring site is more consistent with an intermittent wetland feature contributed by multiple upstream drainage features. Access was limited to this narrow piece of the watercourse, but habitat remained consistent with that observed downstream at the Phelps Road ROW. Although no fish were observed within the watercourse, the watercourse should still be considered habitat despite the intermittent nature as the watercourse contributes to the Grand River approximately 2.5 km downstream.

3.4.3.1.3 Conclusions

Fish habitat, as defined in the Fisheries Act and carried forward to the Provincial Policy Statement (Government of Ontario, 2020), refers to, “spawning grounds and any other areas, including nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes”. Aquatic habitat can provide insight into the extent at which watercourses and features contribute to fish habitat.

Within the Study Area(s), a variety of aquatic habitat was observed, varying in functionality throughout the reaches. The highest quality habitat was observed in the North Branch of Jones Creek with evidence of groundwater contributions and permanent coldwater habitat, with the lowest quality and fragmented habitat was observed in Tributary K, outside of those that demonstrated dry conditions throughout the monitoring year. As discussed in detail within **Section 3.4.3.3**, this is supported by the lowest abundance and diversity of fish sampled throughout the Study Area. The monitoring sites that were observed to run dry through the monitoring year, located within smaller, contributing tributaries were observed with limited function as aquatic habitat, though all sites showed potential to provide important contributing habitat during the freshet when water levels are higher and intermittent flow is present.

In general, aquatic habitat was observed throughout the Study Area as both direct and contributing fish habitat. This is further supported in the following sections. Watercourses throughout the Study Area should be regarded as key features within the NHS and protected under the municipal OP.

3.4.3.2 Benthic Macroinvertebrate Communities

Benthic macroinvertebrates are commonly used to assess water quality, health, and integrity of aquatic ecosystems and are generally dependent on the quantity and quality of available aquatic habitat. Benthic macroinvertebrates also represent important food sources for fish which helps identify direct and contributing fish habitat, a key feature within the NHS. They are suitable for study for many reasons, including:

- a) Benthic invertebrates are highly sensitive to environmental changes which make them excellent indicators of water quality;
- b) Benthic invertebrates are abundant in nearly all watercourses, living on or in the substrate;
- c) Benthic invertebrates can be easily and inexpensively collected and easily quantified;
- d) Benthic invertebrates are easily identified; and
- e) They have restricted mobility and specific habitat preferences, and therefore cannot simply move away from environmental stresses occurring at a site. (Griffiths, 1999)

3.4.3.2.1 Methodology

Due to dry site conditions as discussed above in **Section 3.4.3.1**, benthic community surveys were only conducted in the following watercourses: Jones Creek South Branch; Jones Creek North Branch; Lower Jones Creek; and Tributary K. Watercourses where benthic sampling had been conducted in the past, such as Silver Creek, were not sampled but will be discussed hereafter.

Sites were set up using Section 1: Modules 1-3 (Site Identification and Site Features) of the OSAP. Sampling was conducted in accordance with OSAP, using the transect traveling kick and sweep method (Section 2: Module 3). This method involves walking from one bank to the other for three minutes while kicking the stream bed and holding a 500 µm D-net downstream to

collect dislodged organisms. After three minutes the organisms are emptied from the net, placed in a jar and preserved in the field using isopropyl alcohol. This collection is completed at three sampling locations within a sampling reach (riffle-pool-riffle).

Samples were submitted to an accredited laboratory for subsampling using the teaspoon method until at least 100 specimens were found. Specimens from each sample are then identified to Family level. Specimens are currently being analyzed by the laboratory and therefore cannot be reported on in this phase. Methodology is provided hereafter as well as habitat results from the field exercises. The OSAP field sheets are presented in **Appendix H**.

To analyze samples, water quality can be assessed using multiple indices, or metrics, which are easy to calculate. Multiple indices could relate to specific impacts, making it necessary to use many metrics to detect impacts.

In addition to species richness (e.g., the total number of taxa) and composition metrics (e.g., % Diptera), macroinvertebrates can also be classified according to:

- functional feeding groups (e.g., % Collector-Filterers, % Scrapers, % Shredders)
- habit/behavior characteristics (e.g., % Clingers)

Functional feeding groups provide an indication of food web relationships. Habitat and behavior characteristics indicate the functionality of the organism (e.g., the way it moves or searches for food) (Barbour, Gerritsen, Snyder, & Stribling, 1999).

The samples collected as part of this study are to be analyzed and compared qualitatively using a multimetric approach to summarize the condition of the watercourse, using the following indices:

Taxa Richness:	Indicates diversity of taxa. The number of taxa increases with habitat quality and water quality. >26 Non-impacted 19-26 Slightly impacted 11-18 Moderately impacted; and, 0-10 Severely impacted
% EPT:	Percent composition of Ephemeroptera, Plecoptera and Trichoptera (EPT). Reflects the composition of the benthic community within Families that are considered to be sensitive to water quality. >10 Non-impacted 5-10 Slightly impacted 2-5 Moderately impacted; and, 0-2 Severely impacted
% Oligochaeta:	Percent composition by aquatic worms (tolerant organisms).

- % Diptera:** The percent composition by larvae of true flies.
- % Chironomidae:** The percent composition by larval midges.
- % Collector-filterer:** The percent composition by detritivores (feed on decomposing fine particulate organic matter) which filter feed or are suspension feeders.
- % Collector-Gatherer:** The percent composition by detritivores which gather food or are deposit feeders.
- % Predator:** The percent composition of organisms that feed on living animal tissue (not including parasitic organisms) by engulfing or piercing (Merritt et al, 2008).
- % Scraper:** The percent composition by organisms that feed on periphyton by grazing and scraping mineral and organic surfaces (Merritt et al, 2008).
- % Shredder:** The percent composition by organisms that feed on living vascular aquatic plant tissue by chewing, detritivores that feed on decomposing vascular plant tissue (coarse particulate organic matter) by chewing, and/or organisms that feed on wood by gouging and excavating (Merritt et al, 2008).
- % Clinger:** The percent composition by organisms having fixed retreats or adaptations for attachment to surfaces in flowing water (Barbour et al, 1999).

Shannon’s Diversity Index:

Shannon’s Diversity Index is calculated using the following formula:

$$H' = - \sum (p_i)(\ln p_i)$$

Where p_i is the proportion of individuals in the “ith” taxon of the community. H' increases as the number and distribution of taxa (diversity) in a sample increase.

Hilsenhoff’s Family Biotic Index:

The Hilsenhoff’s Family Biotic Index (FBI) uses the pollution tolerances of organisms to determine the level of stream impairment. Each organism is assigned a tolerance value of 0 to 10, with a value of 0 indicating that the organism has a very low tolerance to pollution and a value of 10 indicating that the organism has a very high tolerance to pollution. The index is calculated using the following formula:

$$FBI = \sum(x_i)(t_i) / n$$

Where x_i is the number of organisms in the i^{th} taxon, t_i is the tolerance value of the i^{th} taxon, and n is the total number of organisms in the sample.

Interpretation of the FBI Value is shown in **Table 3.29**.

Table 3.29: FBI Value Interpretation

Family Biotic Index	Water Quality	Degree of Organic Pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very Good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probably
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly Poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very Poor	Severe organic pollution likely

Percent Model Affinity:

Percent Model Affinity (PMA) compares the sampled community to an ‘ideal’ community from a comparable reference site, and based on the difference between these two communities, infers statements about the overall health of the sampled community. The original theory was developed by sampling streams in New York State and developing a model of expected community composition of seven major groups: Oligochaeta, Ephemeroptera, Plecoptera, Coleoptera, Trichoptera, Chironomidae, and Other (usually composed of Simuliidae, Gammaridae, Asellidae, Physidae and Empididae).

The percent similarity of the sample community is then compared to the ideal community using the following formula:

$$PSC = 100 - 0.5 \sum |a - b|$$

In the above, PSC is the Percent Similarity of the Community, a is the percent of individuals of a taxon in Sample A (model value), b is the percent of individuals of a taxon in Sample B.

A PSC equal to 100% means that the sampled community has exactly the same community composition as the ideal community. Shifts in dominance of less tolerant to more tolerant groups decrease the PSC in order to detect the existence of impaired habitats.

Dr. David Barton from the University of Waterloo modified the model for an urban catchment in Southern Ontario. Based on his research, he concluded that in this area the organism compositions, of a total of 99 organisms, should ideally be 26 Ephemeroptera,

four Plecoptera, 10 Trichoptera, six Coleoptera, 36 Chironomidae, six Oligochaeta, and 11 other organisms. He considered a stream with a PSC value less than 39.1 to be impaired.

3.4.3.2.2 Results

The following are the results of the habitat assessment, benthic invertebrate community, and associated metrics. **Table 3.30** provides a summary of the aquatic habitat conditions of the five (5) sites sampled, including the average wetted width, average wetted depth, average hydraulic head, average bankfull width, channel substrate, and descriptions of instream and riparian habitats. Sample locations are displayed in **Figure 3.98**.

Table 3.30: Benthic Invertebrate Habitat Summary

Site	Average Wetted Width (m)	Average Max Depth (mm)	Average Hydraulic Head (mm)	Substrate	Instream Habitat	Riparian Habitat	Other Site Features
Golf Course Tributary	N/A - Dry						
Jones Creek South Branch	2.50	191.67	0	Silt and Sand	Vegetation and algae absent from this site. Cover largely contributed by woody material with little detritus. Abundant canopy cover from overhanging trees and deciduous forest.	Left bank and right bank riparian vegetation consisted of forest with cropland beyond 100 m.	Cropland both upstream and adjacent to the site provided a possible source of contamination or nutrients. Multiple contributing features were observed dry at the time of sampling. The Golf Road ROW is within the upstream catchment.
Jones Creek North Branch	2.67	326.67	6.67	Largely sand with some silt, clay and gravel	Abundant instream vegetation consisting of emergent and submergent vegetation, including watercress and other macrophytes. Algae was absent. Canopy cover not present with overhanging grasses providing cover at banks.	Right and left bank consisted of meadow up to 10 m with cropland extending beyond.	High-quality, groundwater fed coldwater stream with little evidence of erosion. Governors Road E ROW in upstream catchment with sediment aggradation contributed by adjacent and upstream agriculture.
Lower Jones Creek	2.00	450.00	8.33	Clay and sand with silt	Instream cover was limited, provided entirely by woody material. Canopy cover was abundant, provided by well-established deciduous forest.	Right and left bank consisted of well-established forest up to 100 m, with forest continuing beyond on the right bank scrubland on the left.	Well defined channel with soft unvegetated banks, below the top of bank. Park Road crossing and agriculture upstream of the site was a possible source of contamination or nutrients.
Tributary K	1.17	123.33	3.33	Consolidated clay, cobble, silt and sand	Aquatic vegetation was non-existent throughout the site. Woody material and detritus were also limited. Large, overhanging trees provide canopy cover from the narrow riparian corridor.	Right and left bank consisted of scrubland up to 10 m with cropland extending beyond.	Upstream baseflow contributed by features adjacent to residential area provided a possible source of nutrients or contamination. Perched culvert downstream at Powerline Road crossing acted as barrier.
Ravine Tributary	N/A - Dry						
Karek Tributary North	N/A - Dry						
Karek Tributary South	N/A - Dry						
Silver Creek	N/A – GRCA Background Communities Used for Analysis. Habitat discussed within Section 3.4.3.1						
Phelps Creek	N/A - Dry						

Benthic Invertebrate Communities

The metrics calculated for the organisms collected at each site are summarized in **Table 3.31**, below; detailed information about each sampling site follows. Given that it is difficult to determine specific thresholds for the number, or percentage, of organisms for each metric that should be found in an unimpaired stream sample, sampled sites were compared to each other as well as average values for the entire study area.

There are known differences in the way the indices respond to human disturbance/habitat degradation. For Taxa Richness, % EPT, % Scraper, % Shredder, % Clinger, % Omnivore and the Shannon Index, a larger value implies a healthy biological community and low values imply reduced health (Barbour, Gerritsen, Snyder, & Stribling, 1999) (Jones, Somers, Craig, & Reynoldson, 2007). For % Oligochaeta, % Chironomidae, % Isopoda and FBI, a lower value implies a healthier community (Barbour, Gerritsen, Snyder, & Stribling, 1999) (Jones, Somers, Craig, & Reynoldson, 2007). However, there is no “target value” since there are no reference sites in this study. We can only determine which sites have higher or lower values.

In the case of % Collector-Filterer, % Collector-Gatherer, % Predator and % Diptera, critical values lie at both extremes. Therefore, these metrics were not used as an indication of better water quality between sites. However, they are useful to note habitat differences and changes in habitat quality over time, which suggests a change in water quality.

Table 3.31: Benthic Invertebrate Monitoring Results

	Trib K				Lower Jones				North Branch				South Branch			
	Rep 1 (DS)	Rep 2	Rep 3 (US)		Rep 1 (DS)	Rep 2	Rep 3 (US)		Rep 1 (DS)	Rep 2	Rep 3 (US)		Rep 1 (DS)	Rep 2	Rep 3 (US)	
Total Number of Organisms	64	71	52		478	500	153	1131	984	1888	506		1330	181	617	
Taxa Richness	8	12	8		10	9	10		10	12	12		13	5	6	
% Oligochaeta	0.00	18.31	3.85		10.88	38.40	13.07		16.26	50.85	34.78		16.24	33.15	45.38	26.13
% Diptera	50.00	25.35	65.38	44.92	64.44	26.00	49.67	45.45	46.34	17.80	31.62		60.75	44.20	35.01	
% Chironomidae	40.63	22.54	28.85		59.41	24.40	47.06	42.26	42.28	17.80	28.46		60.45	44.20	35.01	
% Isopoda	42.19	29.58	21.15		5.86	14.40	10.46	10.26	13.82	9.32	5.14		2.71	0.00	0.00	
% EPT	4.69	2.82	1.92	3.21	6.69	0.00	7.84		13.01	7.63	3.16		0.30	0.00	0.00	
% F-C	9.38	2.82	36.54		5.86	0.00	2.61	2.83	4.88	2.54	3.16		0.00	0.00	0.00	
% G-C	87.50	73.24	55.77		84.94	95.20	92.16		86.99	88.14	81.03	86.74	95.49	82.32	89.63	
% Pred	42.19	26.76	30.77	33.16	68.62	27.60	52.29		43.90	22.03	34.78		64.06	57.46	36.30	
% Scr	3.13	1.41	1.92		5.02	14.40	10.46		3.25	4.24	7.91	4.50	6.62	0.00	1.30	
% Shr	0.00	0.00	0.00		5.02	14.40	10.46		0.00	2.54	0.00	1.42	6.32	0.00	1.30	
% Clinger	12.50	4.23	38.46		11.72	14.40	18.30	13.79	20.33	12.71	12.65	14.92	7.52	0.00	1.30	
Shannon-Weiner Diversity	0.56	0.75	0.66		0.60	0.70	0.68		0.67	0.65	0.60	0.70	0.46	0.49	0.46	
FBI	6.69	6.03	6.00		6.43	7.41	6.31	6.85	6.62	7.98	7.81		6.75	7.43	7.43	
PMA																

Indicates best water quality
 Indicates second best water quality
 Indicates worst water quality
 Within PMA Criteria (Severely Impacted: <35)
 Within PMA Criteria (Moderately Impacted: 35 - 49)
 Within PMA Criteria (Slightly Impacted: 50-64)

3.4.3.2.3 Conclusions

Overall, the benthic invertebrate sites in the study area indicated “Fairly Poor” to “Poor” water quality. Based on PMA values, all sites demonstrated slight impacts. Communities varied significantly across the four monitoring sites, with indices largely reflective of the habitat present. Tributary K, Lower Jones Creek and the North Branch sites demonstrated benthic communities that represented the highest valued aquatic habitat and highest water quality, with multiple indices suggesting a variety of contributions to the overall system.

Tributary K, Lower Jones Creek and the North Branch sites, upstream of the majority of existing landuse development, observed the highest taxa richness (15) which represents moderately impacted habitat. Tributary K also demonstrated the highest Shannon-Weiner Diversity Index indicating this site had the most diverse benthic community, and the lowest FBI Value (6.25). This value still represents “Fairly Poor” water quality with “Substantial pollution likely”.

Lower Jones Creek, sharing the highest taxa richness with Tributary K and the North Branch, demonstrated the highest PMA Value, which still represents a slightly impacted watercourse. This site represented the only site which did not have the lowest indicating parameter.

The North Branch, which fell the furthest upstream of the current development limit, in the only coldwater habitat observed within the study area, shared the highest taxa richness with Tributary K and the Lower Jones stations, as well as the highest observed abundance. This site also demonstrated the lowest percentage of pollutant and disturbance tolerant Chironomidae (26.52%), the second lowest percentage of tolerant Isopoda (10.01%), and the highest percentage of intolerant EPT (8.53%). Despite having the highest percent of EPT, which indicates the greatest food source for trout populations and supports observations of Brook trout in this habitat, the value demonstrated here still indicates severely impacted habitat. The feature fell within an agriculture area, limiting riparian cover and canopy cover, which likely limited the aquatic habitat value. This limiting factor, along with sedimentation contributed by upstream sources, likely impacted the overall habitat within this feature and potentially reduced the positive impact of the multiple, contributing groundwater indicators which typically contribute to the health of the benthic community and the overall health of the headwater stream. This feature and system as a whole represented a system which could benefit from riparian restoration and enhanced buffers, creating a valuable coldwater contribution to the study area, and should be protected as such.

Contrary to the generally high water aquatic habitat quality observed within the North Branch, the South Branch which joins with the North Branch to form the Lower Jones Creek demonstrated poor habitat and benthic indicators which support these habitat observations. This station observed a benthic community with the lowest diversity, both in taxa richness and in Shannon-Weiner Diversity Index, indicating moderately impacted water quality. This site also had the lowest percentage of EPT (0.19%) indicating severely impacted water quality and habitat. Moreover, this site demonstrated the highest percentage pollutant and disturbance tolerant Chironomidae (51.69%).

Measures of biodiversity can be influenced by factors outside of water quality. For a better understanding of water quality using benthic invertebrates as indicators, sampling would need to be conducted each spring over multiple years to allow comparison between sites, over time. Establishing a reference site for the study area would also be beneficial for future monitoring.

As discussed above, benthic macroinvertebrates play an important role in the overall health of a subwatershed. They are a valuable aquatic resource for many reasons, including the representation of an important food source for fish. This helps determine both direct and contributing fish habitat, a key feature in the NHS as defined by the municipal OP. All sites displayed benthic macroinvertebrate communities that provide an important food source for fish and can therefore support fish directly or indirectly. These habitats should therefore be considered important fish habitat within the NHS. It is recommended that fish habitat be evaluated through site-specific studies in order to determine if habitat directly supports fish.

3.4.3.3 Fish Communities

Fish are effective biological indicators. They occur in a wide variety of habitats which are widely studied. Ontario fishes exhibit a wide range of tolerances to many disturbances and are easy to identify to species level. The following section focuses on the fish communities found within the North Brantford and Tutela Heights Study Area(s).

Due to dry site conditions as discussed above in **Section 3.4.3.1**, fish community surveys were only conducted in the following watercourses: Jones Creek South Branch; Jones Creek North Branch; Lower Jones Creek, and; Tributary K. Watercourses where fish sampling had been conducted in the past, such as Silver Creek, were not sampled but will be discussed hereafter. Fish sampling was conducted in accordance with OSAP Version 10, Section 3: Module 1: Fish Community Sampling using Screening, Standard, and Multiple Pass Electrofishing Techniques (Stanfield, 2017). Screening surveys were conducted throughout July 2022 by qualified Aquafor Beech Limited biologists.

3.4.3.3.1 Methodology

Fish communities within the Study Area watercourses were surveyed in accordance with the OSAP fish community sampling procedures (Section 3: Module 1). As discussed above, dry site conditions within Tooley Creek prevented staff from conducting electrofishing surveys within the Study Area. Surveys were conducted using a Halltech HT2000 Backpack Electrofisher and involved a standard single pass sampling technique with one netter. OSAP field sheets are presented in **Appendix G**.

3.4.3.3.2 Results

Fish community surveys were completed at a total of four sites, with GRCA monitoring results used to supplement for Silver Creek. A summary of the species found at each site is provided in **Table 3.32**.

Table 3.32: Fish Community Survey Results

Scientific Name	Common Name	Count										
		Golf Course Tributary	Jones Creek South Branch	Jones Creek North Branch	Lower Jones Creek	Tributary K	Ravine Tributary	Karek Tributary South	Karek Tributary North	Silver Creek*	Phelps Creek	Total
<i>Rhinichthys atratulus</i>	Blacknose Dace	Dry	0	12	3	7				21		43
<i>Culaea inconstans</i>	Brook Stickleback		14	0	1	0				0		15
<i>Semotilus atromaculatus</i>	Creek Chub		18	4	11	1	Dry	Dry	Dry	38	Dry	74
<i>Etheostoma nigrum</i>	Johnny Darter		6	3	8	0				0		17
<i>Notropis sp.</i>	Notropis sp.		2	0	0	0				0		2
<i>Catostomus commersonii</i>	White Sucker		4	2	4	0				0		10
Total Abundance		0	44	21	27	8	0	0	0	59	0	159
Species Richness		0	5	4	5	2	0	0	0	2	0	6

* Fish community results provided by the GRCA (GRCA, 2019)

The survey sites on the following sites were unsamplable during the field season due to little to no flow: Golf Course Tributary; Ravine Tributary; Karek North and South Tributaries; and Phelps Creek. However, the watercourses undoubtedly provide indirect fish habitat function to downstream systems. Monitoring results provided by the GRCA were used to supplement for the Silver Creek monitoring site. Results were collected following the same monitoring protocols and were collected in 2019.

A total number of five species representing six genera were recorded across the Study Area. The six species sampled represent a community of a cool-warmwater thermal regime that is intermediately tolerant to tolerant of disturbance. Despite the coldwater thermal regime classification and supporting temperature data for the North Branch of Jones Creek, no coldwater species were collected during the sampling event. Brook Trout (*Salvelinus fontinalis*) was observed upstream of the monitoring site by Aquafor Beech staff on November 1, 2022. Creek Chub (*Semotilus atromaculatus*), a coolwater species that is intermediately tolerant of disturbance, was the most widely distributed, found in all five sites, followed by Blacknose Dace (*Rhinichthys atratulus*), a tolerant coolwater species, found in four of the five sites. Johnny Darter (*Etheostoma nigrum*) and White Sucker (*Catostomus commersonii*) were both observed at three of

the five sites while Brook Stickleback (*Culaea inconstans*) was observed at two sites and an unidentifiable *Notropis* species was recorded at only one site. With five species recorded and the highest number of overall taxa, the South Branch of Jones Creek was the most diverse site, followed by Lower Jones Creek. All species collected are considered common and widespread in Ontario and fall within the Spring Spawning Species In-Water Work Timing Window Guidelines provided by the MNRF (MNRF, 2013).

3.4.3.4 Aquatic Resources Conclusions

Figure 3.105 displays the aquatic resources as identified during the study and as summarized hereafter. Diagnostic indicators, as well as species records and incidental observations, suggest that the North Branch of Jones Creek and the other stations differ significantly in form and function, with the North Branch demonstrating high quality, coldwater habitat with evidence of groundwater contribution, as supported by continuous temperature monitoring and thermal regime analysis. Habitat within the South Branch, as well as the Lower Jones Creek demonstrate urban and agricultural-adaptive watercourse with evidence of degradation, sediment accumulation and a more common cool-warmwater thermal regime. Silver Creek also demonstrated similar conditions, though with more stable banks and less evidence of siltation and sediment aggradation as observed in the Jones Creek system. Tributary K, a contributing feature to the Lower Jones Creek demonstrated high erosion potential with evidence of downcutting and exposed clay material. Many contributing features of the Jones Creek system, such as the Golf Course Tributary and Ravine Tributary, and features of the Fairchild Creek system outside of the Study Area such as the Karek North and South Tributaries, did not accommodate continuous flow and therefore could not be evaluated following accepted assessment protocols.

Phelp's Creek, the only watercourse in the Tutela Heights subject area and direct contributor to the Grand River was observed to run dry shortly after the spring freshet, with water levels only responding to high runoff events for short durations. Habitat observed here was largely representative of intermittent wetland habitat with little definition to the watercourse, low stream velocities and very little substrate sorting. No fish were observed within the watercourse and as it was dry through the majority of the study, benthics could not be collected.

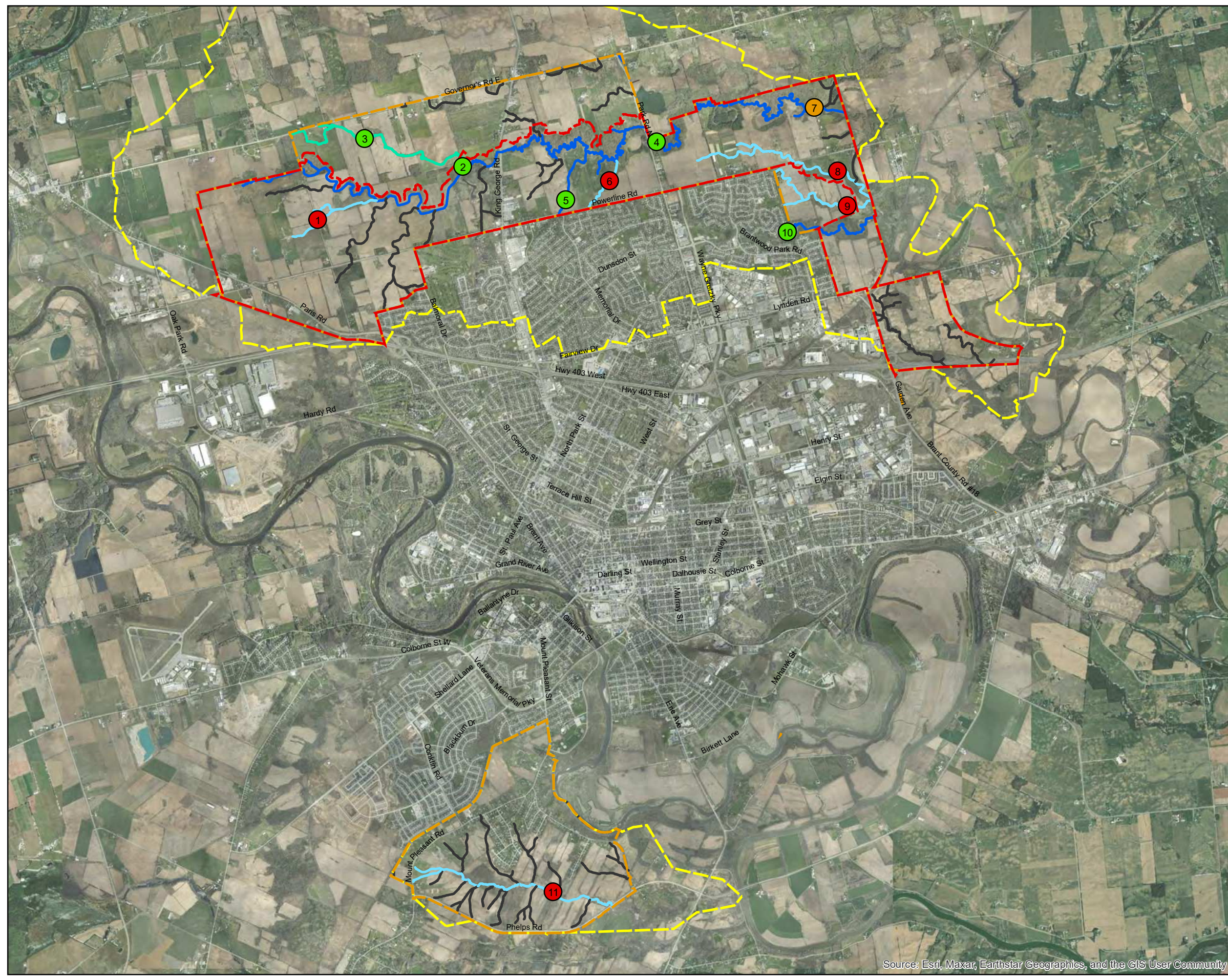
Despite widely varying habitat between the North Branch and the Lower Jones Creek and its contributing features, fish community results were consistent across all three sites, with only an incidental observation of Brook Trout at the Governor's Road E ROW, as well as conversations with adjacent landowners, suggesting that the North Branch supports sensitive, coldwater fish species. Tributary K had the lowest diversity and abundance of fish, suggesting that the habitat is potentially fragmented from the downstream Lower Jones Creek, potentially due to the steep stream gradient and ongoing erosion in the system.

Dry watercourses within the Study Area, including Phelp's Creek in the Tutela Heights area and the Golf Course Tributary, Ravine Tributary, and Karek North and South Tributaries in the North area, could not be evaluated in a manner consistent with other features. However, key hydrologic features and fish habitat as key natural heritage features or key hydrologic features also vary in form and function. Fish Habitat, as defined under the Provincial Policy Statement (2020) and the *Fisheries Act* (2020), defines Fish Habitat as, "spawning grounds and any other areas, including

nursery, rearing, food supply, and migration areas on which fish depend directly or indirectly in order to carry out their life processes” (Government of Ontario, 2020). While these features did not support fish at the time of assessment, these features clearly convey flow in the early season and during high runoff events, suggesting that these features provide habitat for which fish depend directly or indirectly in order to carry out their life processes at any given time of the year.

Benthic community analyses suggested that all watercourses and the contributing aquatic habitat are slightly impacted to various degrees. However, all sites demonstrated an abundant food source for fish communities, representing *Fish Habitat* as defined by the *Fisheries Act*, and should be protected as such under the OP.

In general, the fish communities found within the Study Area subwatersheds are common to abundant, intermediately tolerant to tolerant species that demonstrate a cool-warmwater thermal regime, outside of the North Branch of Jones Creek which supports coldwater habitat. Fish were observed throughout the Study Area, indicating that watercourses within both subwatersheds provide both direct *Fish Habitat* in the main channels and contributing *Fish Habitat* in intermittent watercourses, and should be protected as such under the OP.



Legend

- Aquatic Station
- N/A
- Dry
- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Evaluated Watercourse: Intermittent Habitat
- Evaluated Watercourse: Permanent Coldwater Habitat
- Evaluated Watercourse: Permanent Cool-Warm Water Habitat
- Unevaluated Watercourse

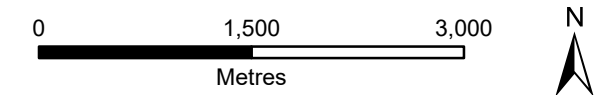
Aquatic Stations

1. Golf Course Tributary (Dry)
2. South Branch
3. North Branch
4. Lower Jones Creek (1)
5. Tributary K
6. Ravine Tributary (Dry)
7. Lower Jones Creek (2) (NA)
8. Kerek Tributary North (Dry)
9. Kerek Tributary South (Dry)
10. Silver Creek (OSAP only)
11. Phelps Creek (Dry)

Figure 3.105

Aquatic Resources Summary

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



3.4.4 Terrestrial Resources

Terrestrial resources in the Study Area include the flora and fauna communities that are present as well as the habitats that support them. Habitat suitability for various species, including Species at Risk (SAR), is generally determined based on the vegetation communities that are present, as there can be specific correlations between certain community types (which often develop only under certain physiographic conditions) and the species that they are able to support. The surveys described in the following sections (vegetation community assessment, botanical inventory, breeding bird survey, and amphibian calling surveys) and their results aid in the delineation of the Key Natural Heritage Features to be protected by municipal policy.

3.4.4.1 Vegetation Community Classification

Vegetation community delineation and assessment focuses on identifying individual habitat features such as forests, wetlands, and meadows, and paints a picture of how these features fit together at the landscape level. Mapping of vegetation communities is an important preliminary step in the delineation of natural heritage features, as it informs our interpretation of habitat patches and mosaics that may be critical to the survival of particular plant or wildlife species in the local context.

The formation of vegetation communities is highly dependent on physical site characteristics such as level of moisture, soil texture, and slope, and so the community types present can also be used to draw conclusions about physical site aspects, such as flooding potential.

3.4.4.1.1 Methodology

Vegetation community assessments were conducted in 2022 on lands where access was permitted and scoped further to target areas where there was conflicting background information. Where access was not permitted, limited site review was conducted from adjacent lands and through aerial photo interpretation. Where information on lands without site access permission was available through other sources (e.g., the 2020 Comprehensive EIS completed Plan B Natural Heritage), that information was incorporated into the current study and refined to the extent possible based on an understanding of the general habitats present elsewhere in the Study Area.

Survey dates are provided above in **Table 3.26**. Vegetation communities were assessed according to Ecological Land Classification (ELC) for Southern Ontario, First Approximation (Lee et al., 1998), a standardized methodology developed by the MNRF, and supplemented with community types from the Draft 2008 Southern Ontario ELC where no applicable community type was available to accurately represent the attributes of the feature. ELC polygons were evaluated to the community type level wherever possible, although there were sometimes missing or conflicting characteristics that necessitated the use of ecosite or series-level labels being applied instead. Although the smallest polygon size generally assessed under this methodology is 0.5 ha, Aquafor Beech Limited reviewed all distinct features on the landscape to determine their sensitivity/significance, and therefore the resulting ELC mapping produced for this report includes some polygons of less than 0.5 ha size.

3.4.4.1.2 Results

A total of 132 ELC polygons were defined through the field work conducted by Aquafor Beech biologists in 2022. In-situ field surveys were completed throughout both Study Areas. Where ELC mapping for these areas was available via other sources, these polygons were incorporated into the current study and refined to the extent possible. A complete list of communities and a general description of each community type is provided in **Appendix J**.

There were five documented communities that are considered provincially significant, representing 15 polygons (**Table 3.33**). Six Fresh – Moist Black Walnut Lowland Deciduous Forest (FOD7-4) polygons were identified. Dry – Fresh Hickory Deciduous Forest (FOD2-3) is considered S3S4 indicating that it is likely provincially rare but with a level of uncertainty. It was found two locations: polygon 195.03 was located in the valley of a tributary off of Jones Creek, in the North Brantford Study Area and polygon 259.01 was south of Phelps Creek in Tutela Heights Study Area. Fresh – Moist Black Maple Lowland Deciduous Forest (FOD7-5) is considered S3 which is rare to uncommon in Ontario. These communities were found in the floodplain of Jones Creek generally defined by the toe of slope. Fresh – Moist Bitternut Hickory Deciduous Forest (FOD9-5) was found in one location on the south valley slope of Jones Creek and is considered S3S4. Gray Dogwood Mineral Deciduous Thicket (SWT2-9) was found in three locations all along Jones Creek and are ranked S3S4.

Table 3.33: Provincially Rare ELC communities

Ecological Land Classification		S Rank	Polygon
FODM2-3 (FOD2-3)	Dry – Fresh Hickory Deciduous Forest	S3S4	195.03 and 259.01
FODM7-4 (FOD7-4)	Fresh – Moist Black Walnut Lowland Deciduous Forest	S2S3	195.04, 206.05, 206.07, 999.02, and 9999.01, 1004
FODM7-5 (FOD7-5)	Fresh – Moist Black Maple Lowland Deciduous Forest	S3	175.03, 206.09, and 211.01
FODM9-5 (FOD9-5)	Fresh – Moist Bitternut Hickory Deciduous Forest	S3S4	175.04
SWTM2-3 (SWT2-9)	Gray Dogwood Mineral Deciduous Thicket	S3S4	172.09, 191.03, and 196.03

The 132 polygons are comprised of a total of 43 unique vegetation types. Field surveys targeted communities where there was the greatest uncertainty in background resources. Resulting in more wetland communities being surveyed with 55 wetlands surveyed, of which 39 were marsh communities and 16 were swamps. There were several information sources for this area with varying wetland boundaries. As a part of the field investigation, the areas where the wetland boundary differed was reviewed where possible. Forest communities were largely surveyed within the valleylands and were either Sugar Maple (*Acer saccharum*) dominant forest or lowland forest with a variety of Willow (*Salix sp.*), Manitoba Maple (*Acer negundo*), Black Walnut (*Juglans nigra*) with some Black Maple (*Acer nigra*), Hickory (*Carya sp.*) and Poplar (*Populus sp.*). Some communities also have ‘inclusions’, defined generally as areas where distinct communities are

found within a larger polygon, but are too small to be individually mapped. These areas have been referred to in Tables and maps as ‘inc’ for short. All polygons were assigned both a community code from the 1998 ELC manual and an updated code provided by MNRF in 2008 (unpublished).

A list summarizing the vegetation types delineated by Aquafor Beech in 2022 is presented in **Table 3.34**, and an overview of Aquafor Beech’s community delineations is provided in **Figure 3.106**. More detailed mapping is provided in **Appendix J** along with a table presenting detailed descriptions and representative photos of the vegetation communities delineated by Aquafor Beech Limited, and the ELC field data sheets from 2022. Areas not surveyed during the 2022 field surveys were delineated based on the 2020 Comprehensive EIS (Plan B Natural Heritage) with minor updates based on updated orthoimage and roadside observations.

Table 3.34: Summary of Vegetation Communities Delineated in 2022.

ELC Community (First Approximation)	ELC Community (2008 Codes)	Polygon(s)
Dry – Moist Old Field Meadow (CUM1-1)	Dry – Fresh Forb Meadow (MEFM1)	175.01
	Goldenrod Forb Meadow (MEFM1-1)	131.06, 135.03, 146.01, 196.04, 211.04, 211.07, 237.02, 9999.02
	Kentucky Blue Grass Graminoid Meadow (MEGM3-4)	113.02, 115.01
	Smooth Brome Graminoid Meadow (MEGM3-5)	175.06, 195.02, 230.03, 206.01*, 1009
Black Walnut Deciduous Plantation (CUP1-3)	Naturalized Deciduous Plantation (FODM12)	115.02
White Pine Coniferous Plantation (CUP3-2)	Dry – Fresh White Pine Naturalized Coniferous Plantation (FOCM6-1)	115.08, 172.03, 196.01, 202.01, 999.03
Mineral Cultural Savannah (CUS1)	Dry – Fresh Black Walnut Deciduous Woodland (WODM4-4)	206.02, 259.02
Hawthorn Cultural Savannah (CUS1-1)	Hawthorn Deciduous Shrub Thicket (THDM2-11)	206.04
Mineral Cultural Thicket (CUT1)	Dry- Fresh Deciduous Shrub Thicket (THDM2)	131.03
	Hawthorn Deciduous Shrub Thicket (THDM2-11)	196.06
	Fresh – Moist Hawthorn / Apple Deciduous Woodland (WODM5-4)	211.05
Gray Dogwood Deciduous Shrub Thicket (CUT1-4)	Gray Dogwood Deciduous Shrub Thicket (THDM2-4)	1010
Mineral Cultural Woodland (CUW1)	Dry – Fresh Black Locust Deciduous Forest (FODM4-11)	131.07, 195.01
	Dry – Fresh Black Walnut Deciduous Woodland (WODM4-4)	999.04, 1003
Dry – Fresh White Oak Deciduous Forest (FOD1-2)	Dry – Fresh White Oak Deciduous Forest (FODM1-2)	115.05
Dry – Fresh Hickory Deciduous Forest (FOD2-3)	Dry – Fresh Hickory Deciduous Forest (FODM2-3)	195.03, 259.01
Dry – Fresh Beech Deciduous Forest (FOD4-1)	Dry – Fresh Beech Deciduous Forest (FODM4-1)	211.02

ELC Community (First Approximation)	ELC Community (2008 Codes)	Polygon(s)
Dry – Fresh Sugar Maple Deciduous Forest (FOD5-1)	Dry – Fresh Sugar Maple Deciduous Forest (FODM5-1)	175.02, 196.09, 206.08, 211.03
Dry – Fresh Sugar Maple – Beech Deciduous Forest (FOD5-2)	Dry – Fresh Sugar Maple – Beech Deciduous Forest (FODM5-2)	135.01, 172.08, 1005, 9999.04
Dry – Fresh Sugar Maple – Red Maple Deciduous Forest (FOD5-9)	Dry – Fresh Sugar Maple – Red Maple Deciduous Forest (FODM5-9)	1012
Fresh – Moist Lowland Deciduous Forest (FOD7)	Fresh – Moist Manitoba Maple Lowland Deciduous Forest (FODM7-7)	131.08*, 141.01, 999.01
	Fresh – Moist Manitoba Maple Deciduous Woodland (WODM5-3)	172.07
Fresh – Moist Willow Lowland Deciduous Forest (FOD7-3)	Fresh – Moist Willow Lowland Deciduous Forest (FODM7-3)	115.07, 175.05
Dry – Fresh Black Walnut Deciduous Woodland (FOD7-4)	Dry – Fresh Black Walnut Deciduous Woodland (WODM4-4)	195.04, 206.05, 206.07, 999.02, 1004, 9999.01
Fresh – Moist Black Maple Lowland Deciduous Forest (FOD7-5)	Fresh – Moist Black Maple Lowland Deciduous Forest (FODM7-5)	175.03, 206.09, 211.01
Fresh – Moist Poplar – Sassafras Deciduous Forest (FOD8)	Fresh – Moist Cottonwood Deciduous Forest (FODM8-3)	131.04
Fresh – Moist Oak – Maple – Hickory – Deciduous Forest (FOD9)	Fresh – Moist Oak – Maple – Hickory – Deciduous Forest (FODM9)	206.10
Fresh – Moist Bitternut Hickory Deciduous Forest (FOD9-5)	Fresh – Moist Bitternut Hickory Deciduous Forest (FODM9-5)	175.04
Reed-canary Grass Graminoid Mineral Meadow Marsh (MAM2-2)	Reed-canary Grass Graminoid Mineral Meadow Marsh (MAMM1-3)	131.01*, 131.10, 172.01, 172.02, 191.02, 195.05, 206.03, 206.11*, 206.12, 211.06, 232.02, 237.01, 9999.03
Horsetail Graminoid Mineral Meadow Marsh (MAM2-7)	Horsetail Graminoid Mineral Meadow Marsh (MAMM1-10)	1007
Forb Mineral Meadow Marsh (MAM2-10)	Panicled Aster Mineral Meadow Marsh (MAMM2-2)	115.06, 172.04, 172.06, 195.08, 206.06, 232.01

ELC Community (First Approximation)	ELC Community (2008 Codes)	Polygon(s)
Forb Mineral Meadow Marsh/Swamp Maple Mineral Deciduous Swamp Complex (MAM2-10/ SWD 3-3)	Panicled Aster Mineral Meadow Marsh /Swamp Maple Mineral Deciduous Swamp Complex (MAMM2-2/SWDM3-3)	115.03
Mineral Shallow Marsh (MAS2)	Common Reed Mineral Shallow Marsh (MASM1-12)	113.01, 115.04, 116.02, 116.03, 230.01, 1008
Cattail Mineral Shallow Marsh (MAS2-1)	Cattail Mineral Shallow Marsh (MASM1-1)	116.04, 172.05, 177.01, 190.01, 191.01, 196.02, 230.02, 259.03, 1001
Silver Maple Mineral Deciduous Swamp (SWD3-2)	Silver Maple Mineral Deciduous Swamp (SWDM3-2)	135.02
Manitoba Maple Mineral Deciduous Swamp (SWD3-4)	Manitoba Maple Mineral Deciduous Swamp (SWDM3-4)	195.06
Willow Mineral Deciduous Swamp (SWD4-1)	Willow Mineral Deciduous Swamp (SWDM4-1)	195.07, 196.05, 9999.05
Mineral Thicket Swamp (SWT2)	Non-native Mineral Deciduous Thicket Swamp (SWTM5-8)	175.07
Willow Mineral Thicket Swamp (SWT2-2)	Missouri Willow Mineral Deciduous Swamp with a Common Reed Graminoid Mineral Meadow Marsh (SWTM3-1)	131.05*, 131.09*
	Slender Willow Mineral Deciduous Thicket Swamp (SWTM3-3)	65.01
	Mixed Willow Mineral Deciduous Thicket Swamp (SWTM3-6)	116.01
Red-osier Mineral Deciduous Thicket Swamp (SWT2-5)	Red-osier Mineral Deciduous Thicket Swamp (SWTM2-1)	131.02
Gray Dogwood Mineral Deciduous Thicket (SWT2-9)	Gray Dogwood Mineral Deciduous Thicket (SWTM2-3)	172.09, 191.03, 196.03

*: Community has an inclusion



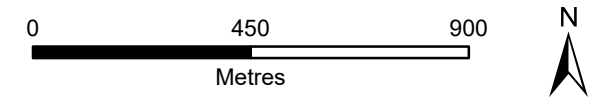
Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Butternut
- Honey-locust
- Butternut Habitat
- Cultural Meadow (CUM)
- Cultural Plantation (CUP)
- Cultural Savannah (CUS)
- Cultural Thicket (CUT)
- Cultural Woodland (CUW)
- Coniferous Forest (FOC)
- Deciduous Forest (FOD)
- Mixed Forest (FOM)
- Hedgerow (HR)
- Meadow Marsh (MAM)
- Shallow Marsh (MAS)
- Open Aquatic
- Deciduous Swamp (SWD)
- Swamp Thicket (SWT)

Figure 3.106

Aquafor Beech 2022 ELC Overview
(refer also to Appendix J)

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO



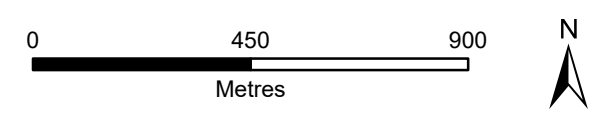
Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Butternut
- Honey-locust
- Butternut Habitat
- Cultural Meadow (CUM)
- Cultural Plantation (CUP)
- Cultural Savannah (CUS)
- Cultural Thicket (CUT)
- Cultural Woodland (CUW)
- Coniferous Forest (FOC)
- Deciduous Forest (FOD)
- Mixed Forest (FOM)
- Hedgerow (HR)
- Meadow Marsh (MAM)
- Shallow Marsh (MAS)
- Open Aquatic
- Deciduous Swamp (SWD)
- Swamp Thicket (SWT)

Figure 3.106

Aquafor Beech 2022 ELC Overview
(refer also to Appendix J)

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend






















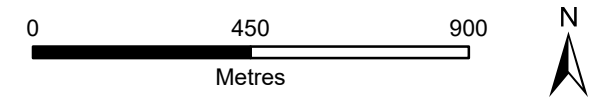
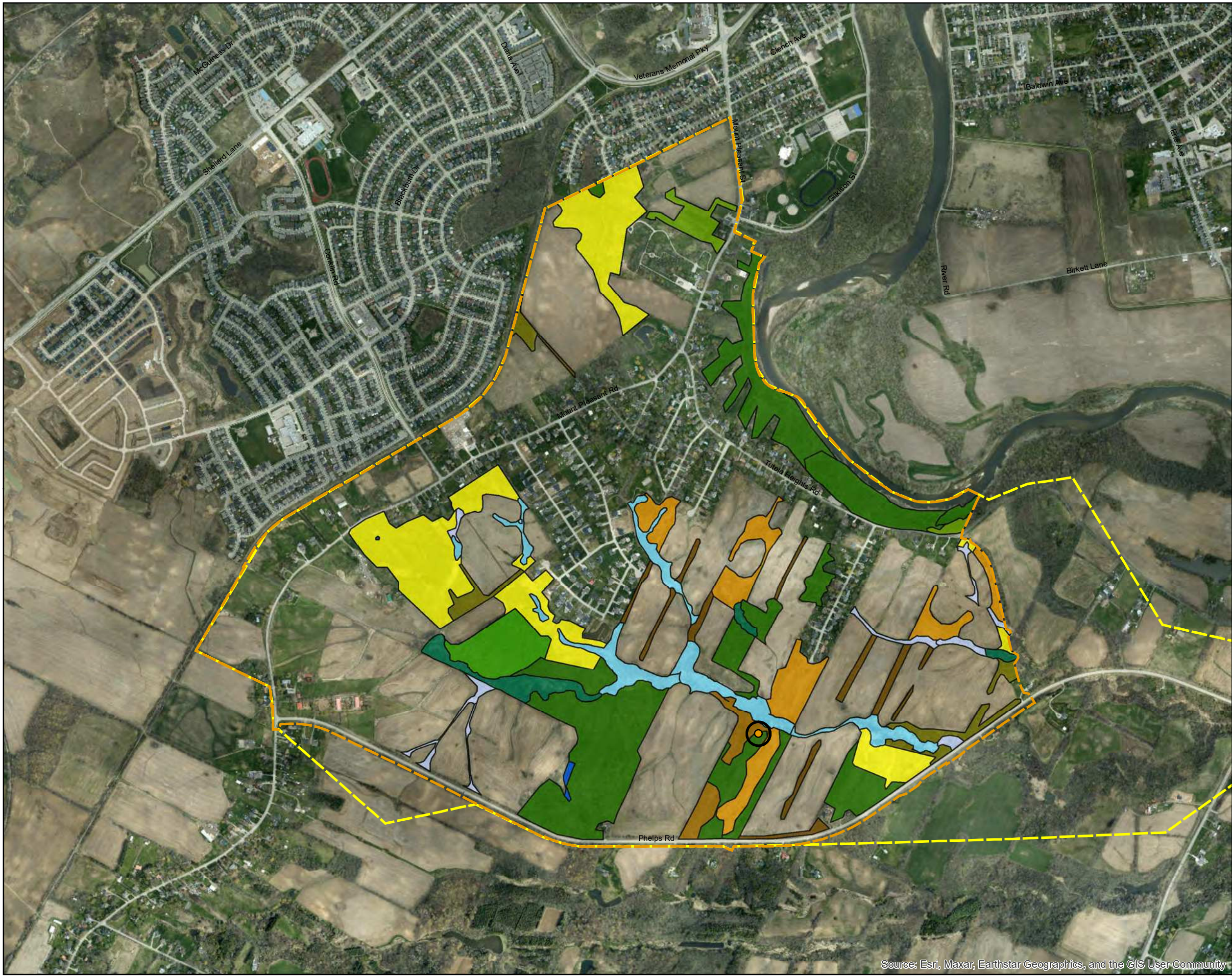
-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Watercourse
-  Butternut
-  Honey-locust
-  Butternut Habitat
-  Cultural Meadow (CUM)
-  Cultural Plantation (CUP)
-  Cultural Savannah (CUS)
-  Cultural Thicket (CUT)
-  Cultural Woodland (CUW)
-  Coniferous Forest (FOC)
-  Deciduous Forest (FOD)
-  Mixed Forest (FOM)
-  Hedgerow (HR)
-  Meadow Marsh (MAM)
-  Shallow Marsh (MAS)
-  Open Aquatic
-  Deciduous Swamp (SWD)
-  Swamp Thicket (SWT)

Figure 3.106

Aquafor Beech 2022 ELC Overview
(refer also to Appendix J)

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO





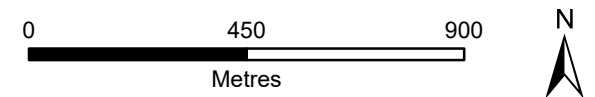
Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Butternut
- Honey-locust
- Butternut Habitat
- Cultural Meadow (CUM)
- Cultural Plantation (CUP)
- Cultural Savannah (CUS)
- Cultural Thicket (CUT)
- Cultural Woodland (CUW)
- Coniferous Forest (FOC)
- Deciduous Forest (FOD)
- Mixed Forest (FOM)
- Hedgerow (HR)
- Meadow Marsh (MAM)
- Shallow Marsh (MAS)
- Open Aquatic
- Deciduous Swamp (SWD)
- Swamp Thicket (SWT)

Figure 3.106

Aquafor Beech 2022 ELC Overview
(refer also to Appendix J)

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO



Provincially Significant Wetland

The Cold Springs Creek Wetland Complex is a Provincially Significant Wetland (PSW) located in the North Brantford Study Area. The wetland communities have been reviewed to determine if they should be considered for inclusion into the wetland complex based on the previous version of the OWES Southern Manual, 3rd Edition (MNRF, 2014) rules for complexing but as a part of Bill 23, MNRF released an updated OWES Southern Manual, 4th Edition (MNRF, 2022). As a part of the most recent update the rules for wetland complexing changed significantly. In the 4th edition rules, wetlands can be grouped if they function together as one. Wetland complexes can be re-evaluated (re-scored and re-mapped) without requiring a complete re-evaluation of all units in the existing wetland complex. Each wetland unit is to retain its current status as a PSW until it has been re-evaluated. As a part of this study we did not collect sufficient data to properly evaluate each PSW patch. Therefore, all wetland patches currently part of the Cold Springs Creek Wetland Complex should remain classified as a PSW. Block Plan Studies and site-specific studies may re-evaluate wetland patches but should consider the PSW functionality as a whole. Unevaluated wetland patches were reviewed for their potential to be considered PSW based on the 4th edition rules. A total of 126 wetland polygons were delineated as a part of the field investigation (52 polygons) and the desktop review (75 polygons) (**Figure 3.107**). Of these polygons, 46 were either too far from the PSW or were not hydrologically and/or functionally related and not likely to be considered locally significant, 35 polygons were already within the PSW, five were directly adjacent to a PSW patch, and 38 do not have the potential to be considered PSW but may be considered locally significant (**Table 3.35**).

Table 3.35: Wetland Communities

Consideration	Polygon*
PSW – Part of Cold Spring Creek Wetland Complex	172.04, 172.05, 172.06, 175.05, 175.07, 177.01, 195.05, 195.05, 195.06, 196.02, 196.03, 196.05, 196.05, 206.03, 206.06, 206.11, 9999.03, 9999.05, W32, W33, W43, W44, W45, W46, W49, W50, W51, W52, W54, W55, W56, W57, W60, W73, W74
To be considered for PSW – Contiguous with Cold Spring Creek Wetland Complex	135.02, 172.09, 191.03, 206.12, W48
Requires further study – Potentially locally significant	115.03, 115.04, 131.09, 131.10, 155.06, 172.01, 172.02, 195.07, 195.08, 211.06, 232.01, 232.02, 259.03, W7, W8, W9, W10, W20, W24, W25, W26, W27, W28, W29, W36, W53, W61, W63, W64, W65, W66, W67, W69, W70, W72, W75
No - Not hydrologically connected to a PSW and not likely to be locally significant	65.01, 113.01, 115.10, 116.01, 116.02, 116.03, 116.04, 131.01, 131.02, 131.05, 190.01, 230.01, 230.02, 237.01, 1001, 1007, 1008, W1, W2, W3, W4, W5, W6, W11, W12, W13, W14, W15, W16, W17, W18, W19, W30, W31, W34, W35, W37, W38, W39, W40, W41, W42, W47, W58, W59, W68, W71

* Only polygons that were a part of the field investigation were assigned polygon numbers. Desktop wetland communities were assigned a unique identifier W#.

3.4.4.1.3 Conclusions

A total of 132 ELC polygons were delineated by Aquafor Beech Limited biologists in 2022. These are comprised of a total of 43 unique vegetation types, including forests, woodlands, wetlands, and culturally influenced community types. Additional polygons were identified in the Study Area desktop review of available resources (namely the 2020 Comprehensive EIS). Five vegetation community types delineated are considered provincially rare representing 15 polygons.

The vegetation community assessment results provide the basis for the SAR habitat assessment discussed in **Section 3.4.5** and the Significant Wildlife Habitat assessment discussed in **Section 3.4.6**. In addition, the woodland communities (i.e., all forests, cultural woodlands, and plantations, per the OP definitions), and wetlands (i.e., all marshes and swamps) delineated through ELC are further assessed for their potential to act as ‘significant woodlands’ and/or ‘wetlands’ that are eligible for inclusion in the NHS, as will be discussed further in **Section 4.2**.

Legend

- Primary Study Area
- Secondary Study Area
- Tertiary Study Area
- Watercourse
- GRCA Wetland Boundary
- Provincially Significant Wetland
- Not evaluated per OWES
- To be considered for PSW - Contiguous with Cold Spring Creek Wetland Complex
- No - Not hydrologically connected to a PSW and not likely to be locally significant
- Requires further Study - Potentially locally significant
- PSW - Part of Cold Spring Creek Wetland Complex

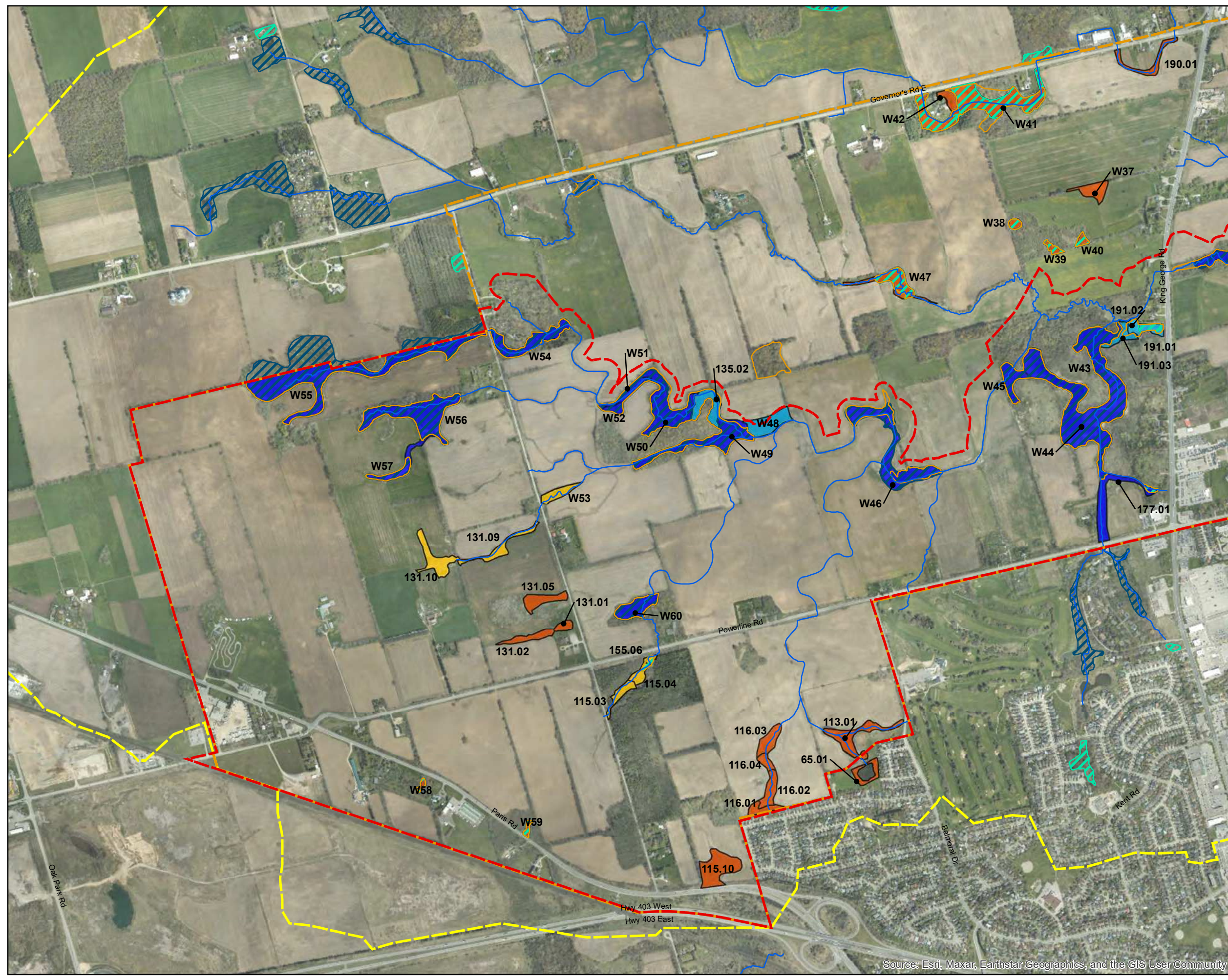
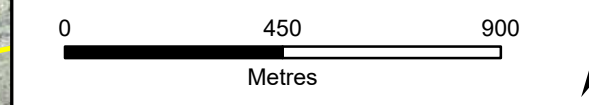


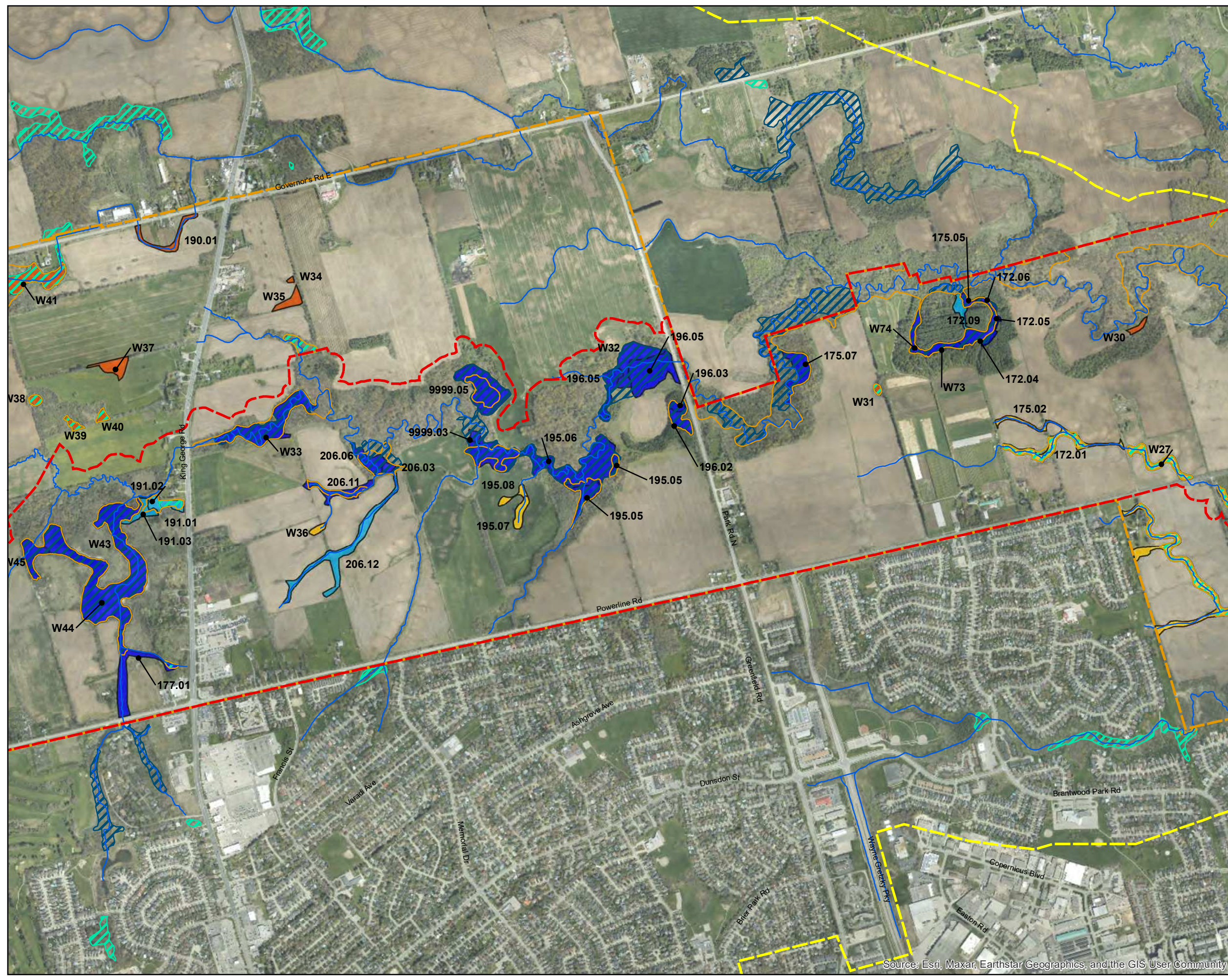
Figure 3.107

Provincially Significant Wetland Complex Considerations

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO



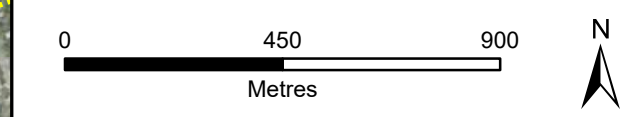
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



- Legend**
- Primary Study Area
 - Secondary Study Area
 - Tertiary Study Area
 - Watercourse
 - GRCA Wetland Boundary
 - Provincially Significant Wetland
 - Not evaluated per OWES
 - To be considered for PSW - Contiguous with Cold Spring Creek Wetland Complex
 - No - Not hydrologically connected to a PSW and not likely to be locally significant
 - Requires further Study - Potentially locally significant
 - PSW - Part of Cold Spring Creek Wetland Complex

Figure 3.107
Provincially Significant Wetland Complex Considerations

Date: June 2023
Author: KB
Projection: UTM_Zone_17N
Source: City of Brantford, Plan B Natural Heritage.LIO



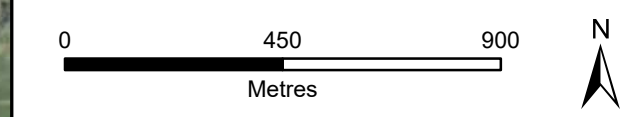
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



- Legend**
- Primary Study Area
 - Secondary Study Area
 - Tertiary Study Area
 - Watercourse
 - GRCA Wetland Boundary
 - Provincially Significant Wetland
 - Not evaluated per OWES
 - To be considered for PSW - Contiguous with Cold Spring Creek Wetland Complex
 - No - Not hydrologically connected to a PSW and not likely to be locally significant
 - Requires further Study - Potentially locally significant
 - PSW - Part of Cold Spring Creek Wetland Complex

Figure 3.107
Provincially Significant Wetland Complex Considerations

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO

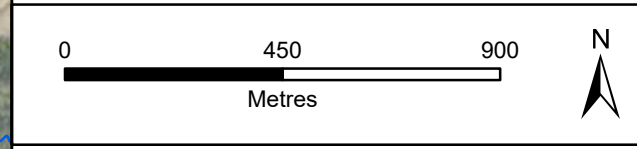


- Legend**
- Primary Study Area
 - Secondary Study Area
 - Tertiary Study Area
 - Watercourse
 - GRCA Wetland Boundary
 - Provincially Significant Wetland
 - Not evaluated per OWES
 - To be considered for PSW - Contiguous with Cold Spring Creek Wetland Complex
 - No - Not hydrologically connected to a PSW and not likely to be locally significant
 - Requires further Study - Potentially locally significant
 - PSW - Part of Cold Spring Creek Wetland Complex



Figure 3.107
Provincially Significant Wetland Complex Considerations

Date: June 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Brantford, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

3.4.4.2 Botanical Inventory

Botanical inventories are a key component of terrestrial ecological investigations, as these support the classification of vegetation communities, as presented in **Section 3.4.4.1** (e.g., through identification of dominant species or wetland indicators), and identify occurrences of noteworthy plant species such as SAR or regionally significant species.

3.4.4.2.1 Methodology

Botanical inventories were undertaken concurrently with the vegetation community studies described in **Section 3.4.4.1**. The botanical inventory aimed to identify as many species as possible that were present within a given community, creating a list associated with each ELC polygon (recognizing that the large Study Area prohibited the completion of thorough, three-season inventories in any one polygon; additional inventory is anticipated to be required during future site-specific studies to create a comprehensive species list for any individual property or feature). The inventory was compiled via wandering area searches, conducted by qualified biologists with botanical expertise.

3.4.4.2.2 Results

A total of 302 species of vascular plants were catalogued during the botanical inventories undertaken by Aquafor staff in the Study Area in 2022. Of these, 296 were identified to the species level and eight were identified to genus level (2.6%). Of those identified to species level, 197 (65.2%) are native to Ontario and 99 (32.8%) are introduced species. An annotated list of flora recorded by Aquafor within the Study Area is contained within **Appendix K**.

Coefficient of Conservatism (CC) values, per the Floristic Quality Assessment System for Southern Ontario (Oldham, Bakowsky, & Sutherland, 1995), are an accepted criterion for assessing botanical quality. Introduced species are not assigned as CC value. The majority of species inventoried have a high range of habitat tolerances, as evidenced by the high proportion of species with a low CC values. Fifteen species with narrow habitat tolerances (i.e., with CC values ≥ 7) were found in a wide variety of communities throughout the Study Area. The number of native plant taxa found within the Study Area for each category of CC values, as categorized by Oldham, Bakowsky, & Sutherland (1995) is presented in **Table 3.36**.

Table 3.36 Study Area Flora – Coefficient of Conservatism by Category

Coefficient of Conservatism Categories	# of Taxa
Wide variety of sites (CC 0-3)	68
Typically associated with a specific community, but tolerate moderate disturbance (CC 4-6)	110
Associated with a plant community in an advanced successional stage (CC 7-8)	16
High degree of fidelity to a narrow range of parameters (CC 9-10)	0
Total species with CC values	194

The majority of the species recorded during surveys are considered to be common and secure in Ontario (S4 or S5).

Butternut (*Juglans cinerea*), is considered to be provincially imperiled (S2?; the ‘?’ indicates that there may be some uncertainty about the ranking), and is also listed as an Endangered species under provincial and federal Species at Risk (SAR) legislation. Butternut was recorded in ELC polygon 259.01, 211.05, and 1006 (see **Section 3.4.5**) but might be present in the valleyland. Full Butternut Health Assessments (i.e., per MNRF protocols) were not carried out as a part of the current study. However, initial assessments revealed that both pure Butternut (protected under the ESA) and hybrid trees (not protected under the ESA) may be present throughout both Study Areas. Further discussion about the protection of Butternut as a SAR can be found in **Section 3.4.5**.

Black Ash (*Fraxinus nigra*) was recorded in one polygon, 259.02, and is considered Endangered in Ontario. There are several other background records in the area including a research grade observation made in 2021 located in polygon 196.09 (iNaturalist).

Honey-locust (*Gleditsia triacanthos*), is considered to be provincially imperiled (S2?; the ‘?’ indicates that there may be some uncertainty about the ranking). One individual was recorded in polygon 230.03 and another was noted in a yard near the intersection of Mt Pleasant Rd and Conklin Rd and was likely planted. Only naturally occurring specimens are considered to qualify as provincially rare.

Of the recorded species, seven were found to have regional significance based on the list for Brant Region contained in “List of the Vascular Plants of Ontario’s Carolinian Zone (Ecoregion 7E)” (Oldham M. , 2017) (**Table 3.37**).

Table 3.37 Study Area Flora – Regionally Rare and Uncommon Vascular Plants

Scientific Name	Common Name	Location (ELC Polygons)
<i>Alnus incana ssp. Rugosa</i>	Speckled Alder	999.01
<i>Carex grayi</i>	Gray’s Sedge	135.02
<i>Carex jamesii</i>	James’ Sedge	115.05
<i>Equisetum pratense</i>	Meadow Horsetail	196.02
<i>Lobelia cardinalis</i>	Cardinal Flower	135.02
<i>Scrophularia marilandica</i>	Carpenter’s Square Figwort	195.09
<i>Symphoricarpos albus</i>	Common Snowberry	259.02

A number of introduced species that are considered to be invasive were present throughout the Study Area. Two of the most prevalent and potentially problematic species are Common Buckthorn (*Rhamnus cathartica*) and European Reed (*Phragmites australis ssp. Australis*). Both species were found throughout both Study Areas.

Emerald Ash Borer (*Agrilus planipennis*) is prevalent in southern Ontario, and has caused severe decline of Ash (*Fraxinus spp.*) trees throughout the Study Area. As ash trees continue to decline, Common Buckthorn (among other invasive species) has become more common, taking advantage of the opening canopy in previously forested and treed swamp habitats.

3.4.4.2.3 Conclusions

A total of 302 plant species were inventoried by Aquafor Beech Limited biologists in 2022. Of these, the majority are considered to be common and secure. One SAR, Butternut, and one SOCC, Honey-locust, were recorded, although Honey-locust is considered likely to be planted and therefore would not be considered as a rare specimen. This species and its habitat protections provided under the ESA are further detailed in **Section 3.4.5**; the implications of SAR habitat on the NHS are discussed under **Section 3.4.7**.

The regionally rare and uncommon plant species listed in **Table 3.37** do not receive regulatory protection and do not constitute a constraint that is carried forward as part of the NHS presented in **Section 3.4.7**. However, these species and their habitat may be subject to further review and/or the application of impact mitigation and/or conservation measures during site-specific studies, at a later planning phase, per the discretion of the Municipality and/or GRCA, as presented in **Section 5**.

3.4.4.3 Corridors/Linkages

Linkages, also referred to as corridors, are an integral part of a functioning NHS. They refer to linear features that provide connectivity across the landscape to allow for plants and wildlife to move between core areas. Within the two Study Areas, the landscape scale linkages run along the watercourses. Smaller functional linkages are also present in both Study Areas and were mapped by Plan B Natural Heritage as a part of the 2020 Comprehensive EIS (Plan B Natural Heritage) as depicted on **Figure 3.108**.

In the North Brantford Study Area, the landscape-scale linkage is associated with Jones Creek and some of the larger tributaries. Smaller functional connections connect features at a smaller scale. Within the North Brantford Study Area there are five functional linkages, as identified by Plan B, including two functional linkages which are present along tributaries extending southwest from the swamp/forest patch that contains ELC polygon 135.02 towards ELC polygon 131.10 and the swamp/forest patch northeast of Powerline Rd and Golf Rd intersection, as well as three functional linkages in the southeast corner of the Study Area connecting communities along HR-4, HR5, and the gap between a small marsh patch and a swamp/forest patch to the north west. Plan B also noted that “the existing railway bridge over Highway 403 provides an important ‘safe’ corridor for white-tailed deer moving between the North Brantford Study Area and the Grand River valley.” As a part of the 2020 Comprehensive EIS, Plan B noted that some tributaries were heavily impacted by adjacent farming with large gaps of natural cover and in some instances ploughed through. They noted that “opportunities exist within the North Brantford Study Area to reestablish connections between natural features and to strengthen existing corridors (e.g., from Jones Creek southwest to Golf Road woodlands, from the woodlands east of Garden Avenue towards Fairchild Creek and the Growth Plan NHS)”, and this comment is still applicable.

The Tutela Heights Study Area has two landscape-scale linkages, one along the Grand River and the other along Phelps Creek. Plan B noted that the Grand River valley provides an active corridor for White-tailed Deer. Phelps creek provides a connection running east-west and ultimately connects to the Grand River. Functional linkages are present in five locations in this Study Area including the rail trail running between Frank Grobb Memorial Forest and natural areas to the southwest (i.e., Shellard Lane area); along HR-69; between Phelps Creek and the forest block north of ELC polygon 259.03; between the forest block adjacent to Phelps Rd and Phelps Creek; and along the cultural thicket community at the east edge of the Study Area that connects the Grand River Valley and Phelp Creek.

3.4.4.3.1 Hedgerows

Hedgerows are present across the Study Area, primarily along the edges of agricultural fields. Many of these features may have intentionally planted as windbreaks, sound barriers, property markers, etc., or may have grown in naturally along unmanaged fences and property lines. Less often, hedgerows are remnants of historical woodlands that have otherwise been cleared. Owing to their purpose and growing conditions, individual trees within hedgerows may grow to a mature state and exhibit wide-spreading canopies and wildlife habitat features, such as well-developed cavities.

Hedgerows were defined by this study as narrow features (generally 1-3 trees in width) either disconnected from adjacent woodlands or ecologically distinct from them (e.g., exhibiting a different species composition, or having different ground cover or understorey structure). Therefore, although some hedgerows are contiguous with woodlands, they were assessed as separate features due to their distinguishing features. Conversely, some linear features contiguous with woodlands were found to exhibit similar characteristics as the woodlands and were included in the boundary of those features.

Hedgerows often play an important role in natural heritage connectivity especially in an agriculture dominated landscapes. They are often some of the only remaining linkages connecting core areas. Hedgerows can be vastly different and therefore can provide a spectrum of levels of connectivity. Wide hedgerows with a greater diversity of habitat types (stream and riparian habitat, dense canopy cover, dense shrubs etc.) will provide more movement paths for a greater range of species.

3.4.4.3.2 Methodology

Hedgerows were reviewed through desktop aerial imagery. Those found to exhibit some level of connectivity between natural features were further examined concurrently with the ELC and botanical inventory surveys.

Linkages and potential linkages are intended to be subject to future study and confirmation/refinement as appropriate. The classification of hedgerows provided in the following subsections and shown on the associated mapping shall be confirmed and may be modified if supported by the results of a site-specific EIS or similar study completed as part of a development application.

The spatial, aesthetic, and biophysical characteristics of each hedgerow assessed in the field are detailed in **Table 3.38**. Based on these characteristics, each individual hedgerow has been assigned one of the following categories:

- Category 1: Existing Linkage, also potentially contains SAR trees (Butternut) – to be retained; recommendations for enhancement provided.
- Category 2: Potential Linkage – may become a valuable NHS connection if recommendations for enhancement are implemented.
- Category 3: Feature Elements Present – does not provide linkage function to the NHS, but contains features (e.g., specimen trees) that could be valuable if integrated into the developing landscape (e.g., in a park setting), or is connected to NHS without providing linkage, but provides habitat for wildlife.
- Category 4: No Management Recommended – no linkage function or features found that are recommended for retention or enhancement. Note that there are more Category 4 hedgerows on the landscape, which were ruled out based on aerial interpretation and are thus not included in the table below.

These categories are the basis for guiding any constraints or restoration opportunities to each individual hedgerow in the future, demonstrated on **Figure 4.6**.

3.4.4.3.3 Results

There were 71 hedgerows identified across both Study Areas. Of these, 21 provided and existing linkage, eight have potential to provide linkage, 28 either had a feature element or were connected to the NHS, and 13 have no management recommended. These hedgerows are depicted on **Figure 3.106** and discussed in **Table 3.38**. A complete assessment of each hedgerow is provided in **Appendix L**.

Table 3.38: Hedgerow Assessment

Category	Hedgerow
1: Existing Linkage	HR-4, HR-5, HR-7, HR-10, HR-11, HR-12, HR-28, HR-32, HR-37, HR-38, HR-41, HR-42, HR-43, R-56, HR-57, HR-58, HR-63, HR-66, HR-69, HR-70, HR-71
2: Potential Linkage	HR-13, HR-15, HR-17, HR-19, HR-24, HR-40, HR-45, HR-49
3: Feature Elements Present	HR-2, HR-3, HR-6, HR-8, HR-9, HR-14, HR-16, HR-18, HR-20, HR-22, HR-23, HR-26, HR-27, HR-31, HR-33, HR-34, HR-36, HR-39, HR-44, HR-46, HR-55, HR-59, HR-60, HR-61, HR-62, HR-64, HR-67, HR-68
4: No Management Recommended	HR-1, HR-21, HR-25, HR-29, HR-30, HR-35, HR-47, HR-48, HR-50, HR-51, HR-52, HR-53, HR-54, HR-65

Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Functional Linkages (ABL, 2022)
- Functional Linkages (Plan B, 2020)
- Core Natural
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow

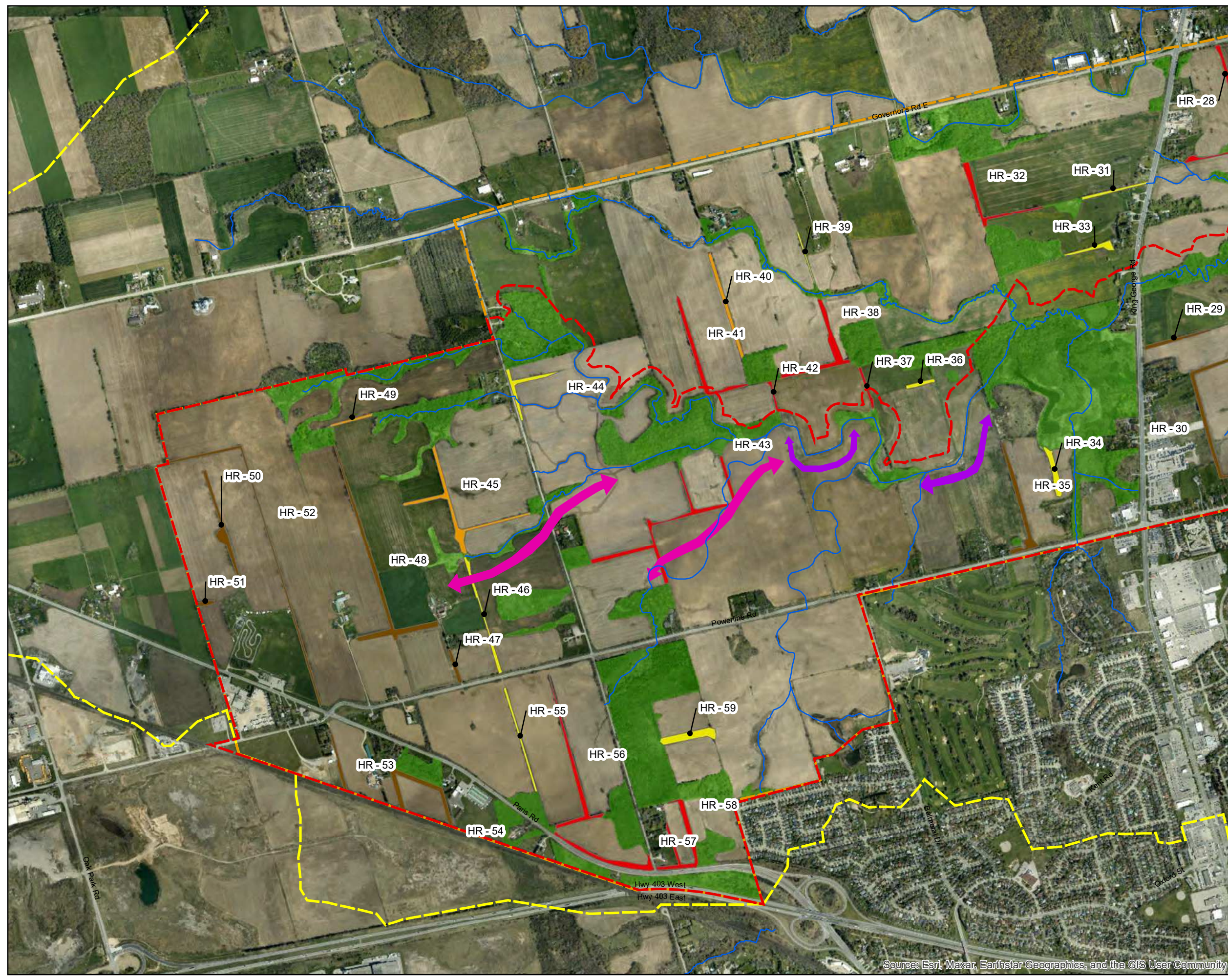
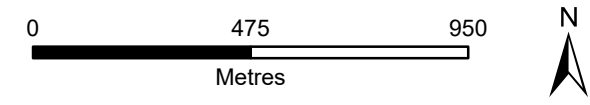


Figure 3.108

Corridors/Linkages

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

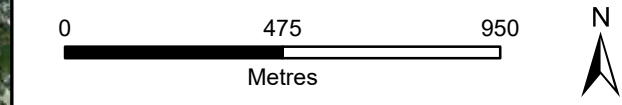


- Legend**
- Primary Study
 - Secondary Study
 - Tertiary Study
 - Watercourse
 - Functional Linkages (ABL, 2022)
 - Functional Linkages (Plan B, 2020)
 - Core Natural
 - Category 1 Hedgerow
 - Category 2 Hedgerow
 - Category 3 Hedgerow
 - Category 4 Hedgerow

Figure 3.108

Corridors/Linkages

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Functional Linkages (ABL, 2022)
- Functional Linkages (Plan B, 2020)
- Core Natural
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow

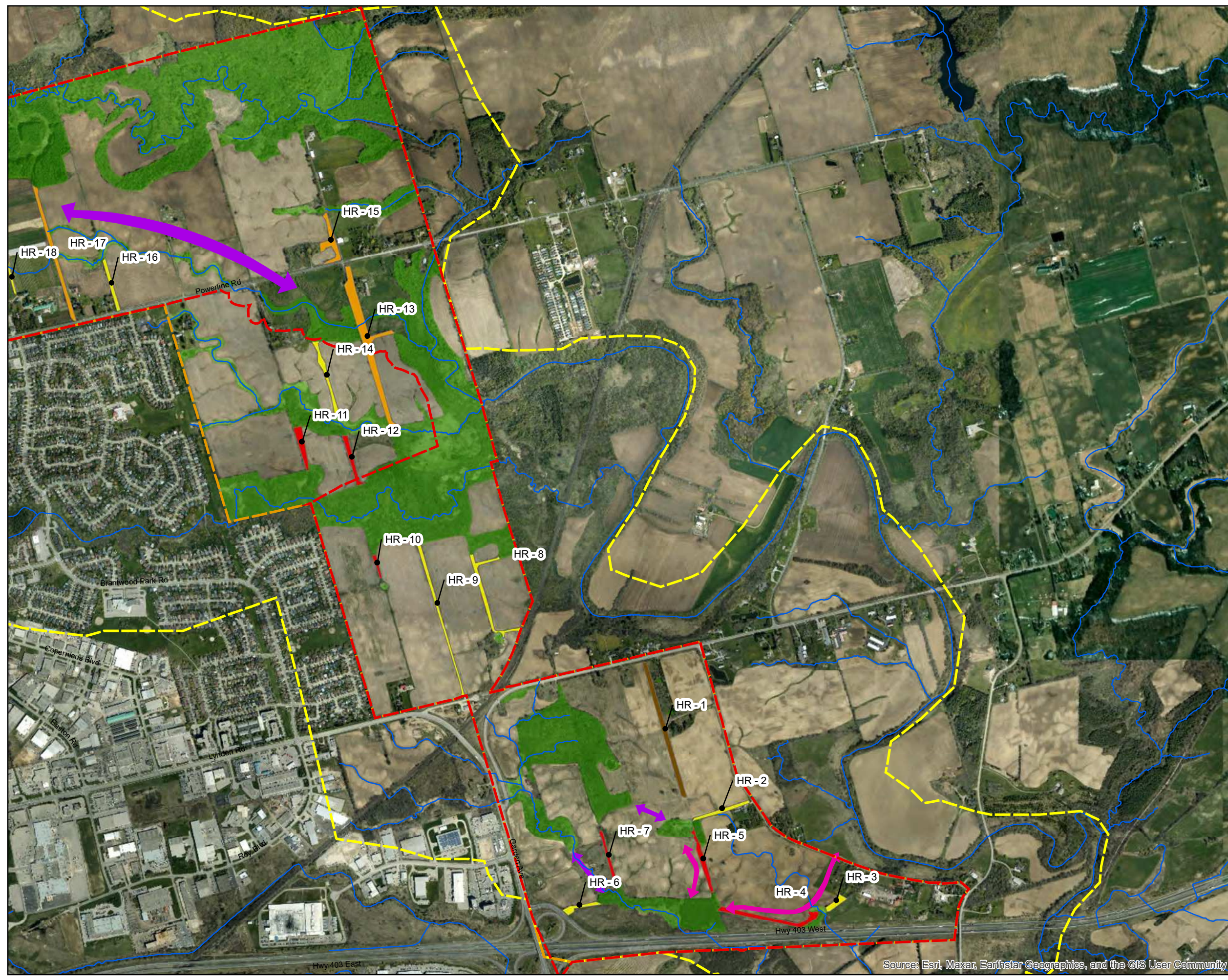
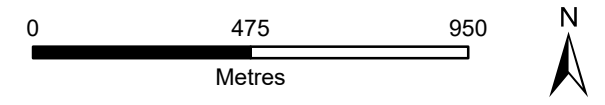


Figure 3.108

Corridors/Linkages

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Functional Linkages (ABL, 2022)
- Functional Linkages (Plan B, 2020)
- Core Natural
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow

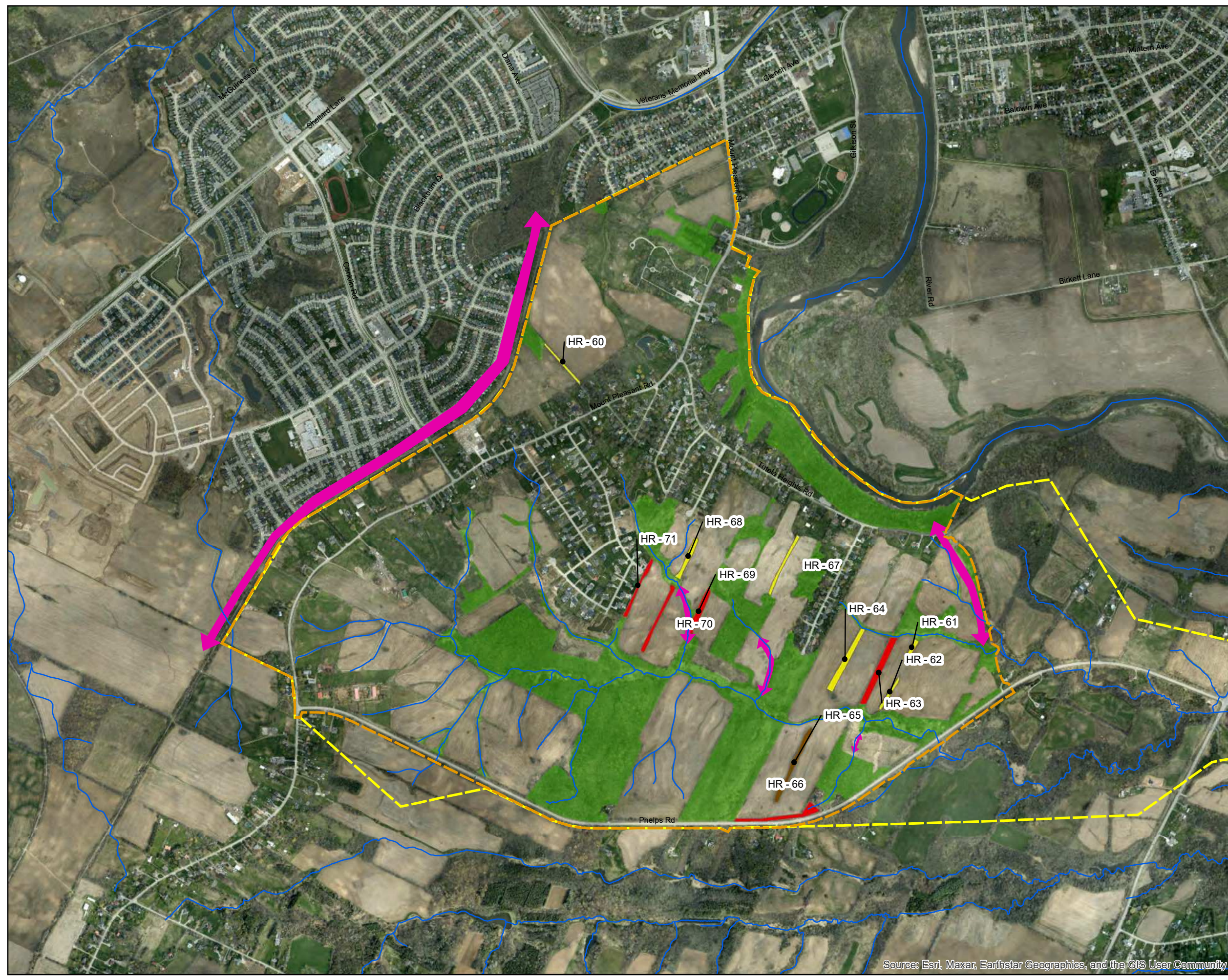
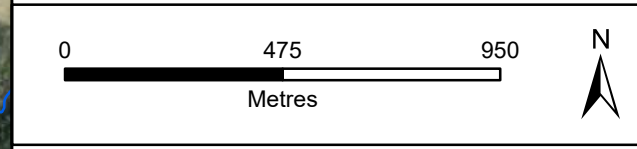


Figure 3.108

Corridors/Linkages

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

3.4.4.4 Breeding Birds

Breeding bird surveys are a standard component of terrestrial ecological investigations since the bird species that breed in an area will reflect the type, quality, and extent of habitat that is present. Certain species of birds will only breed in particular habitat types (e.g., successional thicket, forest interior) or in a minimum habitat patch size (i.e., area-sensitive species). Breeding bird surveys are also completed to support the identification of SAR occurrences (see **Section 3.4.5**) and Significant Wildlife Habitat (see **Section 3.4.6**).

3.4.4.4.1 Methodology

Breeding bird surveys were completed in 2017 and 2018 at a total of 58 stations throughout the Study Area as part of the Comprehensive EIS completed by Plan B Natural Heritage. The data resulting from those surveys were reviewed as part of the current study, and the overall survey coverage was assessed to determine where additional survey effort might be appropriate to confirm or refine natural heritage designations and/or constraint assessments (i.e., any locations where significant bird habitat or SAR presence might result in a higher level of protection or the designation of features not otherwise identified as Key Natural Heritage Features). Overall, it was determined that the previous study provided coverage of all necessary habitat types (constrained by site access restrictions) and was sufficiently comprehensive to establish constraints within the Study Area with regard to breeding birds. Aquafor's breeding bird surveys therefore took a 'spot check' or infill approach to confirm certain species or habitats rather than repeating the prior survey effort throughout the entire Study Area.

Species resulting from the 2020 Comprehensive EIS will be discussed in the following sections, and data will be included in analysis where relevant. However, this report has not reproduced the full results or species lists from that prior document; the 2020 EIS report should be referred to for a full list of species resulting from that study's efforts.

Aquafor's surveys were conducted on two dates during the typical bird breeding period of late May to early July, using primarily area search methodology (to generally review and confirm/update previous conclusions about habitat and species richness) with select point count survey stations at locations of interest. Surveys were completed during appropriate weather conditions, during the required timing window of approximately dawn to midday. All birds seen or heard during the breeding season were recorded along with the level of breeding evidence observed (using Ontario Breeding Bird Atlas terminology and criteria).

Background information sources (such as eBird observation records and the Ontario Breeding Bird Atlas) were also reviewed for this study and will be used to supplement the results of the 2017/18 and 2022 breeding bird surveys where appropriate. eBird hotspots included Brantford--Gordon Glaves Trail-Tutela Heights Rd, Brantford--Grand River Trail - Tutela Heights lookout to Cockshutt Rd, Brantford—Grand Valley Trail from Gilkison Flats to G.G. Trail, Lake Erie & Northern Trail—Ellis Ave to Conklin Rd, and Silver Creek Ravine trails from Ludlow Cres eastwards to CNR tracks. OBBA squares included 17NH57, 17NH58, 17NH67, and 17NH68. These data will only be mentioned in the subsequent sections if the information from these sources indicated significant species or other

constraints relevant to the Study Area and the current subwatershed study. A complete species list has been provided in **Appendix M**.

3.4.4.4.2 Results

Aquafor staff observed a total of 41 bird species during the course of investigations in the Study Area, both via targeted breeding bird surveys and incidental observations during other work (see **Table 3.26** for overall site visit timing and **Table 3.39** for Aquafor’s observed species list). The vast majority of these are common and widespread in Ontario, as is to be expected for an area that is widely disturbed and developed with residential and agricultural properties.

Table 3.39: Bird Species List – Aquafor Beech 2022

Species		Status	Highest Breeding Evidence Observed	Comments
Common Name	Scientific Name			
American Crow	<i>Corvus brachyrhynchos</i>	S5	Possible	
American Goldfinch	<i>Spinus tristis</i>	S5	Possible	
American Robin	<i>Turdus migratorius</i>	S5	Probable	
American Woodcock	<i>Scolopax minor</i>	S4B	Possible	Heard incidentally near frog station B and C during nocturnal surveys
Baltimore Oriole	<i>Icterus galbula</i>	S4B	Possible	
Barn Swallow	<i>Hirundo rustica</i>	S4B, THR	n/a	Foraging near ELC polygon 211.05
Belted Kingfisher	<i>Megaceryle alcyon</i>	S5B	n/a	
Black-capped Chickadee	<i>Poecile atricapillus</i>	S5	Possible	
Blue Jay	<i>Cyanocitta cristata</i>	S5	Possible	
Brown-headed Cowbird	<i>Molothrus ater</i>	S5	Possible	
Canada Goose	<i>Branta canadensis</i>	S5	n/a	Fly over
Cedar Waxwing	<i>Bombycilla cedrorum</i>	S5	Possible	
Chipping Sparrow	<i>Spizella passerina</i>	S5B	Possible	

Species		Status	Highest Breeding Evidence Observed	Comments
Common Name	Scientific Name			
Common Grackle	<i>Quiscalus quiscula</i>	S5	Possible	
Common Raven	<i>Corvus corax</i>	S5	n/a	Fly over
Common Yellowthroat	<i>Geothlypis trichas</i>	S5B	Possible	
Downy Woodpecker	<i>Dryobates pubescens</i>	S5	Possible	
Eastern Wood-pewee	<i>Contopus virens</i>	S4B, SC	Possible	Recorded in ELC polygons 206.07 and 211.03
European Starling	<i>Sturnus vulgaris</i>	SNA	Possible	
Gray Catbird	<i>Dumetella carolinensis</i>	S5B	Possible	
Great Blue Heron	<i>Ardea herodias</i>	S4	n/a	Fly over
Hairy Woodpecker	<i>Dryobates villosus</i>	S5	Possible	
House Sparrow	<i>Passer domesticus</i>	SNA	Probable	
House Wren	<i>Troglodytes aedon</i>	S5B	Probable	
Indigo Bunting	<i>Passerina cyanea</i>	S5B	Possible	
Killdeer	<i>Charadrius vociferus</i>	S4B	n/a	
Mallard	<i>Anas platyrhynchos</i>	S5	n/a	
Mourning Dove	<i>Zenaida macroura</i>	S5	Possible	
Northern Cardinal	<i>Cardinalis cardinalis</i>	S5	Probable	
Northern Flicker	<i>Colaptes auratus</i>	S5	Possible	
Osprey	<i>Pandion haliaetus</i>	S5B	n/a	Fly over
Red-tailed Hawk	<i>Buteo jamaicensis</i>	S5	n/a	Fly over
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	S5	Probable	

Species		Status	Highest Breeding Evidence Observed	Comments
Common Name	Scientific Name			
Ring-billed Gull	<i>Larus delawarensis</i>	S5	n/a	
Rock Pigeon	<i>Columba livia</i>	SNA	n/a	
Song Sparrow	<i>Melospiza melodia</i>	S5	Probable	
Tree Swallow	<i>Tachycineta bicolor</i>	S4S5B	Possible	
Turkey Vulture	<i>Cathartes aura</i>	S5B	n/a	Fly over
Warbling Vireo	<i>Vireo gilvus</i>	S5B	Probable	
Wild Turkey	<i>Meleagris gallopavo</i>	S5	n/a	
Yellow Warbler	<i>Setophaga petechia</i>	S5B	Probable	

The 2020 Comprehensive EIS (Plan B Natural Heritage, 2020) documented a total of 69 species throughout the Study Area, with the most abundant species being common, widespread generalists such as those noted during Aquafor’s surveys (above). Aquafor agrees with the general conclusions of that report that the prevailing habitat in the Study Area (agricultural developments, edges, suburban neighbourhoods, and similar) encourages the presence of mainly tolerant, generalist bird species.

Five SAR birds have been recorded in the Study Area by one or more sources: Barn Swallow (*Hirundo rustica*), Bobolink (*Dolichonyx oryzivorus*), Eastern Meadowlark (*Sturnella magna*), Eastern Wood-pewee (*Contopus virens*), and Wood Thrush (*Hylocichla mustelina*). Both Barn Swallow and Eastern Wood-pewee were observed incidentally outside of the breeding window as a part of Aquafor’s 2022 field investigations. Discussion relating to these five birds, specifically, and other SAR is provided in **Section 3.4.5**.

3.4.4.4.3 Conclusions

Sixty-nine bird species were recorded in the SWS Study Area during the surveys completed for the 2020 Comprehensive EIS by Plan B Natural Heritage. Aquafor’s field surveys, completed in 2022 to supplement and/or confirm the prior data, recorded 41 species of birds (largely overlapping with the species results of the prior surveys), which were primarily those common to rural and suburban generalize habitats in southern Ontario, and which reflected the same general communities and distributions noted in the 2020 EIS. That said, some SAR were reported in the Study Area and will be discussed further in **Section 3.4.5**. The implications of bird observations with regard to Significant Wildlife Habitat, where applicable, are discussed in **Section 3.4.6**.

It is acknowledged that the majority of past and current bird surveying was completed along roadsides and/or at other accessible locations, and that larger, more natural habitat patches may be underrepresented in the above **Table 3.39** and in the 2020 Comprehensive EIS report (Plan B, Natural Heritage, 2020). However, such habitat patches, where present, are likely to be included in the municipal NHS as they are associated with significant woodlands, wetlands, or other designations. The significant habitat review completed in **Section 3.4.6** takes into account access and other study limitations and provides a conservative evaluation of candidate habitat areas based on background data and aerial photo interpretation/existing mapping. Future site-specific studies (e.g., EIS) are expected to be required to complete breeding bird surveys for specific properties/habitats which will address the noted limitations at that time.

3.4.4.5 Amphibian Calling

Amphibians (frogs, toads, and salamanders) are highly sensitive to environmental stresses such as air and water pollution; populations of many amphibian species have been in decline over recent decades, particularly in heavily populated and industrialized areas, due to anthropogenic impacts. Amphibian surveys may therefore be used as an indicator of overall ecosystem health. Locations with high numbers and/or a high diversity of breeding amphibians are considered significant habitats on the provincial level (MNRF, 2015).

3.4.4.5.1 Methodology

Frog and toad species are readily identifiable during their breeding periods, when they migrate to breeding ponds and make mating calls that can be identified to species and are often audible from a great distance. Amphibian calling surveys were completed in 2018 at 19 stations throughout the Study Area as part of the Comprehensive EIS completed by Plan B Natural Heritage. The data resulting from those surveys were reviewed as part of the current study, and the overall survey coverage was assessed to determine where additional survey effort might be appropriate to confirm or refine natural heritage designations and/or constraint assessments (i.e., any locations where significant amphibian habitat might result in a higher level of protection or the designation of features not otherwise identified as Key Natural Heritage Features).

As a result, Aquafor's survey site selection largely focused on isolated pond or wetland features that were not contained within other natural heritage areas and on stream crossings that had not been previously surveyed in 2018. Road accessibility was a further factor in site selection, due to site access permission limitations and staff safety concerns associated with the required nighttime survey window. Additional survey locations completed by Aquafor in 2022 are illustrated on **Figure 3.109**.

Surveys were conducted using the methods of the Marsh Monitoring Protocol (MMP) (Bird Studies Canada, 2009). Three calling surveys were undertaken at all stations, beginning no earlier than half an hour after sunset. Date selection and methodology followed the MMP. Nighttime air temperatures were a minimum of 5°C for the first visit, 10°C for the second visit, and 17°C for the third visit, and survey dates were separated by at least 15 days. Surveys were conducted on still nights, preferably during or immediately after rain. Parameters recorded during each survey

include date, time, air temperature, wind speed, the degree of cloud cover, and level of precipitation.

At each call survey station, the intensity and number of calling amphibians were measured and recorded using call level and abundance codes, as outlined in the MMP. Codes are as follows:

Level 1: Calls are not simultaneous and calling individuals can be counted;

Level 2: Some calls are simultaneous but individual calls are distinguishable and number of individuals can be estimated; and

Level 3: Calls are continuous and overlapping, individuals cannot be distinguished.

3.4.4.5.2 Results

Five species were recorded during Aquafor’s 2022 amphibian calling surveys: Spring Peeper (*Pseudacris crucifer*), American Toad (*Anaxyrus americanus*); Northern Leopard Frog (*Lithobates pipiens*); Wood Frog (*Lithobates sylvaticus*), and Green Frog (*Lithobates clamitans*). The site conditions and full results of the amphibian calling surveys are contained in **Table 3.40** and **Table 3.41**, respectively. It must be noted that weather conditions in spring of 2022 were very dry and that this could have impacted the amphibian populations and activity in the area, particularly in temporary flooded ponds and shallow small wetlands which could dry up quickly under those circumstances.

Table 3.40: Conditions During Amphibian Calling Surveys

Survey	Date	Time (24hr)	Beaufort Wind Scale	Cloud Cover (%)	Air Temp	Other Comments
1	2022-04-22	20:28 – 21:21	0 – 1	70 – 80	8 – 9	No precip. Rainy/windy previous day
2	2022-05-25	21:12 – 22:10	1	100	14	Brief rain earlier in evening, on/off drizzle throughout
3	2022-06-23	21:38 – 22:37	1	0	21	None

Table 3.41: Anuran Calling Survey Results – Aquafor Beech 2022

Station	Survey 1			Survey 2			Survey 3		
	Species	Call Level	# Heard	Species	Call Level	# Heard	Species	Call Level	# Heard
A	No calls	-	-	No calls	-	-	No calls	-	-
B	Spring Peeper	3	Chorus	No calls	-	-	No calls	-	-
	Wood Frog	1	2						
C	Spring Peeper	3	Chorus	No calls	-	-	Green Frog	1	1
	American	1	1						
D	Spring Peeper	2	10	No calls	-	-	No calls	-	-
E	Spring Peeper	2	15	Gray Tree Frog	2	10	No calls	-	-
	American Toad	2	8						
	Northern Leopard Frog	1	1						

In addition to the amphibian calling survey results, and American Toad, Northern Leopard Frog, and Wood Frog were recorded incidentally during vegetation surveys in late summer. American Toad was observed in ELC polygons 131.10, 135.01, and 196.02 which were meadow marsh (MAM), deciduous forest (FOD), and shallow marsh (MAS) communities, respectively. Northern Leopard Frog was seen in ELC polygon 172.09 which is a swamp thicket (SWT). Wood Frog was recorded in 175.03 and 196.09, both deciduous forests.

The previous Comprehensive EIS (Plan B Natural Heritage, November 2020) reported similar overall conditions to those observed by Aquafor in 2022. Per the EIS report, “four areas of high frog calling concentration were recorded.... The species in these concentration areas were dominated by Spring Peepers with smaller numbers of American Toads. During the second and third surveys, only small numbers of Gray Tree Frog and Green Frog were recorded. These individuals were primarily located in small, isolated dug ponds, and stormwater retention ponds.” One of the noted ‘concentration areas’ coincides with one of Aquafor’s 2022 survey station locations; the other indicated areas have been included for reference on **Figure 3.109**.

3.4.4.5.3 Conclusions

Five species of breeding amphibians were documented by Aquafor during calling surveys completed in 2022; similar species composition and habitat conditions were observed by Plan B Natural Heritage in 2018. This relatively low result is not unexpected for a Study Area that is dominated by agricultural lands with limited wetland and pond habitat. No SAR amphibians were recorded during surveys or reported in the Study Area via background data. Implications for amphibian breeding with regards to Significant Wildlife Habitat are discussed in **Section 3.4.6**.

Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Core Natural
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Functional Linkages (ABL, 2022)
- Functional Linkages (Plan B, 2020)
- Watercourse

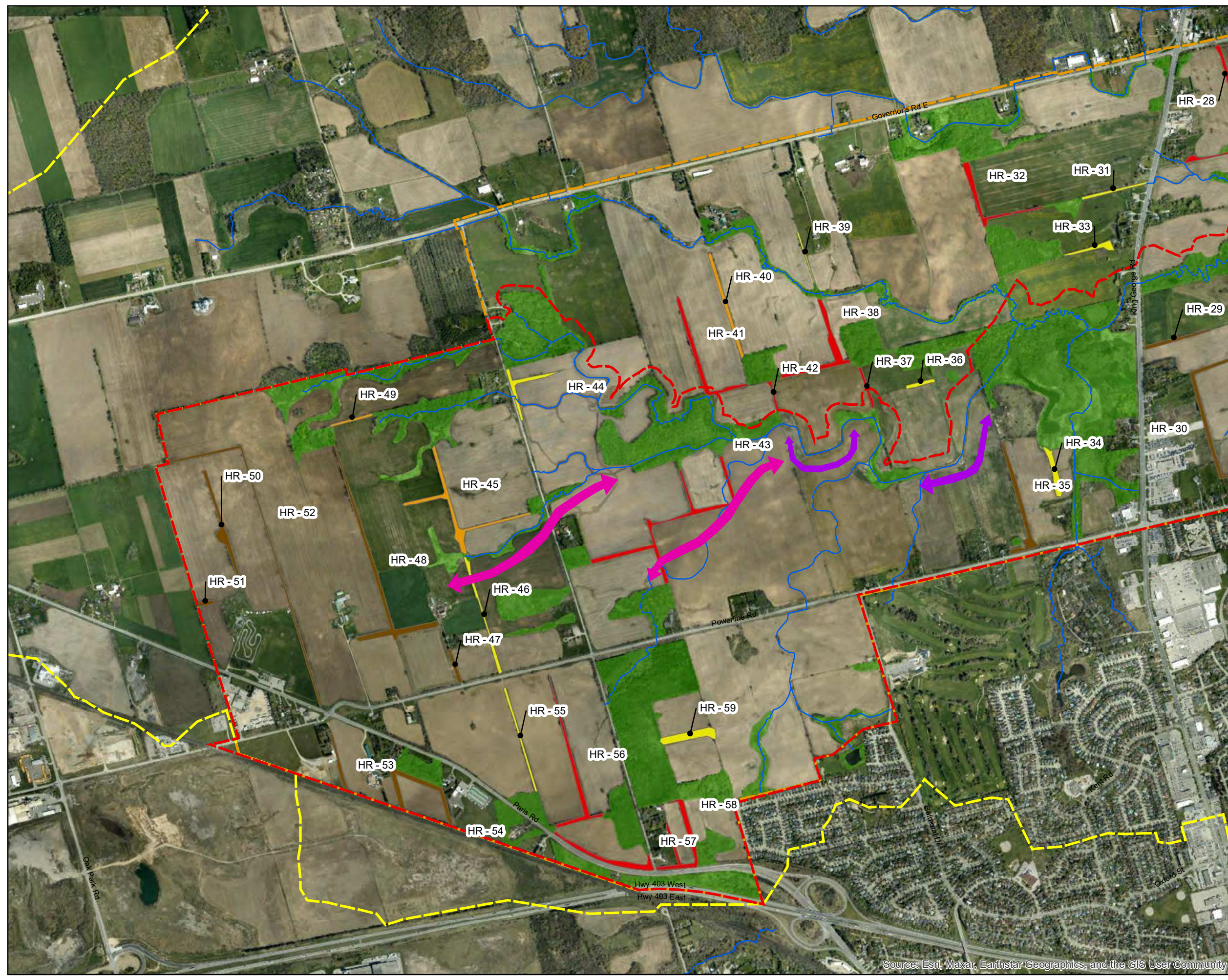
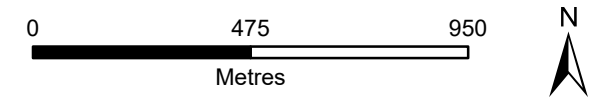


Figure 3.109

Corridors/Linkages

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

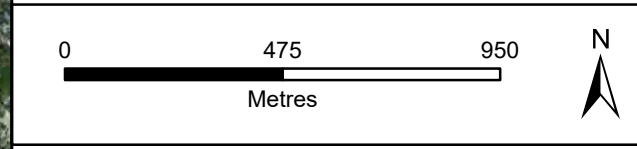
- Primary Study
- Secondary Study
- Tertiary Study
- Core Natural
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Functional Linkages (ABL, 2022)
- Functional Linkages (Plan B, 2020)
- Watercourse



Figure 3.109












Corridors/Linkages

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Core Natural
-  Category 1 Hedgerow
-  Category 2 Hedgerow
-  Category 3 Hedgerow
-  Category 4 Hedgerow
-  Functional Linkages (ABL, 2022)
-  Functional Linkages (Plan B, 2020)
-  Watercourse

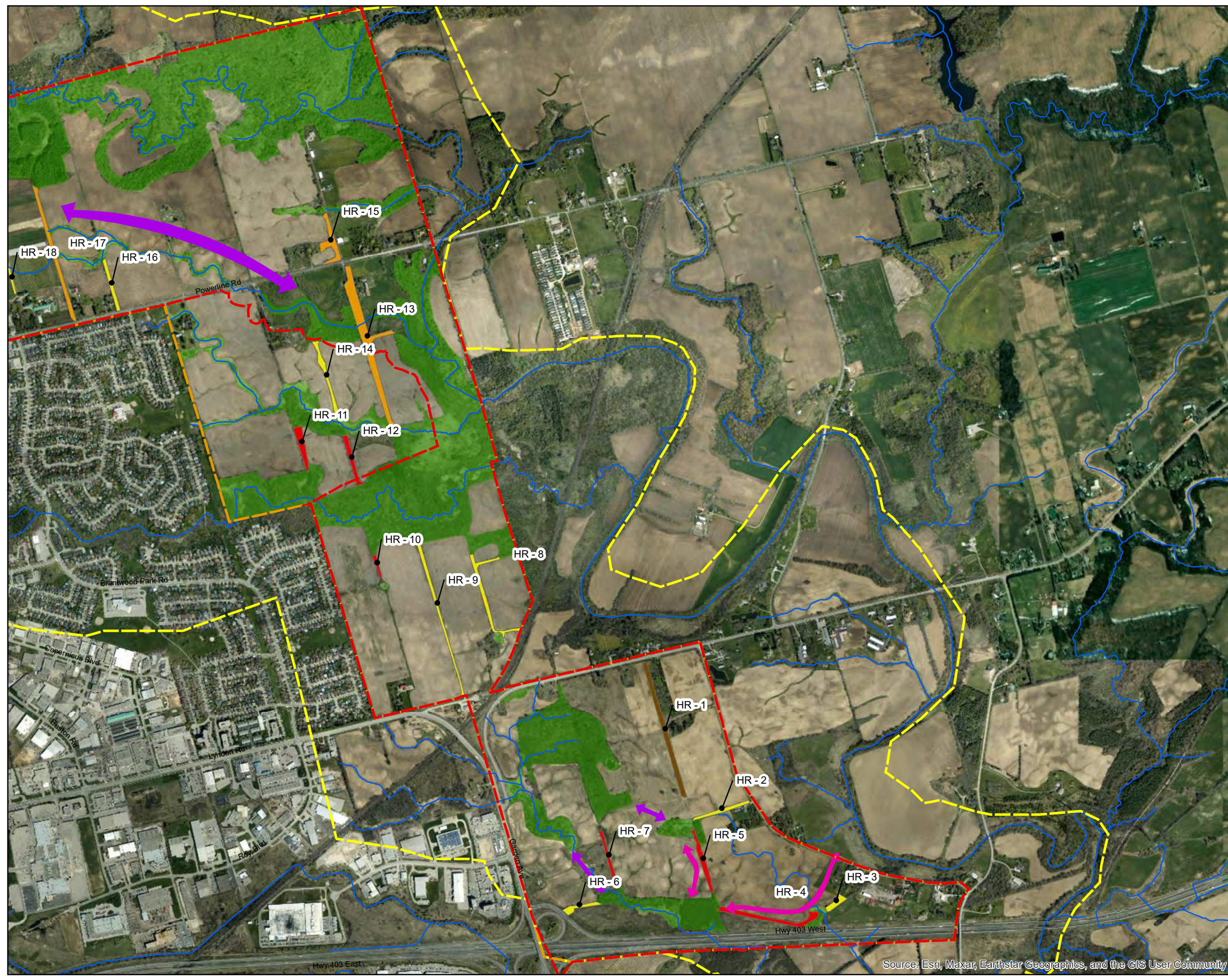
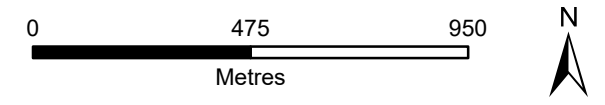













Figure 3.109

Corridors/Linkages

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Legend

-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Core Natural
-  Category 1 Hedgerow
-  Category 2 Hedgerow
-  Category 3 Hedgerow
-  Category 4 Hedgerow
-  Functional Linkages (ABL, 2022)
-  Functional Linkages (Plan B, 2020)
-  Watercourse

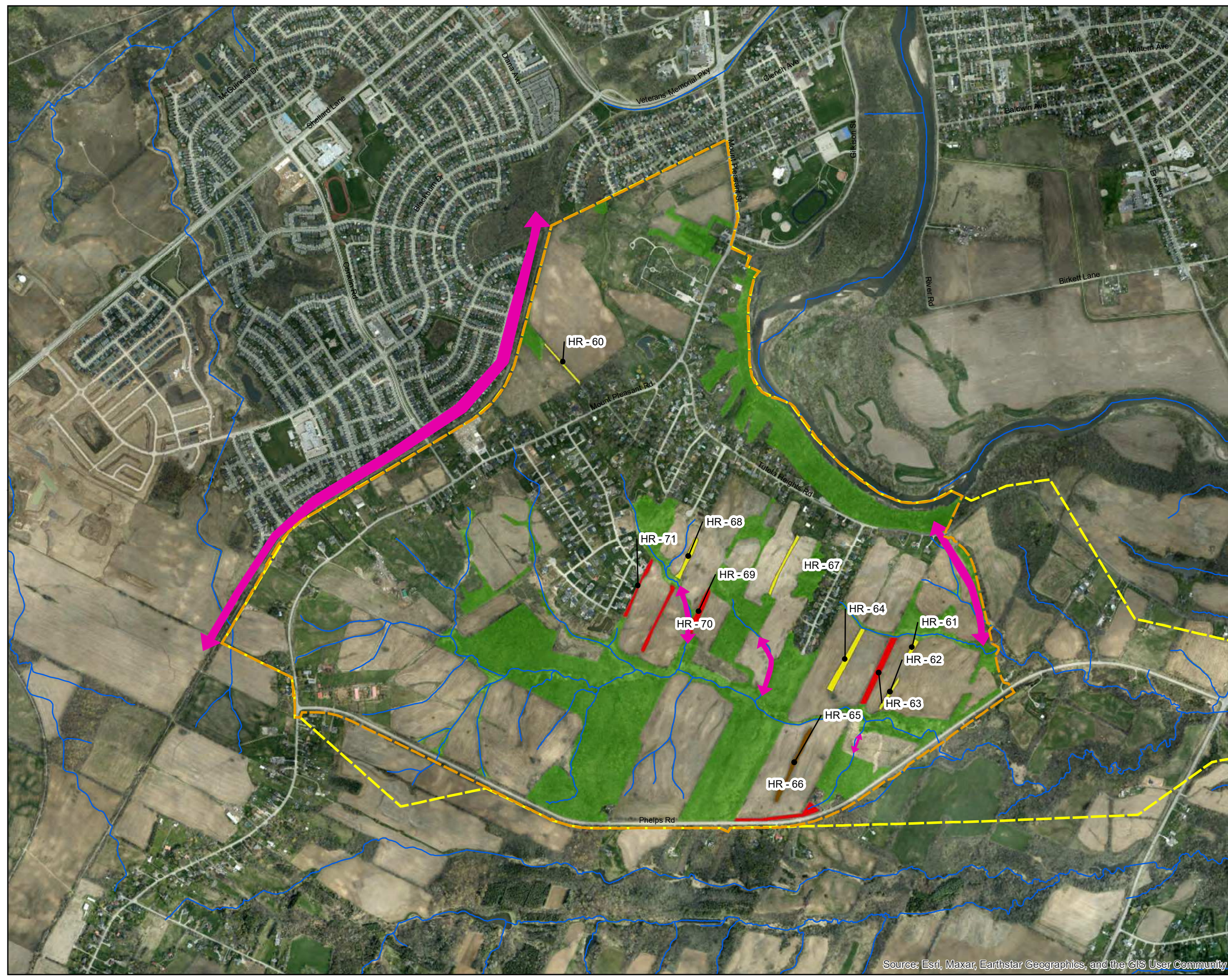
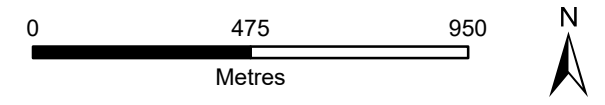


Figure 3.109

Corridors/Linkages

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



3.4.4.6 Other Wildlife

Other wildlife groups were not subject to targeted surveyed during this study, although incidental wildlife observations were recorded during all terrestrial and aquatic ecology field surveys in order to make the characterization of the Study Area as comprehensive as possible. Incidental bird and amphibian observations have been incorporated into their respective sections, above. Other wildlife, including insects, mammals, and reptiles are discussed below.

Discussion of species and habitat from background information sources have been incorporated into the following sections where appropriate.

3.4.4.6.1 Results

Arthropods

A total of 12 arthropod species were recorded during field surveys (**Table 3.42**). However, it is expected that a wide range of other insects are present within the Study Area; dedicated insect surveys were not completed as part of this study. Larger patches of meadows and meadow marshes containing wildflowers, in particular, are likely to support high numbers and diversity of pollinating insects and other arthropods.

One of the species recorded, Monarch (*Danaus plexippus*) is a SAR. Monarch has the potential to occur in any area containing flowers as a food source, including suburban yards, unmown roadsides, and parks. Further information regarding this species and its presence within the Study Area is contained within **Section 3.4.5**.

Spined Orbweaver (*Micrathena gracilis*) was observed in a number of locations along the Jones Creek corridor. It has an S Rank of S3S4 indicating that it is likely provincially rare but with a level of uncertainty.

Mammals

The 2020 Comprehensive EIS (Plan B Natural Heritage, 2020) reported evidence of Eastern Gray Squirrel (*Sciurus carolinensis*), Red Squirrel (*Tamiasciurus hudsonicus*), Eastern Chipmunk (*Tamias striatus*), Meadow Vole (*Microtus pennsylvanicus*), Eastern Cottontail (*Sylvilagus floridanus*), Northern Raccoon (*Procyon lotor*), Striped Skunk (*Mephitis mephitis*), Woodchuck (*Marmota monax*), White-tailed Deer (*Odocoileus virginianus*), Red Fox (*Vulpes vulpes*), and Coyote (*Canis latrans*) in the Study Area. Aquafor recorded eight species of mammal in the Study Area during field investigations in 2022, adding Beaver (*Castor canadensis*) to the list (**Table 3.42**). All of the listed species are common and widespread in southern Ontario and frequently thrive in rural agricultural and lower-density suburban settings.

Reptiles

No reptiles were observed during Aquafor's 2022 field investigations nor the prior field studies completed for the 2020 Comprehensive EIS. Common species such as Eastern Garter Snake (*Thamnophis sirtalis sirtalis*) are likely present in the Study Area nonetheless and have been recorded in opensource databases such as iNaturalist. Ponds, wetland patches, and watercourses

could host Midland Painted Turtle (*Chrysemys picta marginata*) and/or Snapping Turtle (*Chelydra serpentina*) of which both were noted in the NHIC database query, particularly where these features contain abundant vegetation and naturalized riparian areas. Turtle shell fragments and exit holes were found in ELC polygon 175.06 in a patch of exposed sandy/gravel soil on a northeast facing slope.

Table 3.42: Additional Wildlife Observations from 2022 Field Surveys

Common Name	Scientific Name	Status
Arthropods		
Arabesque Orbweaver	<i>Neoscona arabesca</i>	S5
Cabbage White	<i>Pieris rapae</i>	SNA
Common Eastern Bumble Bee	<i>Bombus impatiens</i>	S5
Common Green Darner	<i>Anax junius</i>	S5
Ebony Jewelwing	<i>Calopteryx maculata</i>	S5
Fall Webworm Moth	<i>Hyphantria cunea</i>	S5
Hickory Tussock Moth	<i>Lophocampa caryae</i>	SNR
Lichen-marked Orbweaver	<i>Araneus bicentenarius</i>	SU
Monarch	<i>Danaus plexippus</i>	S2N, S4B; SC
Red Admiral	<i>Vanessa atalanta</i>	S5
Shamrock Orbweaver	<i>Araneus trifolium</i>	S5
Spined Orbweaver	<i>Micrathena gracilis</i>	S3S4
Mammals		
Beaver	<i>Castor canadensis</i>	S5
Coyote	<i>Canis latrans</i>	S5
Eastern Chipmunk	<i>Tamias striatus</i>	S5
Eastern Cottontail	<i>Sylvilagus floridanus</i>	S5
Eastern Gray Squirrel	<i>Sciurus carolinensis</i>	S5
Northern Raccoon	<i>Procyon lotor</i>	S5
Red Squirrel	<i>Tamiasciurus hudsonicus</i>	S5
White-tailed Deer	<i>Odocoileus virginianus</i>	S5

3.4.5 Species at Risk

For the purpose of this study, Species at Risk (SAR) are defined as species listed as Endangered (END), Threatened (THR), or Special Concern (SC) under the provincial *Endangered Species Act* (ESA) and/or the federal *Species at Risk Act* (SARA). Species that have been designated in these categories by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) but are not yet provincially or federally listed have also been considered SAR in this document for the purpose of discussion.

Species listed provincially as Endangered and Threatened receive regulatory protection for themselves and their general or specific habitat under the ESA:

- **General Habitat:** an area on which a species depends directly or indirectly to carry out its life processes (under clause 2(1)(b) of the ESA) or,
- **Regulated Habitat:** the area prescribed for a species in a habitat regulation (under clause 2(1)(a) of the ESA). A habitat regulation may prescribe an area as the habitat of a species by describing the boundaries of the area, the features of the area, or by describing the area in any other manner. Regulated habitat may be smaller or larger than general habitat. As well, unlike the general habitat of a species, regulated habitat may include areas currently unoccupied by the species, such as areas where the species formerly occurred or areas where there is the potential for the species to become re-established. These areas are commonly referred to as “recovery habitat”.

The habitat of Special Concern species does not receive regulatory protection under the ESA but may be considered significant wildlife habitat (SWH) and thus be protected under municipal policy and the PPS (see **Section 3.4.6**).

3.4.5.1 Methodology

In addition to the results of field surveys conducted for this study, a number of primary and secondary information sources were consulted to assess the presence of SAR within the Study Area, as described in **Section 3.4.1**. Information from all background sources was combined to create a comprehensive list of potential SAR associations which was then screened by comparing the habitat needs of each species with the habitat conditions present within the subject property and adjacent lands. The full results of this assessment are provided in **Appendix N**. The following sections provide a more comprehensive discussion of species that were either confirmed or determined likely to occur within the Study Area in the present day based on the availability of suitable habitat.

3.4.5.2 Results

The species listed below were confirmed within the Study Area, either by Aquafor staff during field investigations or by background information resources, or were deemed to have high likelihood of occurring in the Study Area based on historical and/or nearby records and the availability of suitable habitat. Other species noted in **Appendix N** were either screened out based on lack of habitat and/or had some habitat potential but were considered to have low applicability to the current project (e.g., any potentially-suitable habitat features are expected to be captured under other Natural Heritage System criteria and therefore additional discussion specific to those species was not explored at this time). All confirmed habitat is displayed on **Figure 3.110**.

3.4.5.2.1 Endangered and Threatened Species

Barn Swallow – Threatened

Barn Swallow is a Threatened bird species of open-country habitats. It is commonly found in close proximity to humans as it forages over agricultural fields and builds its cup-shaped mud nests inside barns, on the underside of bridges, and in drainage culverts. Although it is the most widespread and abundant swallow in the world, it has been listed as a SAR due to population declines over the northern part of its North American breeding range (Heagy, et al., 2014).

Barn Swallows were observed in the Study Area during breeding bird surveys, and potentially-suitable habitat features (e.g., barns, culverts, and other structures) are present at various locations throughout. No nests were recorded Barn Swallows were recorded over many years throughout the two study areas. All site applications with structures including but not limited to bridges, culverts, barns and other buildings should have a qualified biologist check for the presences of nests.

General habitat for Barn Swallow in Ontario includes nest sites (Category 1 habitat), the area within 5 m of the nest (Category 2 habitat), and the associated foraging habitat between 5 m and 200 m from a nest (Category 3) (MNR, 2013). While nest sites on artificial structures are not appropriate to include in municipal natural heritage designations or related policy discussions, there are requirements under the ESA for the removal or disturbance of structures that provide Barn Swallow nesting habitat, potentially including the provision and monitoring of replacement habitat structures (refer to O.Reg. 830/21). Any proposed development of properties that are associated with nest habitat or foraging habitat adjacent to known nest sites should be assessed during the site-specific EIS stage to determine the potential impacts to this species, as removal of associated foraging areas could cause nest sites to be abandoned.

Bats – Endangered

Four of Ontario’s native bats have been designated Endangered due to an introduced fungal pathogen called “White-nose Syndrome”: Northern Myotis (*Myotis septentrionalis*), Little Brown Myotis (*Myotis lucifugus*), Eastern Small-footed Myotis (*Myotis leibii*), and Tri-colored Bat (*Perimyotis subflavus*). These species are generally associated with forested habitats, specifically where there are standing snags (e.g., cavity trees, trees with large cracks and/or loose or peeling bark), large maples or oaks, other trees or features with collections of dead leaf clusters or fallen pine needles, rock piles or crevices, and other similar features. Some of these species have also been associated with human structures, particularly abandoned buildings which are warm, dark, and close to water or trees. In locations where woodlands are sparse, individual isolated trees or hedgerows may also provide important habitat if the trees include the features described above.

In the Study Area, the potential for SAR bat habitat is considered to be present in all wooded habitats. Although acoustic surveying or other detailed analysis was not completed for this SWS, Aquafor’s past experience indicates that one or more of these species are highly likely to be found where habitat conditions are suitable.

General habitat for the four indicated bat species is protected under the ESA. Development proposals requiring the removal of potentially suitable habitat features are expected to require additional assessment to quantify habitat in the impacted area and to assess the presence/absence of SAR bats via acoustic monitoring per current provincial survey protocols. The MECP may require an Overall Benefit Permit under the ESA for the removal of bat habitat features.

Black Ash – Endangered

Black Ash (*Fraxinus nigra*) is a widespread, formerly common species in Ontario, particularly associated with floodplain forests, swamps, treed shorelines, and other wet areas. It is considered a foundational species in many wet forested ecosystems of central and eastern North America and can play an important role in regulating hydrology through evapotranspiration, which helps in

maintaining suitable site conditions for associated tree, shrub, and herbaceous species less tolerant to flooding. Black Ash populations have undergone significant losses due to the introduced insect pest Emerald Ash Borer, but also experienced losses prior to the introduction of that pest as a result of habitat conversion and the draining/filling of wetlands (COSEWIC, 2019).

Black Ash (*Fraxinus nigra*) was recorded in one polygon, 259.02, and is considered Endangered in Ontario. There are several other background records in the area including a research grade observation made in 2021 located in polygon 196.09 (iNaturalist). Suitable conditions for this species occur in multiple locations, with the highest likelihood considered to be present in the Jones Creek valleylands. In most cases, Black Ash occurrences might be expected to occur in wetlands and other areas that will be protected under municipal Natural Heritage System policies. Individual trees could, however, be found in other areas if conditions are suitable, and therefore future site-specific assessments should seek to identify any occurrence of these trees in impacted areas and to determine necessary actions under the ESA associated with proposed site alteration or land use.

Black Redhorse and Silver Shiner – Threatened; Eastern Sand Darter – Endangered

These three fish species were all identified via DFO's online SAR mapping as having critical habitat present within the Grand River to the north of the Tutela Heights portion of the Study Area.

Black Redhorse (*Moxostoma duquesnei*) lives in pools and riffles of medium-sized rivers and streams that are usually less than 2 m deep, have few aquatic plants, have a moderate to fast current, and provide a sand or gravel substrate. Protected general habitat for this species has not been specifically defined under the ESA, but can be expected to include both the occupied watercourse and the adjacent floodplain and riparian zone which support aquatic habitat function.

Eastern Sand Darter (*Ammocrypta pellucida*) is found in shallow habitats within lakes, streams, and rivers with clean, sandy bottoms. Provincially regulated habitat for this species is defined under O.Reg. 832/21, section 12, and includes: any part of the watercourse up to the high water mark that is currently being used or has been used within the past four years; any part of a watercourse up to the high water mark that is within the same watercourse segment as the preceding; and any area adjacent to those watercourses that is a) an area consisting primarily of vegetation that occurs naturally or with minimal human intervention, such as a forest, woodland, thicket, wetland, old field, pasture, or meadow, or b) within 30 m of the relevant high water mark.

Silver Shiner (*Notropis photogenis*) prefers moderate to large watercourses with swift currents that are free of vegetation and have clean gravel or boulder substrate. The provincial general habitat description for this species includes occupied reaches plus shallow nearshore habitats and vegetated sections associated with those reaches, and the adjacent floodplains and riparian edges.

Blanding's Turtle – Threatened

Blanding's Turtle occurs in a variety of habitats including swamps, marshes, wet meadows, lakes, ponds, slow-flowing creeks, river sloughs, and some human-made features. Preferred habitats, however, are shallow, eutrophic wetlands with organic substrate, slow to no flow, and a high density of aquatic vegetation. Upland habitat is also extensively used as travel corridors and for

hatchling dispersal; adult turtles move extensively between wetlands and can move great distances between habitat features and to find suitable nesting areas (COSEWIC, 2016).

No Blanding’s Turtles were observed within the Study Area, but aquatic and wetland habitat in the Study Area could potentially provide some habitat for this species, and it was noted in multiple background records for the general vicinity. While the majority of potential Blanding’s Turtle habitat is anticipated to be captured under Core Natural Areas designations (e.g., wetlands, watercourses), smaller ponds and wetlands that do not meet NHS thresholds could also provide some habitat function, and nesting areas could occur in exposed gravel or sandy sites at a distance from water (i.e., outside of other NHS boundaries). Future site-specific assessment studies should review the potential for habitat in such features, and ensure that land use plans do not sever potential migration routes or travel corridors for this and other species. Review of road mortality potential and the provision of wildlife road crossing structures may be appropriate for any proposed new or modified roads near potential habitat features.

Bobolink and Eastern Meadowlark – Threatened

Bobolink is an open-habitat bird species that nests on the ground in grasslands, meadows, hayfields, and similar habitats, although they are not typically found in row-cropped agricultural fields or areas with bare soil patches. They prefer grass-dominated fields and may prefer or at least tolerate wetter conditions. They will occupy fields having scattered shrubs or fence posts for perches, but tend to avoid fields where woody cover (i.e., trees and shrubs) is more than 25% of the area. Bobolink is considered an area sensitive species, generally preferring larger grassland patches of >10 ha, although other factors can contribute to site selection and smaller fields may be used if habitat is limited (McCracken, et al., 2013).

Eastern Meadowlark, similarly, is an open-habitat bird that nests most commonly in pastures, hayfields, native grasslands, and savannahs, but also has been known to nest in weedy meadows, young orchards, golf courses, grassy roadsides and similar marginal areas. It rarely nests in row crops. Preferred habitat features are moderately tall grasses with abundant litter cover, a high proportion of grasses, low woody cover and a low proportion of bare ground. They frequently use scattered trees, shrubs, telephone poles, and fence posts as elevated song perches, which could be an additional important habitat component. It is considered area-sensitive, preferring larger tracts of grassland with minimum patch size about 5 ha (McCracken, et al., 2013).

Both Bobolinks and Eastern Meadowlarks were recorded in the Study Area during prior breeding bird surveys. Plan B noted Bobolink on July 9 2017 at Station 22 and 24 which are located along Governors Rd. Plan B also recorded Eastern Meadowlark at Stations 23, 24, and 25 located along Governors Rd and Park Rd N. There were noted in Aquafor’s habitat review in 2022 indicated that the majority of agricultural lands in the Study Area at that time were in active cultivation for row crops and therefore did not support Bobolink or Eastern Meadowlark habitat. However, any change in agricultural practices (e.g., fields being left fallow) could result in increased habitat suitability. Cultural meadow patches currently occur in some locations within the Study Area. Habitat for these species should be confirmed in future site-specific studies that document current conditions at the time of a proposed development application. As both of these birds are known to require large tracts of contiguous habitat, future site-specific assessments should bear in mind

that a partial removal of an area providing habitat may render the remaining habitat unsuitable for future occupation.

As a Threatened species, these two birds receive general habitat protection under the ESA. General habitat for Bobolink and Eastern Meadowlark includes the area within 10 m of a nest (Category 1 habitat), the area between 10 m and 60-100 m of a nest or approximate center of defended territory (Category 2 habitat), and the area of continuous suitable habitat up to 300 m from a nest or the approximate center of a defended territory (Category 3 habitat) (MNRF, 2013). Some development of habitat areas may be permitted under certain conditions as covered by O.Reg. 830/21 to the ESA, provided that the proponent complies with the stated requirements including the creation or enhancement of replacement habitat.

Butternut – Endangered

Butternut is a short-lived (<75 years), mast-bearing tree that is frequently found along floodplains, streambanks, and ravine slopes, but can occur in a wide variety of other conditions. It is more common in areas with underlying limestone and is generally absent from regions with acidic soil such as the granite-dominated areas of the Canadian Shield. Butternut is intolerant of shade and tends to be found either as a mature canopy tree or in or in openings and edges (COSEWIC, 2017). The primary threat to Butternut is an introduced exotic fungal pathogen, *Sirococcus clavigignenti-juglandacearum* (“butternut canker”). Infection generally occurs through wounds, broken branches or leaf scars, causing twig dieback and eventual tree mortality. The most obvious sign of infection is a black, oozing canker on the stem or twigs.

Potential habitat for Butternut occurs throughout the subwatershed Study Area, and background records identified Butternut within the North Brantford portion of the SWS Study Area. Butternuts were found by Aquafor staff in ELC polygons 259.01, 211.05, and 1006. It is considered highly likely that there are more Butternut trees in the Study Area, particularly throughout the Jones Creek and Phelps Creek valleylands.

Butternut is currently designated as Endangered and receives general habitat protection under the ESA. The provincial Butternut Recovery Strategy (Poisson & Ursic, 2013) recommends that a minimum radius of 25 m from the base of the stem of all Butternuts be considered protected habitat. However, it also recommends that this protection only be applied to healthy trees (i.e., trees which are not affected by the canker to the degree they are classed as “non-retainable” by a Butternut Health Assessment). The MNRF’s interim guidance on general habitat for Butternut under the ESA (2015) confirms that a 25 m radius from each tree should be considered Category 1 habitat which protects the critical root zone and other functions that support the life of that individual, but further adds that suitable areas from 25-50 m of a tree should be considered Category 2 habitat necessary for nut dispersal and seedling establishment. Aquafor Beech therefore recommends a 50 m radius around each retainable Butternut be assessed for tree and/or habitat impacts during site-specific assessments prior to any site alteration or development. Some removal of or injury to Butternuts may be permitted under certain conditions as covered by O.Reg. 830/21 to the ESA, provided that the proponent comply with the stated requirements for assessment of individual trees, mitigation of impacts, and replanting and monitoring where appropriate.

3.4.5.2.2 Special Concern Species

Eastern Wood-pewee and Wood Thrush

These two Special Concern bird species are typically found in wooded habitats throughout southern Ontario. Both were documented in the SWS Study Area during breeding bird surveys.

The Eastern Wood-pewee occurs throughout Southern Ontario, breeding most often in deciduous forests with an open understory, with a preference for nest sites near clearings and forest edges. In general, the size of forest fragments does not appear to be an important factor in habitat selection for this species, though the presence of residential developments surrounding woodlots does appear to decrease the likelihood that Eastern Wood-pewee will be present. The presence of dead branches that are used as hunting perches may be an additional habitat need (COSEWIC, 2012). Threats contributing to the decline of this species are not fully understood. Forest fragmentation of itself does not appear to be a major factor since the size of forest fragments was not found to significantly affect nest site selection. However, the overall amount of forest cover on the landscape and the proximity of human development to remaining woodlots may both influence habitat suitability. As noted above, Eastern Wood-pewees are less likely to be found in urban woodlots surrounding by residential developments as opposed to forests in natural or rural settings. Reductions in flying insect populations, which are the main food source for Eastern Wood-pewee, are also a likely factor (COSEWIC, 2012).

Similarly, Wood Thrush nests in moist deciduous and mixed forests, preferring stands with previous disturbance (i.e., second growth), closed canopy cover, and a dense undergrowth beneath tall trees that act as singing perches. It prefers nesting large forest mosaics but will also use fragmented forests.

As Special Concern species, Eastern Wood-pewee and Wood Thrush habitat does not receive regulatory protection under the ESA. Key habitat components could, however, be considered Significant Wildlife Habitat and included as part of the Core Natural Areas designation under municipal policy. It is anticipated that the majority of habitat features and functions utilized by these species will be encompassed by significant woodland and other similar feature designations, but future impact assessment studies should ensure that appropriate setbacks to Eastern Wood-pewee nesting habitat areas are established and that land use plans do not fragment or isolate habitat features on the landscape.

Grasshopper Sparrow

Grasshopper Sparrow (*Ammodramus savannarum*) typically nests in medium to large grasslands both of anthropogenic origin, such as hayfields and pastures, and of natural origin such as prairies, alvars, or other areas where tree and shrub cover is limited. Habitat is typified by well-drained and often poor dry soil, patches of bare ground, low sparse perennial vegetation cover, and few shrubs. They tend to avoid fields where the density of shrubs or other vegetation is too high, but also may avoid intensively-grazed pasturelands with few perches (COSEWIC, 2013). Grasshopper Sparrow is a small, drab-coloured bird with a quiet, buzzy song, that frequently skulks low in grassy cover, and as such may be overlooked or missed at times during surveys. It is considered area-sensitive, requiring larger contiguous patches of habitat typically >10 ha (MNRF, 2000).

Grasshopper Sparrow was not directly observed within the Study Area, but the presence of species with similar habitat requirements (Bobolink and Eastern Meadowlark) and the fact that much of the surveying for this study was done from roadsides, suggests that Grasshopper Sparrow could be present in areas with suitable habitat but might have been overlooked during past surveys. As a Special Concern species, regulatory habitat protection does not apply for Grasshopper Sparrow.

Midland Painted Turtle and Snapping Turtle

These two Special Concern turtle species are, despite their designation, still fairly ubiquitous in southern Ontario and known to inhabit a variety of habitats including rivers, creeks, and other watercourses, ponds (including stormwater ponds and other anthropogenic features), and wetlands. Both tend to prefer sites with soft substrate, and will nest in sandy or gravelly material in sunny locations such as road shoulders, field edges, etc. While neither species was directly confirmed by field investigations within the Study Area, individuals are expected to be present at one or more locations where habitat conditions are suitable.

As Special Concern species, neither species receives regulatory protection under the ESA. However, important habitat features that support the life cycle of either species could be considered Significant Wildlife Habitat and provided protection under municipal policy. While most habitat features are anticipated to be captured under other Core Natural Areas designations (e.g., for watercourses or wetlands), this additional consideration of SWH could be a factor in the assessment of small wetland patches, isolated pools or farm ponds, or other features which might not otherwise be evaluated for the NHS. Future site-specific assessment studies are recommended to review the potential for habitat in such features, and ensure that land use plans do not sever potential migration routes or travel corridors for this and other species. Review of road mortality potential and the provision of wildlife road crossing structures may be appropriate for any proposed new or modified roads near potential habitat features.

Eastern Ribbonsnake

Eastern Ribbonsnake are found close to water, most commonly marshes. They hibernate in underground burrows or rock crevices to hibernate together. The northern study area has many records of this species within the Cold Springs Creek Complex (PSW) and to the north in the Tertiary study area. The riparian areas along Jones Creek has patches of marsh that have the potential to provide habitat. While most habitat features are anticipated to be captured under other Core Natural Areas designations (e.g., for watercourses or wetlands), this additional consideration of SWH could be a factor in the assessment of small wetland patches, isolated pools or farm ponds, or other features which might not otherwise be evaluated for the NHS. Future site-specific assessment studies are recommended to review the potential for habitat in such features, and ensure that land use plans do not sever potential migration routes or travel corridors for this and other species. Review of road mortality potential and the provision of wildlife road crossing structures may be appropriate for any proposed new or modified roads near potential habitat features.

Monarch

The well-known Monarch butterfly is currently listed as Special Concern both provincially and federally and therefore receives no regulatory protection. However, the Committee on the Status

of Endangered Wildlife in Canada (COSEWIC) recommended the redesignation of the Monarch as Endangered in 2016, citing declines of greater than 50% in the last decade. The primary threats facing the Eastern North American Monarch population include the degradation and loss of overwintering habitat in Mexico, the widespread use of pesticides and herbicides throughout their breeding grounds, climate change, severe weather events, succession and/or conversion of breeding and nectaring habitat, and the impacts of bark beetles on overwintering habitat (COSEWIC, 2016).

Adult monarchs were observed during field investigations in the Study Area and reported via background sources. It is anticipated that adult Monarchs will also be present at additional locations throughout the Study Area, wherever flowers occur as a food source. As a Special Concern species, neither Monarch nor its habitat receives regulatory protection under the ESA. The federal Management Plan for the Monarch (Commission for Environmental Cooperation, 2009) recommends the conservation and enhancement of Monarch breeding and nectaring habitat in Ontario – i.e., open grasslands, meadows, wetlands, etc. which contain wildflowers, particularly milkweeds which are the required larval host plants. The Management Plan also encourages landscaping with native species and the creation of butterfly gardens in residential developments, which is a measure that could be carried forward to future development proposals.

3.4.5.3 Conclusions

SAR associated with the Study Area were screened based on background information and the availability of habitat. Five SAR (Barn Swallow, Bobolink Eastern Meadowlark, Eastern Wood-pewee, and Wood Thrush) were directly observed in the Study Area during the field investigations completed for the 2020 Comprehensive EIS by Plan B Natural Heritage. Two additional species (Butternut and Monarch) were documented by Aquafor Beech in 2022. Additional species, listed above, were reviewed using background information and knowledge of habitat preferences and determined to have the potential to occur in the Study Area and to be relevant to the current discussion regarding natural heritage constraints and future land use planning.

Certain SAR habitats (e.g., Barn Swallow nest sites) are associated mainly with anthropogenic structures and therefore would not be appropriate to designate as part of the Natural Heritage System. In many cases, SAR requirements and habitat protections are more appropriate to evaluate in the context of provincial and/or federal legislation as opposed to municipal policy. Therefore, while SAR observation and habitat information has been provided in this SWS for reference and discussion, it is expected that future site-specific studies completed as part of development proposals in the Study Area will include an updated SAR screening and assessment based on the most up-to-date listings and available knowledge at that time. Those studies shall confirm the presence/absence of the species listed above, plus any additional species as appropriate, and their habitat, and identify the requirements for each under both applicable SAR legislation and municipal policy.

Legend

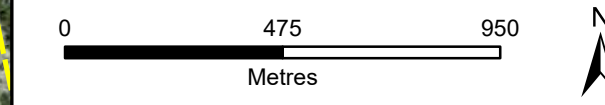
- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Butternut
- Honey-locust
- Butternut Habitat
- Rare Vegetation Communities - Confirmed
- Black Ash
- Turtle Wintering Areas -
- Amphibian Breeding Habitat (Confirmed) - Adjacent Wooded Features



Figure 3.110

**Species at Risk and Significant
Wildlife Habitat**

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Legend












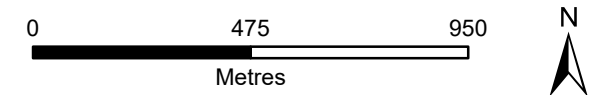
-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Watercourse
-  Butternut
-  Honey-locust
-  Butternut Habitat
-  Rare Vegetation Communities - Confirmed
-  Black Ash
-  Turtle Wintering Areas -
-  Amphibian Breeding Habitat (Confirmed) - Adjacent Wooded Features

Figure 3.110

**Species at Risk and Significant
Wildlife Habitat**

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Legend

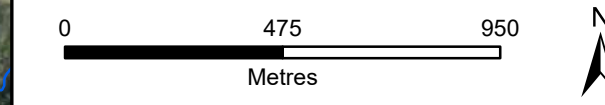
- Primary Study
- Secondary Study
- Tertiary Study
- Watercourse
- Butternut
- Honey-locust
- Butternut Habitat
- Rare Vegetation Communities - Confirmed
- Black Ash
- Turtle Wintering Areas -
- Amphibian Breeding Habitat (Confirmed) - Adjacent Wooded Features



Figure 3.110

Species at Risk and Significant Wildlife Habitat

Date: August 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

3.4.6 Significant Wildlife Habitat

Wildlife habitat is considered to be significant when it is “ecologically important in terms of features, functions, representation or amount, and contributing to the quality and diversity” of wildlife habitat (MMAH 2020). Specifically, when habitat provides features and functions critical to the survival of an individual, species, or group, it may be considered Significant Wildlife Habitat (SWH); for example, specialized vegetation communities, nest/den sites, overwintering sites, and migratory stopovers with particular characteristics may be limited on the landscape and/or provide habitat function during key life stages of the organism, and would therefore be considered significant.

3.4.6.1 Methodology

The *Significant Wildlife Habitat Criteria Schedules for Ecoregion 7E* (MNRF, 2015) document was used as a basis to evaluate and discuss the presence of Significant Wildlife Habitat (SWH) within the Study Area. The corresponding analysis and assessment of all SWH types are detailed in **Appendix O**. Confirmed and Candidate SWH types identified through this screening process are described below and illustrated, as appropriate, on **Figure 3.110**. Please note that for properties where access permission was not granted or where field investigations data were not sufficient to fully confirm the presence/absence of a species or feature, a conservative approach to identifying candidate habitat was used where required. It is expected that future site-specific studies completed as part of development proposals in the Study Area will include an updated SWH assessment based on the most up-to-date available information at that time. Those studies shall confirm the presence/absence of the habitat types discussed below, plus any additional categories as appropriate, and identify the requirements for each under applicable municipal policy.

3.4.6.2 Results

Raptor Wintering Area – Candidate

Candidate habitat in this category includes areas with a combination of forest and field to provide all of the necessary habitat functions. It is possible that the valleylands and forests along Jones Creek in the northeastern portion of the North Brantford Study Area could provide this type of habitat in conjunction with cultural thicket, cultural meadow, and adjacent agricultural fields. Additionally, there is a large forest block in the Tutela Heights Study Area that, along with adjacent agricultural fields, could also provide this type of habitat. Further studies would be required to determine if habitat is in use.

Bat Maternity Colonies – Candidate

Mature forests meeting the requirement for candidate maternity habitat are present in the Study Area. Therefore, all woodlands (e.g., forests, treed swamps, cultural woodlands, and plantations) with trees exhibiting suitable habitat characteristics are considered to be candidate bat maternity habitat; these areas are not depicted on **Figure 3.110**, as mapping all woodlots in the Study Area would render the figure largely illegible for other features. Further studies at subsequent planning stages may be required to confirm the presence of this SWH type in specific woodlands, if impacts to those woodlands are proposed.

Turtle Wintering Areas – Candidate

Five ponds (W2, W3, W68, W72, and W73) were identified in the Study Area as having potential for this habitat type. Spring basking surveys would be required to confirm whether these features provide turtle habitat, as confirmation studies were not part of the current SWS scope.

Rare Vegetation Communities – Confirmed

Five rare vegetation communities were identified in the Study Area during field investigations:

- FODM2-3 (FOD2-3) – Dry – Fresh Hickory Deciduous Forest, S3S4
- FODM7-4 (FOD7-4) – Fresh – Moist Black Walnut Lowland Deciduous Forest, S2S3
- FODM7-5 (FOD7-5) – Fresh – Moist Black Maple Lowland Deciduous Forest, S3
- FODM9-5 (FOD9-5) – Fresh – Moist Bitternut Hickory Deciduous Forest, S3S4
- SWTM2-3 (SWT2-9) – Gray Dogwood Mineral Deciduous Thicket, S3S4

This assessment has included communities with S3S4 ranking as there is a stated uncertainty as to the community's rarity and therefore the more conservative measure will be used unless and until there is reason to determine otherwise.

Turtle Nesting Areas – Candidate

Candidate habitat includes sand/gravel areas close to water; SWH confirmation would require observation of minimum numbers of nesting turtles of particular species. One observation of a recent turtle nest was recorded by Aquafor in ELC polygon 175.06, in a sandy gravel patch along a northeast facing slope, but the turtle species associated with that nest could not be confirmed. The observed turtle nest location will be enclosed in Natural Heritage System designations; however, there is the potential for other nesting sites outside of the features surveyed. It should be noted that road shoulders do not technically qualify as SWH per the published criteria, although these types of areas do frequently provide a high habitat function.

Amphibian Breeding Habitat (Woodland) – Confirmed

The provincial criteria for significance in this category were met at Aquafor's survey station E, where at least 20 total individuals of two of the listed species (Spring Peeper and Gray Tree Frog) were reported via field investigations. The significant habitat area surrounding the breeding pond/wetland is to include woodland areas within a 230 m radius as well as consideration of travel corridors/dispersal routes; for station E, the adjacent woodland includes only small treed patches along property margins and isolated trees, with what appears cultural meadow habitat in the travel corridor between these features.

Given the overall scarcity of habitat and observed amphibian breeding in the SWS Study Area, however, such areas that might be considered marginal habitat in other locations could have greater significance in the Study Area if they provide the only available habitat in the vicinity. Future site-specific assessments are recommended to evaluate amphibian presence and habitat not only in the context of the provincial criteria schedule thresholds for significance but in the

context of potential local significance if development or site alteration will remove features that support isolated amphibian populations.

Special Concern and Rare Wildlife Species – Confirmed

Special Concern species (Wood Thrush, Eastern Wood-pewee, Monarch) were documented in the Study Area, with potential for other species and their habitat to also be present (primarily Midland Painted Turtle and Snapping Turtle). Significant habitats of these species would include areas that are integral to their important life processes; not every observation location of a Special Concern species is necessarily going to represent an important habitat. For the noted species, important habitats are expected to include woodlands (for Eastern Wood-pewee and Wood Thrush nesting) and ponds/wetlands and adjacent turtle nest sites. All of these features have been previously discussed under other SWH categories or other constraints identified for this study.

Amphibian Movement Corridors – Confirmed

An amphibian movement area was identified between the breeding pond/wetland at survey station E (which was associated with sufficient numbers and species to confirm SWH for amphibian breeding) with the nearest (and only) adjacent wooded habitat area, in keeping with provincial SWH criteria requirements. Future ground-truthing and mapping in the field may be completed to confirm the configuration and limits of this area.

3.4.6.3 Conclusions

Using the MNRF criteria schedules for identifying SWH, four categories of SWH were confirmed in the Study Area based on current information (amphibian breeding habitat and movement corridors, rare vegetation communities, and rare or Special Concern species habitat). Additional candidate SWH features were flagged for future consideration as well based on the observed conditions and available information (raptor and turtle wintering areas, bat maternity colonies, turtle nesting areas). In all cases, significant habitat concepts and features identified in this SWS were based on observed conditions and background information available at the time of this study, addressing the large-scale Study Area of the entire SWS. SWH is therefore expected to be reviewed and subject to additional investigation as appropriate during future site-specific assessment studies, particularly for properties which had limited access for field investigations or which contain complicated micro-habitats which may have been beyond the scope of this SWS to assess sufficiently.

3.4.7 Summary of Ecological Resources

The ecological resources within the Study Area were characterized through a combination of field investigations and background information review.

Watercourses in the Study Area provide both direct and contributing fish habitat. The Jones Creek system provides a variety of aquatic habitat, with the highest quality habitat occurring in the North Branch. Silver Creek, the Golf Course Tributary, Ravine Tributary, and Karek North and South Tributaries showed limited function as aquatic habitat with intermittent flow regimes. Fish were observed throughout the Study Area, consisting of common to abundant, intermediately tolerant to tolerant species that demonstrate a cool-warmwater thermal regime. Only habitat within the North Branch of Jones Creek demonstrate coldwater characteristics with incidental observations of Brook trout supporting this. Minimal barriers to fish passage were found in the main channels, with fragmentation observed in intermittent watercourses and contributing features such as Tributary K.

Benthic invertebrates were collected and submitted to an accredited laboratory for identification. These results will be analyzed and evaluated to contribute to aquatic habitat and fish habitat observations at a later date.

A total of 121 ELC polygons consisting of 40 unique vegetation types were identified in the Study Area. These included forests, woodlands, wetlands, and culturally influenced community types. Four of the vegetation community types, representing nine polygons, are considered provincially rare. Additional polygons were identified in the Study Area where required via desktop review of available resources (namely the 2020 Comprehensive EIS). Within these areas, Aquafor identified 279 plant species including one Species at Risk, Butternut. Wetland communities were reviewed in the context of whether they would be appropriate to include in the Provincially Significant Wetland Complex that is present in the North Brantford Study Area. Hedgerows were assessed for their potential to provide linkage function on the landscape.

Sixty-nine bird species were recorded in the Study Area during the previous surveys completed for the 2020 Comprehensive EIS, and Aquafor's field surveys, completed in 2022 to supplement and/or confirm the prior data, recorded 41 species of birds (largely overlapping with the species results of the prior surveys). Most observed species were those common to rural and suburban generalist habitats, but five SAR (Eastern Wood-pewee, Wood Thrush, Bobolink, Eastern Meadowlark, and Barn Swallow) were also documented. Other wildlife species observations in the Study Area included five amphibians, eight mammals, and 12 arthropods.

SAR with the potential to occur in the Study Area were identified via background resources and screened against the habitat that is currently present on site. The full results of this screening are provided in **Appendix O**, and **Section 3.4.5** provides discussion on those species which confirmed or potentially present and/or which had habitat potential and were deemed require further discussion relevant to the objectives of this SWS. Similarly Significant Wildlife Habitat concepts were evaluated as detailed in **Appendix O**, with several confirmed or candidate habitat categories being identified for further review as part of this or future studies, as discussed in **Section 3.4.6**.

4 Opportunities and Constraints

The preceding sections provided an overview of the environmental features and functions within the Study Area. These environmental features and functions have been summarized below to describe how they provide opportunities or constraints to future development within the Study Area.

The term “constraints” is used here to indicate features or areas which will be subject to some limitation regarding future development (this includes natural heritage features which will be protected as part of the City’s NHS and natural hazard policy as outlined in the Official Plan) or which are recommended for further investigation to fully understand the features/functions present and therefore the potential impacts of development before any action is approved.

Opportunities for restoration and enhancement of existing natural heritage resources were identified based on the results of site investigations and a landscape-level review. It is recognized, however, that the opportunities identified do not represent the only opportunities for improvement that may exist within the Study Area, and that future site-specific studies may refine or revise the noted locations with support from a suitable impact assessment or similar study.

4.1 Natural Hazards

Natural Hazards within the Study Area include both Flood Hazards associated with riverine flooding as well as the Erosion Hazard associated with channel migration and bank instability. All restrictions from the City of Brantford’s Official Plan shall be followed, including Section 6.1 (Floodplain Areas) and Section 6.2 (Steep Slopes and Erosion Hazards).

Along with the policy in the City’s Official Plan, relevant natural hazards policy includes Ontario Regulation 150/06 Regulation of Development, Interference with Wetlands and Alteration to Shorelines and Watercourses which is administered and enforced by the Grand River Conservation Authority (GRCA). This regulation was created for the following reasons:

- To minimize the risk to loss of life and property damage as a result of flooding
- To direct development away from natural hazard prone land (e.g., flooding, erosion)
- To determine whether or not in the opinion of the Authority, the development proposal will affect the control of flooding, pollution, or the conservation of land
- To require permission to straighten, change, divert or interfere with the existing channel of a river, creek, stream or watercourse or change or interfere with a wetland

Regulation allowances of 15 m are added to both banks of the flood and erosion hazard limits. Regulation allowances allow the GRCA to regulate development adjacent to erosion and flooding hazards in a manner that provides protection against unforeseen or predicted external conditions that could have an adverse effect on the natural conditions or processes of the river or stream valley. Development within the allowance must be regulated to ensure that existing erosion and flooding hazards are not aggravated, that new hazards are not created, and to ensure that

pollution and the conservation of land will not be affected. The allowance provides GRCA and the partner municipalities with the opportunity to maintain, restore or enhance the natural features of the river or stream valley. Regulation of development in the allowance is also required to deal with issues related to accuracy of the modeling and analysis tools utilized to establish the limits of the erosion and flooding hazards.

4.1.1 Flood Hazards

Per the City's Official Plan, development is limited within the floodplain limits of the Grand River, D'Aubigny Creek, Jones Creek, Phelps Creek and the tributaries of Fairchild Creek. Development will minimize hazards to the public and will be limited to public infrastructure, flood control works, and structures associated with open space uses.

As discussed in **Section 3.3.3**, hydrologic and hydraulic modeling were completed for the Study Area. The governing storm for floodplain delineation is the larger of the 100-year and Regional storm. In some reaches, it was found that the 100-year floodplain was larger, while in other reaches, the Regional floodplain was larger. **Figure 4.1** and **Figure 4.2** present the 100-year and Regional floodlines, respectively, as compared to the existing estimated GRCA floodlines.

4.1.2 Erosion Hazards

Generally, the erosion hazard limit in unconfined fluvial systems is delineated by the meander belt while confined systems are offset by a stable slope assessment. While meander belt delineation was not included in the scope of work for this SWS, and will need to be developed all unconfined reaches, the stable slope hazard was evaluated for development constraint assessment in the confined watercourses.

The final LTSS setbacks are to be confirmed based on detailed geotechnical field investigations after completion of the Subwatershed Study. The detailed studies are to follow the MNR (2002) technical guidelines to refine, as appropriate, the generic setbacks of 15 meters erosion allowance plus 3-horizontal to 1-vertical stable slope plus 6 m erosion access allowance.

The reaches in the Study Area were assessed for their critical grain size erosion threshold through the use of the hydraulic model and its computed channel velocity associated with specific flow events including the 2-, 5-, 10-, 25-, 50- and 100-year flow scenarios. The channel velocity values were used with Komar's and Isbash's equations to identify the critical grain size erosion thresholds. The Komar and Isbash equations are shown below:

Komar Equation:

$$v = 57 * D^{0.45}$$

Where:

v = Velocity (m/s)

D= Characteristic particle diameter of the sediment (m)

Isbash Equation:

$$D = V^2 / 2gC^2(s-1)$$

Where:

V = Water Velocity(m/s)

C = Isbash Coefficient dimensionless

g = Acceleration due to gravity (m/s²)

s = Specific Gravity of stone or rock

D= Characteristic particle diameter of the sediment (m)

For both equations, the characteristic particle diameter of the sediment was calculated. Specifically, for the Isbash equation, the Isbash coefficient that was used assumed high turbulence conditions for a more conservative estimation – which has a dimensionless value of 0.86. The specific gravity of stone or rock value of 2.68 was used which represents the specific gravity of silty sand – the soil type found through each reach.

The diameter calculated from both equations were compared and the larger grain size of the two was chosen. The grain size values were further interpreted into the Wentworth grain size nomenclature. The table below summarizes the most conservative critical threshold grain size for each reach for all flood events mentioned above. Reaches that were not assessed was due to the unavailability of hydraulic data.

The hydraulic model provides channel velocity for each flow event. A summary of the critical erosion threshold is shown in **Table 4.1**. Based on the critical grain size erosion threshold calculated, all reaches that could be assessed are erodible during all flow events with the exception of Reach UJT2-6-HOL. The banks in Reach UJT2-6-HOL are erodible for all flow events and substrate is erodible only under the 2yr, 5yr and 10yr flow events upstream of Golf Rd due to the culvert on this reach at Golf Rd (**Figure 4.3**). **Figure 4.3** shows the water elevation of all flows relative to the culvert at Golf Rd. All flows above the 2-year event create a backwater to Golf Road that slows the channel velocity and decreases shear stress on the channel. Enlarging the culvert will further increase erosion at higher flows and should be considered along with any improvements to the culvert at this crossing.

4.1.2.1 Erosion Hazard Constraints

The erosion hazard assessment was mapped with all known geomorphic erosion hazards, including those reaches that need to fulfill the requirement of a meander belt assessment at the block planning stage. **Figure 4.4** and **Figure 4.5** show the stable slope hazard limit with respect to confined watercourses and the reaches requiring meander belt assessment. Where access was not provided to assess the watercourse, the assumption of a channelized watercourse was made in all cases, thereby requiring a meander belt assessment, whereas the presence of an HDF would preclude this requirement. Stable slope offset requirements may in turn be reduced with appropriate geotechnical evaluation of a reduced stable slope from the 3:1 ratio used in this analysis.

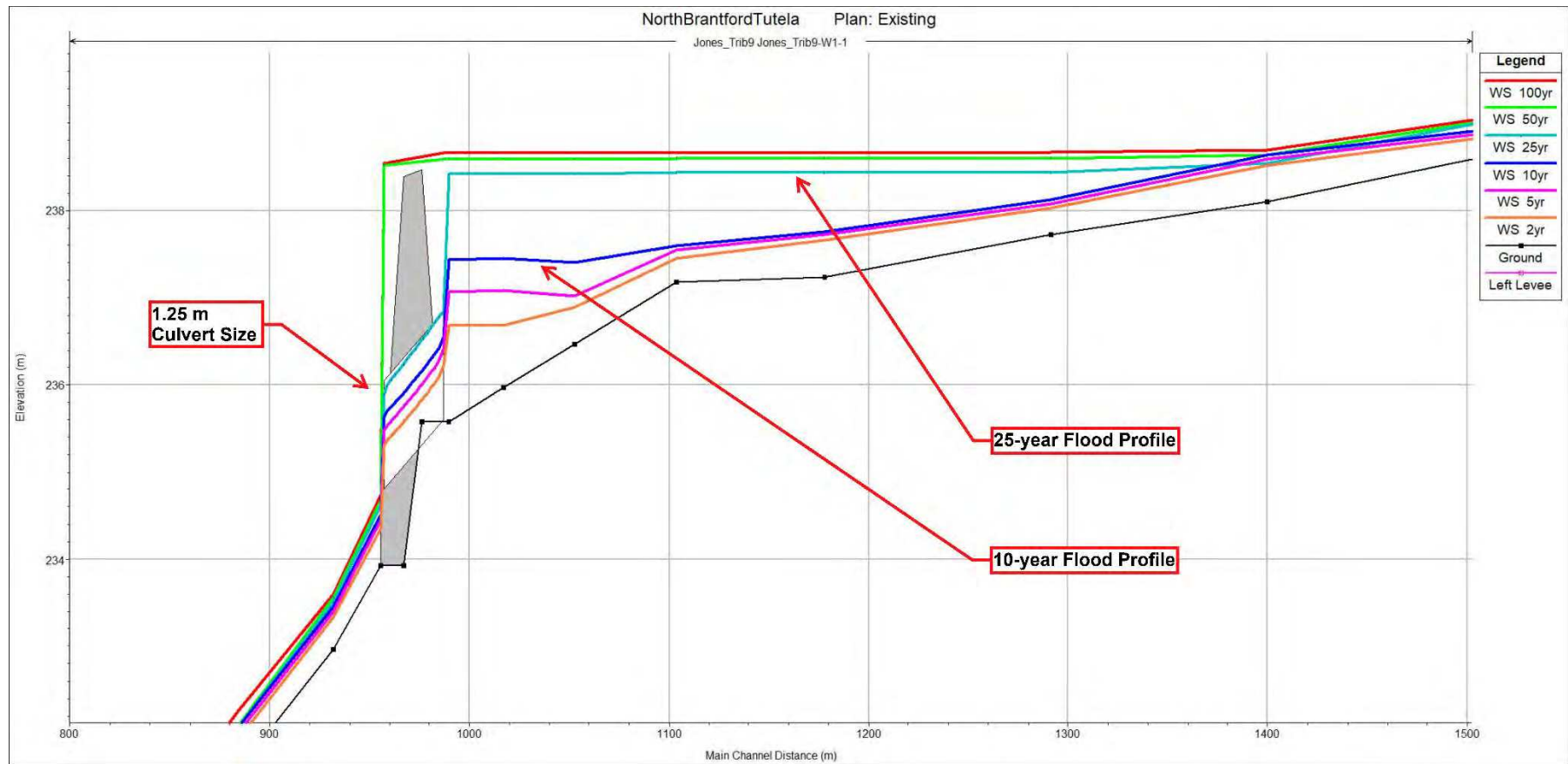


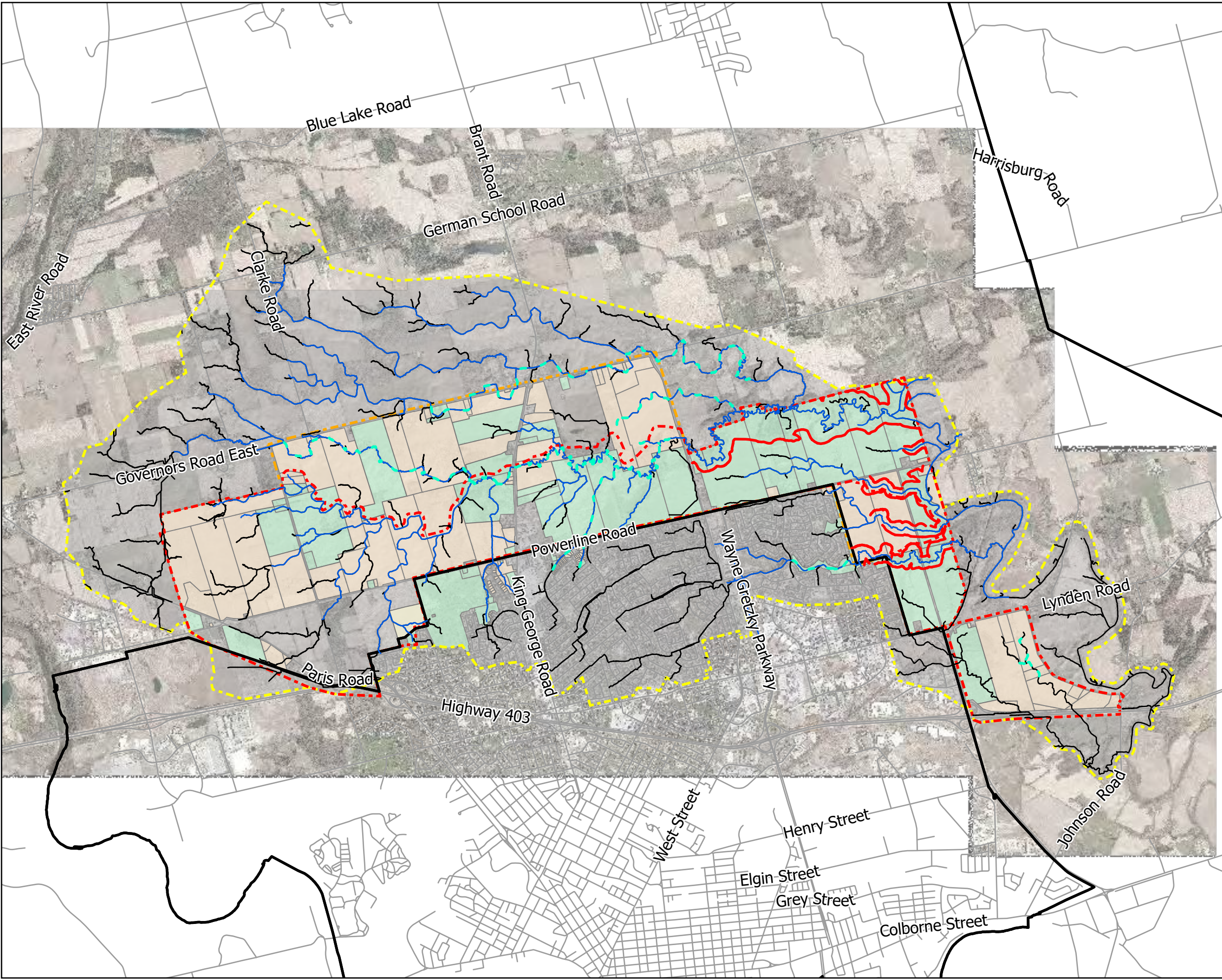
Figure 4.3: Profile for Reach UJT2-6-H0L (Jones Trib9 W1-1) for all flow events.

Table 4.1: Erosion Thresholds by Study Reaches









Reach	Existing Bank Material	Existing Bed Material	Erodibility	Grain size transportable by specific flow event					
				2yr	5yr	10yr	25yr	50yr	100yr
T1	Silt to fine sand	Silt to fine sand	All Flood Events		Medium Pebbles	Medium Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles
T2-H	Silt to fine sand	Silt to fine sand	All Flood Events	Coarse Pebbles	Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles
T2-Ha	Silt to fine sand	Silt to fine sand	All Flood Events	Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Cobbles	Cobbles
T2	Silt and Clay to very fine sand	Silt and Clay to very fine sand	All Flood Events	Fine Pebbles	Medium Pebbles	Medium Pebbles	Medium Pebbles	Medium Pebbles	Medium Pebbles
T2-Hb	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
T3	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
T3-H	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
T4	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
GDT1-2-H10	HDF	HDF	Cannot be assessed	-	-	-	-	-	-
GDT1-2-H8	silt to fine sand	silt to fine sand	No Station	-	-	-	-	-	-
GDT1-2-H9	silt to fine sand	silt to fine sand	No Station	-	-	-	-	-	-
SC	Stiff Clay	Silty Loam to Pebbles	No Station	-	-	-	-	-	-
SC-A1	Stiff Clay	Stiff Clay to Pebbles	No Station	-	-	-	-	-	-
SC-1	HDF	HDF	No Station	-	-	-	-	-	-
SC-2	HDF	HDF	No Station	-	-	-	-	-	-
SC-A-H	Inaccessible	Inaccessible	No Station	-	-	-	-	-	-
SC-B-H	HDF	HDF	No Station	-	-	-	-	-	-
SC-C-H	HDF	HDF	No Station	-	-	-	-	-	-
SC-D-H	HDF	HDF	No Station	-	-	-	-	-	-
SC-E-H	HDF	HDF	No Station	-	-	-	-	-	-
FCT2-1A	HDF	HDF	No Station	-	-	-	-	-	-
LF-A TRIB	Inaccessible	Inaccessible	No Station	-	-	-	-	-	-
FCT4	Silt to fine sand	Silt to fine sand	All Flood Events	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles
FCT3	Silt to fine sand	Silt to fine sand	All Flood Events	Cobbles	Coarse Pebbles	Coarse Pebbles	Cobbles	Cobbles	Cobbles
FCT3-H	HDF	HDF	N/A	-	-	-	-	-	-
F2ah1b	Silt to fine sand	Silt to fine sand	All Flood Events	Medium Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles
F2-a-h1b	HDF	HDF	N/A	-	-	-	-	-	-
F2-a-h1a	HDF	HDF	N/A	-	-	-	-	-	-
fct3-2h0e	HDF	HDF	N/A	-	-	-	-	-	-
LF TRIB B-H	HDF	HDF	N/A	-	-	-	-	-	-
LF TRIB B	Silt	Silt	All Flood Events	Medium Pebbles	Coarse Pebbles	Medium Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles
LF-B-H	HDF	HDF	N/A	-	-	-	-	-	-
LF TRIB A-H	Silt to sand	Silt to sand	No Hydraulic Data						
LF TRIB A-C	Silt	Silt	All Flood Events	Medium Pebbles	Medium Pebbles	Medium Pebbles	Medium Pebbles	Medium Pebbles	Coarse Pebbles
LF TRIB A	Silt	Silt	All Flood Events	Medium Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles
JC B-Ha	HDF	HDF	N/A	-	-	-	-	-	-
JC-B-Hb	Silt to sand	Silt to sand	All Flood Events	Very Coarse Pebbles	Very Coarse Pebbles	Cobbles	Cobbles	Very Coarse Pebbles	Coarse Pebbles
JC-C-H	HDF	HDF	N/A	-	-	-	-	-	-
JC-D-H	Silt to sand	Silt to sand	All Flood Events	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles

Reach	Existing Bank Material	Existing Bed Material	Erodibility	Grain size transportable by specific flow event					
				2yr	5yr	10yr	25yr	50yr	100yr
JC TRIB E	Silt to sand	Silt to sand	All Flood Events	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles
JC TRIB C-A	could not locate	could not locate	could not locate	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles
JC-G-H	HDF	HDF	N/A	-	-	-	-	-	-
JC-H TRIB	Sand to granules	Sand to granules	All Flood Events	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles	Cobbles	Cobbles
JC-F TRIB	Sand to granules	Sand to granules	No station	-	-	-	-	-	-
JC-K TRIB	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
JC TRIB N-Hb	HDF	HDF	N/A	-	-	-	-	-	-
JC TRIB N-Ha	Inaccessible	Inaccessible	N/A	-	-	-	-	-	-
JC TRIB N-H	HDF	HDF	N/A	-	-	-	-	-	-
JC TRIB B-J-Ha	HDF	HDF	N/A	-	-	-	-	-	-
JC TRIB B-J-H	HDF	HDF	N/A	-	-	-	-	-	-
LJT6-22H1A	HDF	HDF	N/A	-	-	-	-	-	-
JC TRIB M-A	Silt to sand	Silt to sand	All Flood Events	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles
JC-N-H	HDF	HDF	N/A	-	-	-	-	-	-
JC TRIB K-1A	Fine to fine upper sand	Fine upper sand to coarse pebbles	No Station	-	-	-	-	-	-
JC TRIB K-1B	engineered	engineered	Engineered	-	-	-	-	-	-
JC TRIB K-1C	silt to very fine lower sand	Fine upper sand to coarse pebbles	No Station	-	-	-	-	-	-
JC-R-H	HDF	HDF	N/A	-	-	-	-	-	-
JC-S-H	HDF	HDF	N/A	-	-	-	-	-	-
JC-T-H	HDF	HDF	N/A	-	-	-	-	-	-
UJT1	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-1B	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-1	Inaccessible	Inaccessible	N/A	-	-	-	-	-	-
UJT2-1A	Silt	Granules to coarse pebbles	N/A	-	-	-	-	-	-
UJ3E-1B1	HDF	HDF	N/A	-	-	-	-	-	-
UJ3E-AB	HDF	HDF	N/A	Fine Pebbles	Medium Pebbles	Coarse Pebbles	Medium Pebbles	Very Coarse Pebbles	Very Coarse Pebbles
UJ3E-1	HDF	HDF	N/A	-	-	-	-	-	-
UJ3E-1A	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-6B	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
UJT2-6C	Silt to sand	silt to sand	N/A	Medium Pebbles	Coarse Pebbles	Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles
UJT2-9	silt to sand	silt to sand	All Flood Events	Very Coarse Pebbles	Very Coarse Pebbles	Very Coarse Pebbles	Cobbles	Cobbles	Cobbles
UJT2-9a	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-9b	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-8	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-8a	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-6-B	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-61H0A	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-61H1C	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-6-D	Silt to sand	Silt to sand	All Flood Events	Medium Pebbles	Medium Pebbles	Coarse Pebbles	Coarse Pebbles	Coarse Pebbles	Very Coarse Pebbles

Reach	Existing Bank Material	Existing Bed Material	Erodibility	Grain size transportable by specific flow event					
				2yr	5yr	10yr	25yr	50yr	100yr
UJT2-6-E	Silt to fine lower sand	Gravel	All Flood Events	Granules or Very Fine Pebbles	Fine Pebbles	Medium Pebbles	Coarse Pebbles	Very Coarse Pebbles	Cobbles
UJT2-6-H0L	Silt to fine lower sand	Gravel	Banks: All Events, Bed: 2yr to 10yr	Medium Pebbles	Medium Pebbles	Medium Pebbles	Coarse Sand	Coarse Sand	Coarse Sand
UJT2-8	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-8a	HDF	HDF	N/A	-	-	-	-	-	-
UJT2-8H4C	Inaccessible	Inaccessible	Cannot be assessed	-	-	-	-	-	-
UJT2-4-H1	HDF	HDF	N/A	-	-	-	-	-	-



Legend

-  Municipal Boundary
-  No Private Property Access Granted
-  Private Property Access Granted
-  Road Centreline
-  Watercourse (GRCA)
-  Future HDF Studies Required
-  Stable Slope Constraint
-  Meander Belt Assessment Required

Subwatershed Study Area:




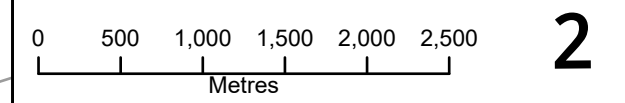
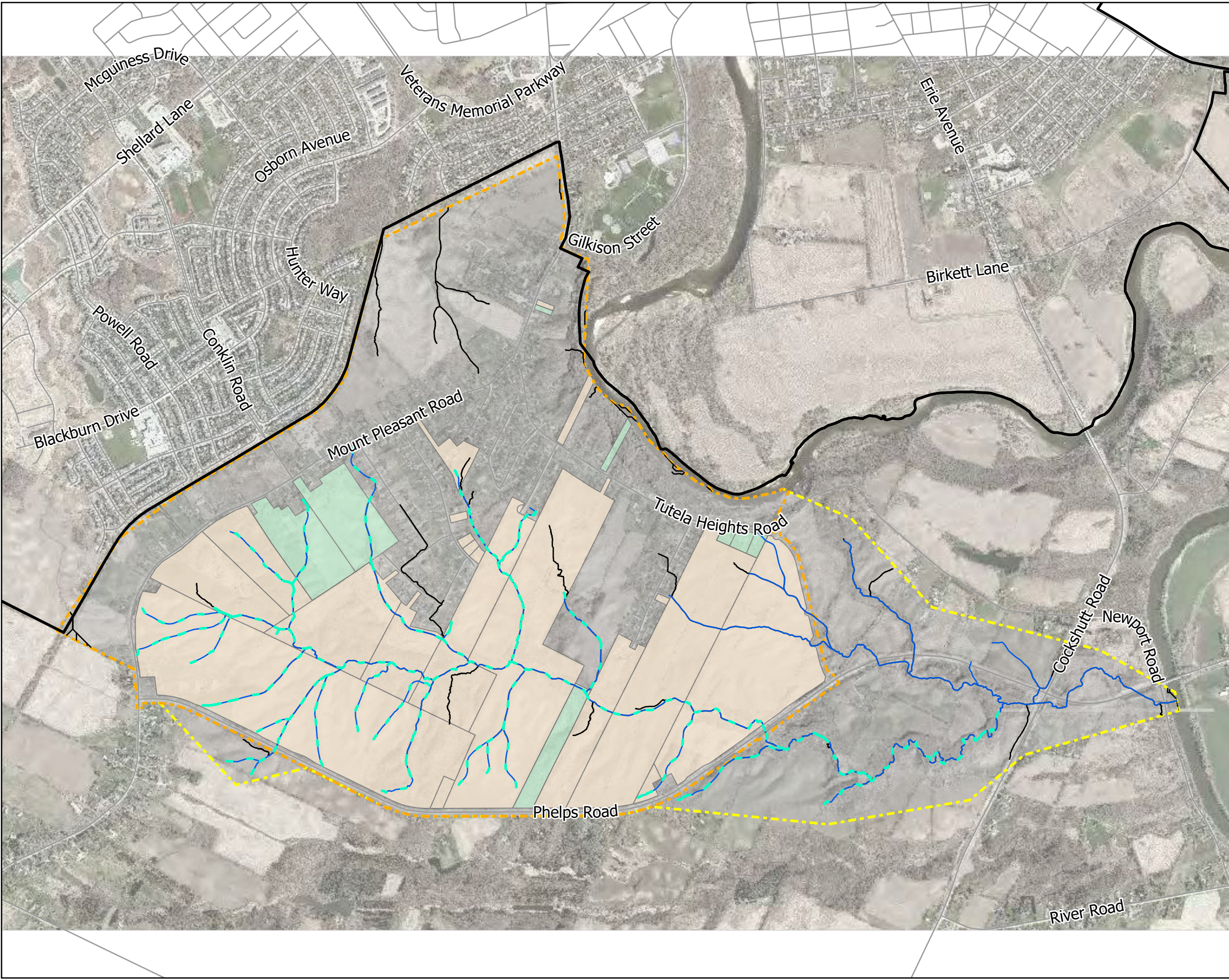
-  Primary
-  Secondary
-  Tertiary

Figure 4.4 (1 of 2)

Geomorphic Constraints to Development

Date: 2023-06-16
 Projection: NAD83, UTM, Zone_17N
 Data Source: City of Brantford
 Created by: J.R.





Legend

- Municipal Boundary
- No Private Property Access Granted
- Private Property Access Granted
- Road Centreline
- Watercourse (GRCA)
- Future HDF Studies Required
- Stable Slope Constraint
- Meander Belt Assessment Required

Subwatershed Study Area:

- Primary
- Secondary
- Tertiary

Figure 4.4 (2 of 2)

Geomorphic Constraints to Development

Date: 2023-06-16
 Projection: NAD83_UTM_Zone_17N
 Data Source: City of Brantford
 Created by: J.R.

0 500 2
 Metres

Document Path: C:\Project\City of Brantford\GIS\Projects\GIS\Development\GeomorphicConstraints\GISDevelopment\Map

4.2 Natural Heritage

The Natural Heritage component of this North Brantford and Tutela Heights Subwatershed Study builds upon the existing City of Brantford Natural Heritage System (as depicted on Schedule 6 of the Official Plan) and the analysis provided in the 2020 Comprehensive Environmental Impact Study by Plan B Natural Heritage (plus associated documents and mapping). The following sections utilize the existing conditions data contained in the preceding sections and from background information sources, and assess these data in the light of concepts such as landscape-level linkages and buffers to protect both ecological features and functions on the landscape in keeping with the goals and objectives identified for this study. The following sections provide details of the analysis that was completed to determine the natural heritage constraints and opportunities within the Study Area.

4.2.1 Municipal Natural Heritage System

The City of Brantford's OP, Section 5.6, defines the policies applicable to the Natural Heritage System (NHS) and the components that are included in that system (refer to **Section 1.2.4**). Specific to this analysis, the NHS is defined as comprising the following components:

- The **Core Natural Areas** designation, which includes the environmental features themselves plus an associated 30-metre buffer, plus portions of the NHS for the Growth Plan for the Greater Golden Horseshoe (key natural heritage features and key hydrologic features) which are located within Brantford.
- The **Adjacent Lands** overlay, which is based on an approximate 90 m setback from the boundary of the Core Natural Areas designation and which is intended to act as a trigger for the completion of an EIS. Adjacent Lands may have ecological and hydrological functions or linkages that are important to the long-term health of the features and functions of the Natural Heritage System.
- The NHS for the Growth Plan as mapped by the province.

These components will be discussed further in the following subsections. With regards to the noted Growth Plan NHS components, this includes key hydrologic features (permanent streams; intermittent streams; inland lakes and their littoral zones; seepage areas and springs; and wetlands) and key natural heritage features (habitat of endangered species and threatened species; fish habitat; wetlands; life science areas of natural and scientific interest [ANSIs], significant valleylands, significant woodlands; significant wildlife habitat [including habitat of special concern species]; sand barrens, savannahs, and tallgrass prairies; and alvars) as defined by the A Place To Grow: Growth Plan for the Greater Golden Horseshoe (Government of Ontario, 2020). Many of the defined key natural heritage features overlap with components of the City's Core Natural Areas (see **Section 4.2.1.1**), with the exception of aquatic features and fish habitat which will be discussed in the context of the provincial Growth Plan NHS.

4.2.1.1 Core Natural Areas

Table 4.2, below, provides additional discussion specific to those components of the Core Natural Areas designation which were identified in the Study Area.

Table 4.2: Core Natural Areas Components for the North Brantford & Tutela Heights Study Area

Core Natural Areas Designation Components	Discussion
Provincially significant wetlands (PSW)	PSWs are evaluated and designated via the Ontario Wetland Evaluation System (Ministry of Natural Resources, 2014), which uses a series of science-based criteria to determine if the wetland should be considered significant on the provincial scale. Portions of the provincially significant Cold Spring Creek Wetland Complex are present in the northern part of the Study Area. As a part of the vegetation community classification, all wetland polygons were reviewed to determine if they have the potential to be added to the PSW complex (see Section 3.4.4.1 and Figure 3.107). Existing wetland mapping from all available sources (e.g., GRCA, MNRF, Plan B Natural Heritage) was reviewed and consolidated where possible based on <i>in situ</i> observations made by Aquafor staff.
Provincially significant woodlands	The PPS (2020) defines significant woodland as any woodlot that is greater than 4 ha. Any treed habitats in the Study Area (excluding actively managed woodlots for forestry or agriculture) that meet this size threshold have been identified as provincially significant features in this category.
Significant wildlife habitat (SWH) attributes and functions, including habitat for SAR and rare plant communities such as prairie, savannah, and oak woodland	SWH was evaluated on a subwatershed level in Section 3.4.6 , above, and SAR and SAR habitat were discussed in Section 3.4.5 . The features or areas identified in those sections are largely intended to be investigated further during a site-specific assessment study at a later date, which will confirm presence/absence of habitat and species and determine/confirm the appropriate designations and protections under both municipal policy and other legislation as appropriate.
Significant areas of natural and scientific interest (ANSI)	There are no designated ANSIs within the Study Area.
Hazard lands	Please see Section 4.1 for discussion of natural hazards.

Core Natural Areas Designation Components	Discussion
Other natural heritage features (i.e., woodlands that are less than 4 ha, locally significant wetlands, treed slopes, and cultural habitat features)	The identified “other natural heritage features” were evaluated during the course of vegetation and habitat assessments completed for the Study Area and through a review of existing information and mapping. Cultural Thicket, Cultural Savannah, and Cultural Woodlands were included in this designation.
Enhancement/restoration areas	Opportunities for enhancement and/or restoration of natural heritage features and functions will be discussed in greater detail in Section 4.2.1.1.2 .
Additional Key Natural Heritage Features and Key Hydrologic Features (as appropriate)	Key Natural Heritage Features and Key Hydrologic Features as defined by the Growth Plan largely overlap with the Core Natural Areas definitions provided above. Additional features which have been identified under these categories by this study include: permanent and intermittent streams and fish habitat. These features will be treated as Core Natural Areas components and given a 30 m buffer accordingly.

4.2.1.1.1 Vegetation Protection Zones/Buffers

The City’s Core Natural Areas designation includes a 30 m vegetation protection zone from the identified features to protect their ecological and hydrological functions. The City’s OP indicates that 30 m is generally accepted as the minimum requirement but that it may be adjusted as a result of further analysis carried out in an EIS. Allowances may be made for municipal infrastructure such as roads, public trails, and SWM facilities provided grading is restricted to the outer third of the buffer zone. Local catchments, or contributing drainage areas, could be a basis for development setbacks from significant wetlands and cold-water fish habitat.

4.2.1.1.2 Enhancement and Restoration Opportunities

The City’s Official Plan policies and requirements support the principle of enhancement and restoration of ecological feature and functions, stating that *“it is the intent of this Plan to ensure that the biodiversity, ecological function and connectivity of the Natural Heritage System is protected, maintained, restored or, where possible, enhanced for the long-term, recognizing linkages between and among natural heritage features and areas, surface water features and ground water features”*. “Enhancement/restoration areas” are included as a component of the Core Natural Areas designation. Opportunities to improve the existing NHS should be reviewed and developed at the site-specific assessment stage and should be considered in keeping with the following factors:

- **Size:** Larger patches of habitat are generally more valuable than smaller. Opportunities to increase the size of existing patches of natural cover (e.g., by designating open space or establishing parks adjacent to existing natural areas) should therefore be considered.

- **Shape:** Habitat patches which are compact (i.e., those which have less ‘edge’ per area) are generally more valuable than those which are linear or elongated. Edges are often associated with effects such as greater establishment of introduced and invasive plant species, increased rates of predation, increased noise disturbance, and changes to microclimate. Opportunities to fill in gaps and reduce the edge to interior ratio of natural heritage patches should therefore be considered.
- **Complexity:** Natural areas with a high diversity of vegetation communities, microhabitats, and topographical features often support a wider variety of species (and a greater proportion of rare species) than those which are more uniform. Opportunities to increase the diversity of habitat across the landscape (e.g., by planting restoration areas with a variety of native species, by creating sloughs or pit/mound topography in restoration areas, or by conserving successional meadows and thickets in addition to forests) should therefore be considered.
- **Connectivity:** Fragmentation of natural areas by development can lead to the isolation of habitat patches and the wildlife they support, limiting dispersal of individuals and reducing genetic variability within the population. Opportunities to maintain and improve existing connections between natural areas (e.g., by completing riparian planting along ephemeral watercourses and HDFs, or by widening and enhancing canopy cover along hedgerows) and to create new connections where they are currently lacking should therefore be considered.

Restoration and/or enhancement of a site may be done either actively (i.e., by planting or seeding native vegetation, potentially accompanied by grading to create specific topography or features such as constructed wetlands) or passively (i.e., by ceasing management and allowing vegetation to colonize according to the in-situ seed bank). Active restoration is a more costly and labour-intensive approach, but it offers opportunities for community involvement (e.g., tree planting days) and can accelerate a site to a more advanced stage of succession (i.e., promote forest development through tree and shrub planting). Locations of active restoration should be considered at a landscape scale and take into account existing natural resources included wildlife habitat and linkages. It is also more likely to achieve a target vegetation community or species diversity target; passively allowing succession to occur is more likely to allow colonization of a site by non-native and/or invasive species. Active restoration is likely to be a component of any required ecological offsetting plan or compensation strategy related to impacts of proposed development; the need for and scope of such a plan would be identified through the development application process (i.e., addressed as a component of a site-specific EIS or equivalent study) and would need to be developed in consultation with the City and GRCA. These locations should be considered first for replacement opportunities.

Opportunities for restoration and enhancement within the Study Area, as mapped on **Figure 4.6**, were generally identified in three categories: infill areas adjacent to or between existing NHS components, stream corridor restoration, and restoration of buffers.

NHS Infill

The maps provided illustrate multiple locations where cleared or highly disturbed land (mainly fields currently in use for agriculture) are fully or nearly surrounded on all sides by the identified NHS. These locations may be undevelopable due to a lack of access and are therefore ideal candidates for restoration in order to improve the size and shape of the existing NHS patches.

This ‘infill’-type restoration would be particularly valuable in the North Brantford Study Area along the Jones Creek corridor to establish a pocket of interior habitat which is currently missing from the landscape. In the Tutela Height Study Area many of the features are long and narrow where filling gaps between two proximal patches will dramatically widen the linkage corridor.

Stream Corridor and Riparian Restoration

Restoration and enhancement of riparian zones along watercourses and HDFs is also recommended; well-vegetated riparian zones provide shade, cover and food sources for in-stream wildlife, help control water temperature, and allow the filtration/settling of suspended sediment in runoff before it reaches a watercourse channel. This is specifically effective along the tributaries connecting Jones Creek to the urban area as well as along the tributaries extending off Phelps Creek that provide the majority of the connectivity in the Tutela Heights Study Area. Other restoration opportunities include the removal of any barriers to fish movement.

VPZ/Buffer Restoration

Restoration of the identified VPZs around eligible components of the NHS would provide a benefit to the NHS as a whole and increase the effectiveness of the buffering function the VPZs were established to provide. Restoration of VPZs is not, however, eligible for consideration as ecological offsetting, if such is required, since the naturalization of VPZs is a pre-existing requirement.

Compatible land uses or low-impact development (e.g., LIDs) may be allowed within VPZs as previously discussed in **Section 1.2.3**, but should not compromise the ability of the VPZ to provide the necessary buffering function to the NHS feature for which it was established.

Linkages















Hedgerows were evaluated in this study with regard to the linkage function that they provide; linkages are important ecological features that promote the diversity and spread of plants and animals on the landscape, and the restoration or enhancement of these features can have a positive net impact on the adjacent core features. Where linkages/hedgerows have been identified by this study, it is important to note that in many cases it is the linkage *function* that is important, and that some modification of the *feature* itself may be allowed (if supported by EIS or equivalent study) so long as any important functions are maintained or replicated elsewhere. Future site-specific assessments (e.g., EIS) shall review and address linkages in the Study Area (including but not limited to or restricted by those hedgerow linkages identified in this SWS) and ensure that habitats are not fragmented or isolated by future site alteration or development.

The spatial, aesthetic, and biophysical characteristics of each identified hedgerow within the Study Area was assessed in the field, as detailed in **Section 3.4.4.3**, **Table 3.38**, and **Figure 3.108**.

Hedgerows have not been identified as a major component of connectivity and linkage throughout the watershed, but a few hedgerows have been characterized as Category 1 or 2, indicating that they have, or potentially have, high value for connectivity in the subwatershed area, or contain protected SAR such as Butternut that warrant retention. Based on these characteristics, management recommendations or enhancement opportunities may exist to further increase their value as linkage corridors within the NHS. Hedgerows that are Category 3 (containing other valuable attributes unrelated to connectivity or linkage) may be also considered for integration based on the presence of mature or specimen trees or wildlife habitat, where adjacent land uses allow (e.g., where parklands can be integrated).

In general, management or linkage enhancement recommendations for high value hedgerows (e.g., Category 1 and 2) include the removal of invasive species and native species planting to widen existing corridors or bridge existing tree gaps. It is recommended that dead/dying ash also be replaced with native trees.

Legend

-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Growth Plan Natural Heritage
-  Watercourse
-  Functional Linkages (ABL, Plan B)
-  Functional Linkages (Plan B)
-  Category 1 Hedgerow
-  Category 2 Hedgerow
-  Category 3 Hedgerow
-  Category 4 Hedgerow
-  Vegetation Protection Zone
-  Enhancement/Restoration
-  Significant Valley Boundary

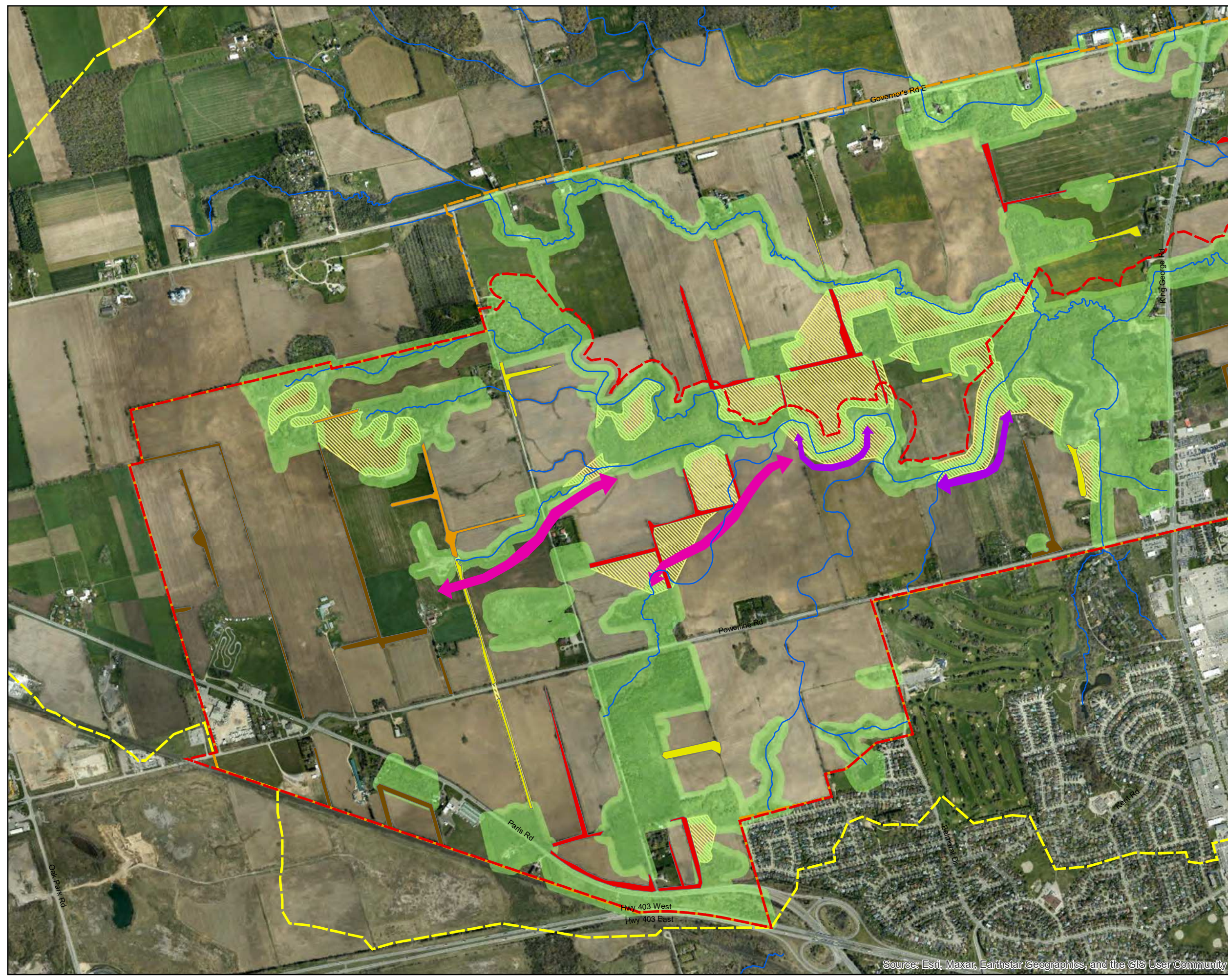
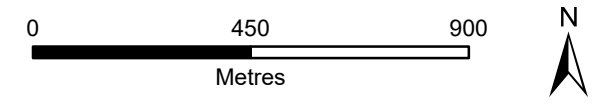


Figure 4.6 (1 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO

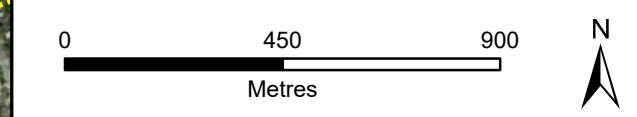




- Legend**
- Primary Study
 - Secondary Study
 - Tertiary Study
 - Growth Plan Natural Heritage
 - Watercourse
 - Functional Linkages (ABL, Plan B)
 - Category 1 Hedgerow
 - Category 2 Hedgerow
 - Category 3 Hedgerow
 - Category 4 Hedgerow
 - Vegetation Protection Zone
 - Enhancement/Restoration
 - Significant Valley Boundary















Figure 4.6 (2 of 4)
 Restoration/Enhancement Opportunities

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Legend

-  Primary Study
-  Secondary Study
-  Tertiary Study
-  Growth Plan Natural Heritage
-  Watercourse
-  Functional Linkages (ABL, Plan B)
-  Functional Linkages (Plan B)
-  Category 1 Hedgerow
-  Category 2 Hedgerow
-  Category 3 Hedgerow
-  Category 4 Hedgerow
-  Vegetation Protection Zone
-  Enhancement/Restoration
-  Significant Valley Boundary

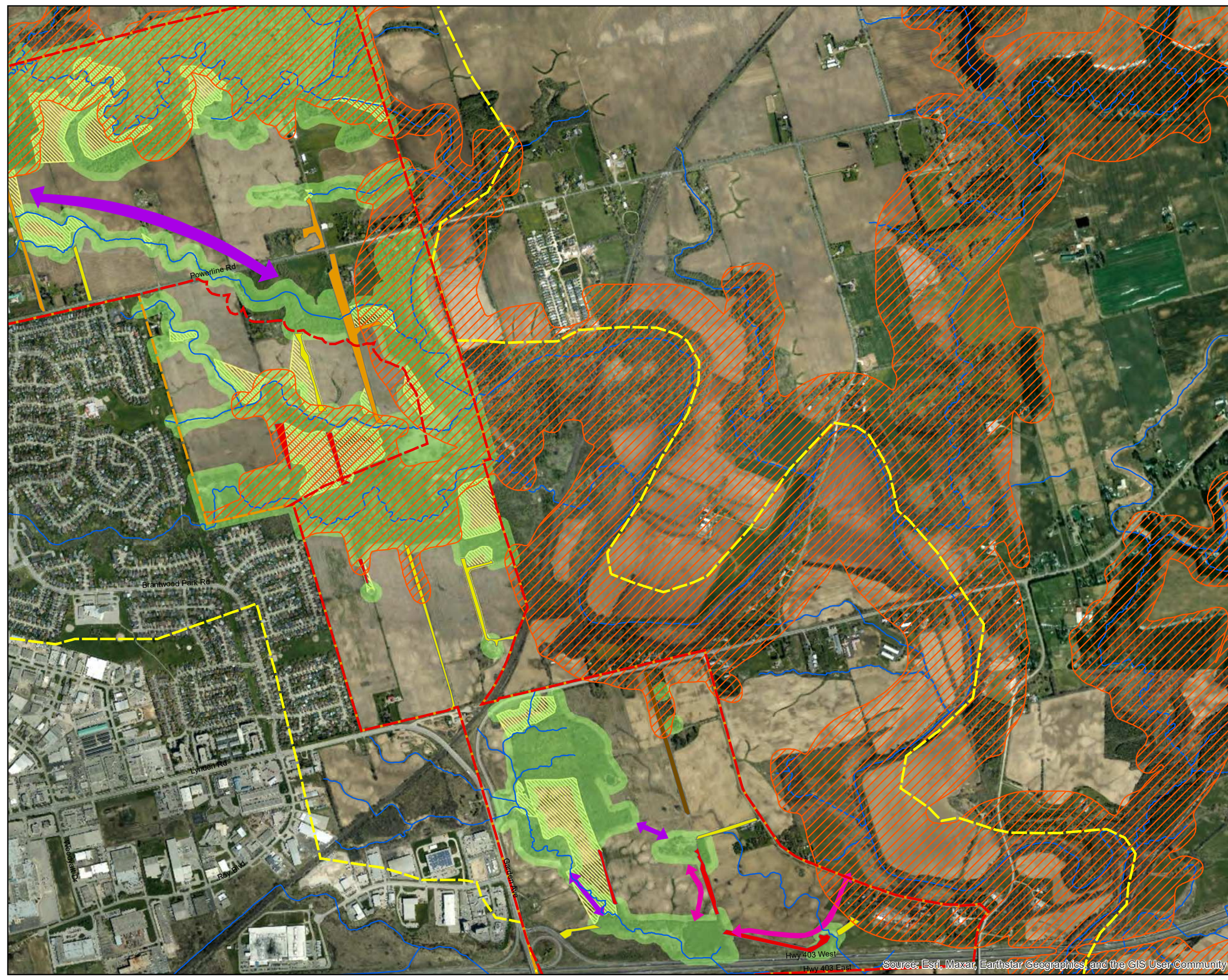
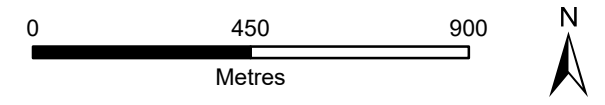


Figure 4.6 (3 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Legend

- Primary Study
- Secondary Study
- Tertiary Study
- Growth Plan Natural Heritage
- Watercourse
- Functional Linkages (ABL, Plan B)
- Category 1 Hedgerow
- Category 2 Hedgerow
- Category 3 Hedgerow
- Category 4 Hedgerow
- Vegetation Protection Zone
- Enhancement/Restoration
- Significant Valley Boundary

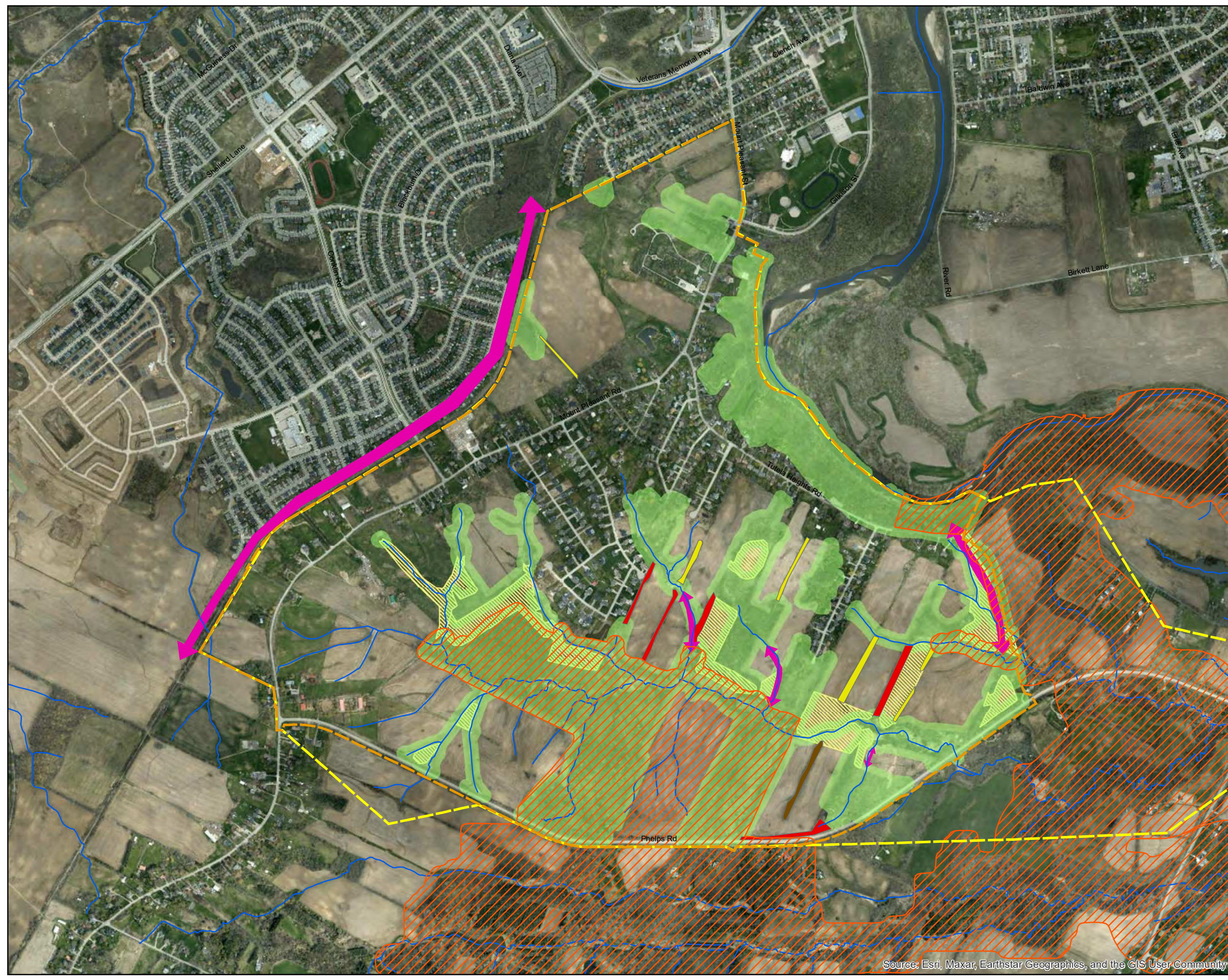
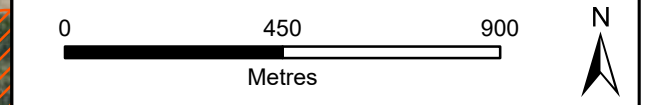


Figure 4.6 (4 of 4)

Restoration/Enhancement Opportunities

Date: April 2023
 Author: KB
 Projection: UTM_Zone_17N
 Source: City of Burlington, Plan B Natural Heritage, LIO



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

4.2.2 Summary of Natural Heritage Considerations

The preceding sections describe the natural heritage features and functions that form part of the overall developmental constraints for the Study Area, including features which meet the criteria for the municipal NHS and their associated minimum required buffers. Restoration/enhancement opportunities, which form a component of the Core Natural Areas designation, were discussed in greater detail and with specific regard to opportunities that were identified on a preliminary level in the Study Area.

Natural heritage constraints and opportunities were assessed based on background information (primarily the Comprehensive EIS completed by Plan B Natural Heritage in 2020) and the results of a Aquafor's own field survey program executed in 2022, which was described in detail in **Section 3.4**. Constraints and opportunities identified by this SWS are intended to provide guidance and information during the development of land use plans and future site-specific assessment studies.

4.3 Other Considerations

4.3.1 Groundwater Resource Opportunities

Any areas of high groundwater recharge within the Study Area should be maintained to preserve of infiltration and to maintain groundwater flows towards wetlands and watercourses. An opportunity exists within the Study Area to develop an urbanization strategy which preserves groundwater recharge via the use of strategically located source and conveyance controls which take advantage of local infiltration capacities.

4.3.1.1 Groundwater Protection Plan

While there are limited shallow aquifer resources within the North Brantford and Tutela Heights study areas, there are high recharge areas and significant aquifer resources west and south of the North Brantford area. Recharge in these neighbouring areas likely supply the deeper overburden and bedrock aquifers that underly the study area.

Land development in the western portion of the secondary study area should preserve the high groundwater recharge, as it is expected that the high recharge in that area supports both the aquifers and the headwater tributaries. Low impact development and recharge galleries are recommended in that area. The model indicates that there are some recharge fed stream reaches in the western portion of the study area.

There were no significant recharge areas or shallow groundwater resources in the Tutela Heights study area.

Zones of shallow depth to water table primarily occur in the riparian areas near the streams (**Figure 4.7**). Development is unlikely to encroach on those areas and will not likely affect those water table conditions. It is important to note that the number of shallow wells used to estimate this surface can be limited, so the known well locations used to estimate the water table are posted as circles on the map. Areas of shallow groundwater may be of a concern during development, for both construction and implementation of effective LID measures. To further

illustrate the shallow areas, a second map is attached highlighting areas where the water table may be less than 3 m in depth (**Figure 4.8**).

4.3.1.1.1 Significant Groundwater Recharge Areas

Significant Groundwater Recharge Areas (SGRAs) are defined as areas where the local climate, topography, and surficial geology favour groundwater recharge. They are also referred to as High Volume Recharge Areas (HVRAs). These areas are recognized provincially significant for groundwater protection. The Technical Rules for conducting Source Protection Studies under the Clean Water Act (Ontario Ministry of the Environment, 2009) define SGRAs using either of the following two criteria:

1. The annual recharge rate is at least 1.15 times the annual recharge rate of the area under consideration.
2. The annual recharge volume is at least 55% of the annual water budget surplus (precipitation minus actual evapotranspiration) of the area under consideration.

Results of the models were used to do a more detailed mapping of SGRAs in the study area following the second criteria.

First, the annual water budget surplus was defined by subtracting the AET values calculated by PRMS from the annual average precipitation on a cell-by-cell basis. Next, the ratio of net groundwater recharge to the annual water budget surplus was calculated. Cells with ratios greater or equal to 0.55 were selected as potential SGRAs. Because of the cell-by-cell variation in the ratios, some isolated cells (both above and below the threshold) were found. A smoothing filter was passed over the grid to infill holes and remove isolated cells to create more continuous SGRAs for planning purposes. Final results are shown in **Figure 4.9**. The results generally follow surficial geology mapping of the more permeable materials but also account for reduced groundwater recharge in urban areas. These results can be used to identify areas for groundwater protection.

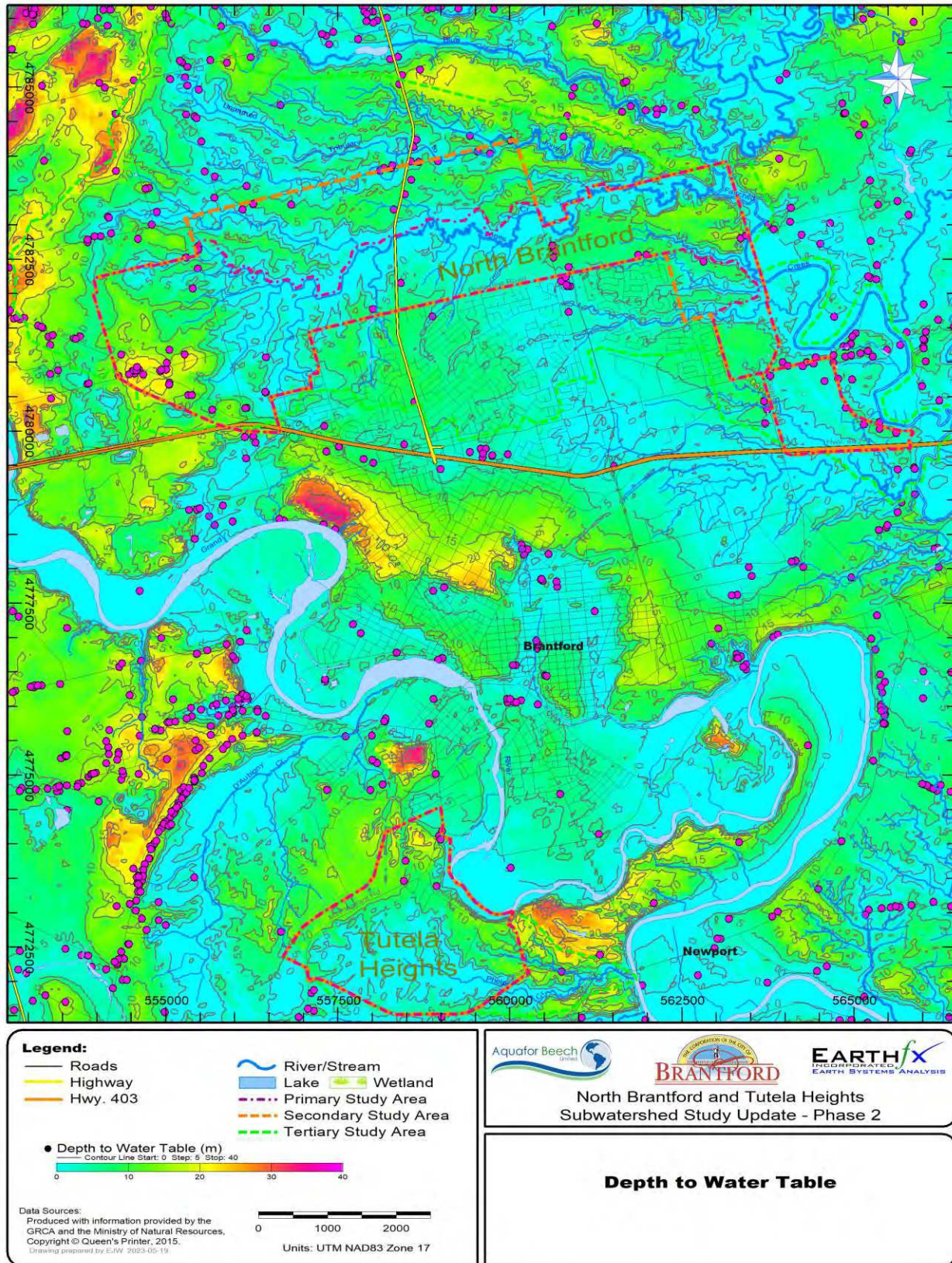


Figure 4.7: Depth to water table (m)

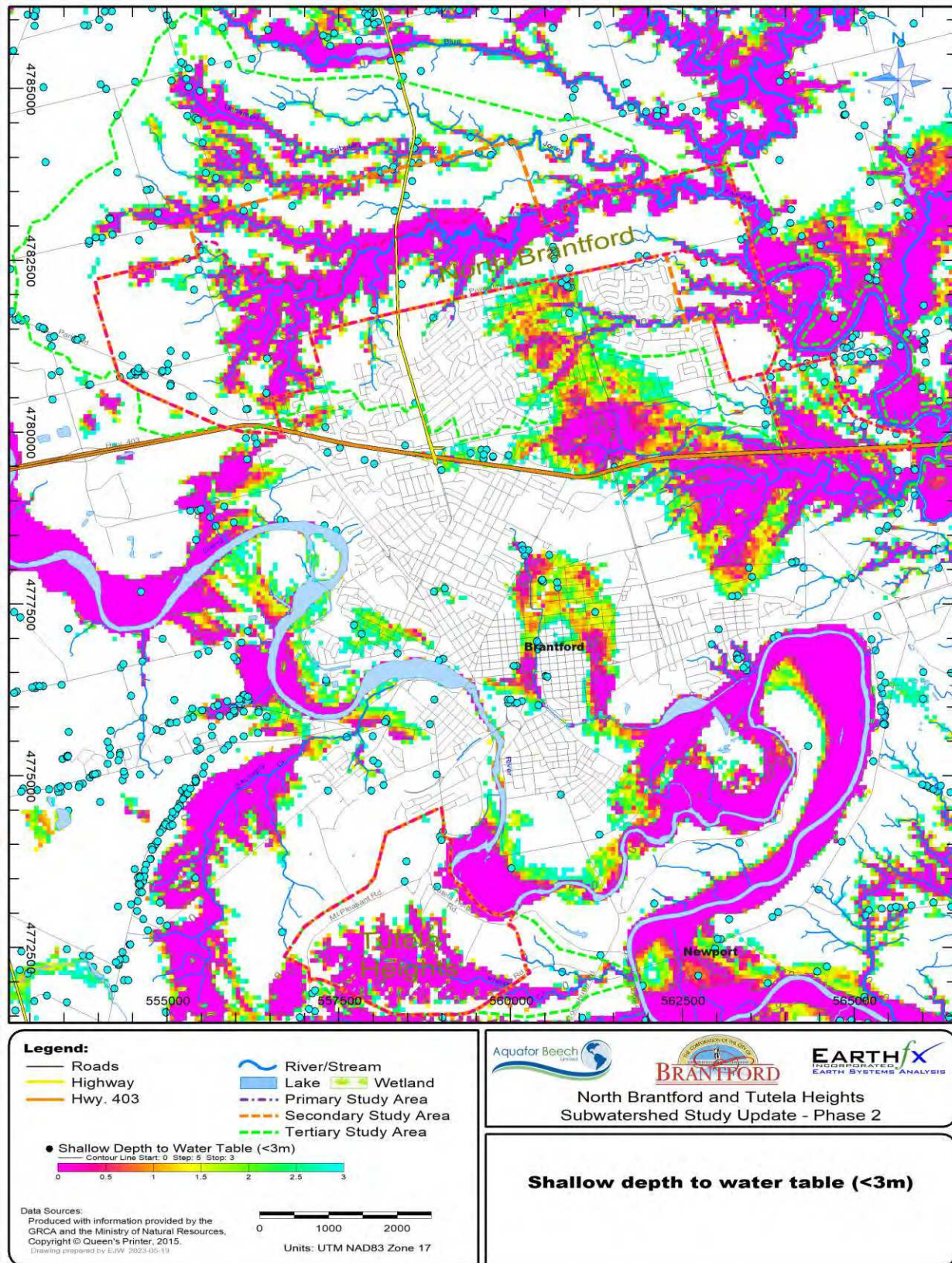


Figure 4.8: Areas of shallow depth to water table (<3m).

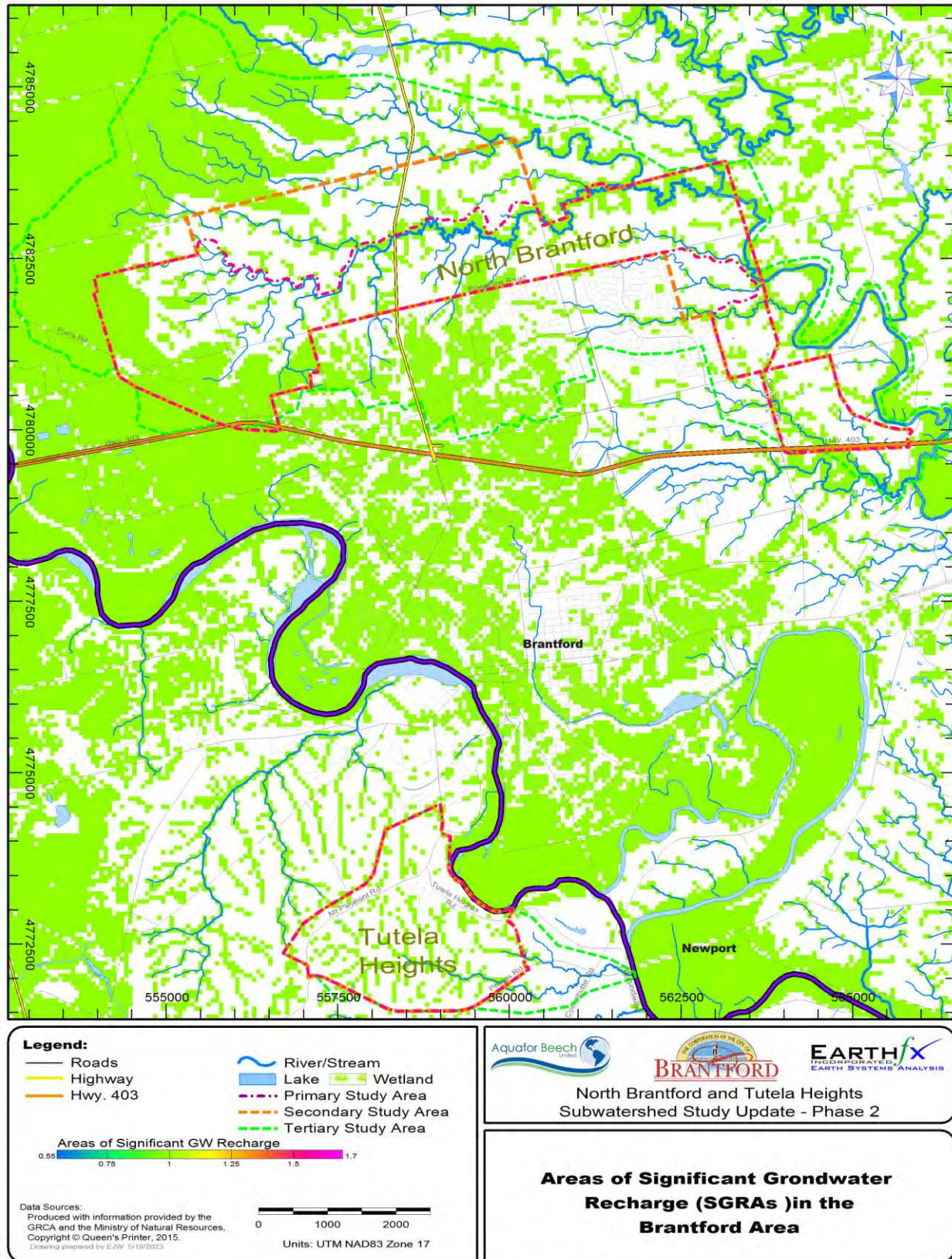


Figure 4.9: Areas of significant groundwater recharge.

4.3.2 Headwater Drainage Features

HDFs are important in maintaining primary and secondary inputs to surface water, groundwater, and fish habitat as applicable; HDFs within the Study Area were previously defined as a part of the Phase 1 program, but were not assessed as a part of the Phase 1 Update study due to timing and access constraints. A desktop analysis was completed to build upon the management recommendations made as a part of Phase 1 and to further identify potential features within the Study Area, as described in **Section 3.3.1** and as shown in **Figure 3.68**. HDF management recommendations shall be carried forward from the Phase 1 study. HDFs on lands not accessed during either phase of this study will have to be assessed as part of a future study to address the potential management implications displayed below in **Table 4.3**.

HDFs with a “Protection” management recommendation are to be retained and protected in situ. As these features within the Study Area were documented to provide indirect fish habitat, “Protection” HDFs should therefore be treated as *fish habitat and key hydrologic features*, which are protected as part of the Municipal NHS, with appropriate VPZs applied. These recommendations and implications are displayed in **Figure 4.4** and **Figure 4.5**, where appropriate.

Table 4.3: Summary of HDF Management Implications

Management Implications	HDF Classification			
	Protection	Conservation	Mitigation	No Management Required
Must remain open	Yes	Yes	Yes	n/a
Relocate using Natural Channel Design	Not permitted, enhancement only	May be considered, not preferred	Natural Channel Design not required ¹	n/a
Maintain or replicate groundwater or wetlands	Maintain or enhance	Maintain or replicate, restore if possible	n/a	n/a
Maintain hydroperiod	Yes	Yes	Yes	n/a
Direct connection to downstream	Yes	Yes	Yes	n/a
Replicate function through enhanced lot conveyance control	n/a	n/a	Replicate using bioswales, LID, vegetated swales or constructed wetlands	n/a

¹Unless the management recommendations call for the restoration of lost function or enhancement and creation of fish habitat.

HDFs with a “Conservation” or “Mitigation” classification also provide indirect fish habitat within the Study Area and would, per Brantford’s OP, qualify for protection as Key Hydrologic Features where outside of the Settlement Area. However, the Management Recommendations provided in the HDF Guidelines indicate that these features can be relocated or replicated within certain guidelines/requirements (detailed previously in **Table 3.10**). To rectify this apparent conflict between municipal policy regarding fish habitat and the management recommendations of the HDF Guidelines, this study recommends the following approach: proposed development or land-use change should consider HDFs first using the Management Recommendations, as these were developed specific to HDFs and account for the preservation of important features and functions associated with these features. Relocation or replication of “Conservation” or “Mitigation” HDFs may therefore be proposed in keeping with the Management Recommendations.

However, once any proposed relocation of a “Conservation” HDF is completed as part of a new development, the new channel would then need to have the Key Hydrologic Feature designation applied and all associated setbacks and VPZs would need to be observed for the new alignment. For “Mitigation” HDFs where function is to be replication through LIDs or similar, NHS designation would not apply but an EIS or other appropriate study would need to be completed to ensure no

net loss of function to downstream systems (i.e., maintenance of indirect fish habitat function would need to be demonstrated).

Please note that other considerations (e.g., flood hazard limits, wetland vegetation communities) may also apply to HDFs.

4.4 Summary of Constraints

The above sections detail the various constraints to development that are present in the Study Area. This study recognizes that not all constraints function at the same level. Thus, constraints have been categorized according to their implications towards future land management and development.

Figure 4.10 provides a visual summary of the constraints to development posed by Natural Hazards and Natural Heritage, and **Table 4.4** below, details the various categories of constraint that are illustrated on that figure. It is the intention that future site-specific studies may refine the boundaries of the constraints illustrated on **Figure 4.10** based on updated information (e.g., staking and survey of wetland boundaries or forest driplines, updated geotechnical investigations, etc.). Further, it is acknowledged that studies related to transportation and utilities/servicing are currently underway or will be undertaken in the near future, which may affect the constraints illustrated in this SWS; if the placement of essential infrastructure results in impacts to constraint areas, it is expected that the Environmental Assessment for that infrastructure will address those impacts and provide any necessary mitigation or compensation.

Table 4.4: Summary of Constraints

Colour on Figure 4.10	Category	Management Recommendation	Included Features	Further Discussion
Red	High Constraint	No development intrusion is generally allowable.	<p><u>Natural Hazards: Confirmed</u></p> <ul style="list-style-type: none"> Regulatory Flood Line <p><u>Natural Hazards: Requiring Detailed Site Investigation</u></p> <ul style="list-style-type: none"> Slope Hazard and Long-term Stable Slope Setback (top-of-bank may be confirmed/refined by future studies) GRCA Slope Erosion and River Valley Slopes <p><u>Natural Heritage System: Confirmed</u></p> <ul style="list-style-type: none"> Provincially significant wetlands Provincially significant woodlands (i.e., woodlands >4 ha in size) Provincially significant valleylands Other natural heritage features (i.e., woodlands that are less than 4 hectares, locally significant wetlands, treed slopes, and cultural habitat features) Watercourses / fish habitat and “Protection” level HDFs 	<p>Generally, no development should occur in High Constraint areas.</p> <p>Meander belt, once delineated, should be included as a high constraint.</p>
Orange	Moderate Constraint	Potential for development is not confirmed and will require further site-specific study to determine the presence/absence or define the boundaries of features.	<p><u>Natural Heritage System: Requiring Detailed Site Investigation</u></p> <ul style="list-style-type: none"> Significant wildlife habitat and Threatened/Endangered Species at Risk habitat, pending further study to confirm presence/absence and extent of features that are appropriate to include in the municipal NHS. Enhancement/restoration areas, including linkages, pending further study to refine and/or amend the identified areas based on the results of site-specific analysis. Wetlands not considered locally significant “Conservation” or “Mitigation” level HDFs, per the conditions described in Section 4.3.2. 	<p>Several categories of feature were identified as Moderate Constraint to signify that they require additional assessment and review at a later stage (e.g., as part of a scoped Environmental Impact Study) before they can be designated as part of the Natural Heritage System (if/where appropriate). Whether development will be permitted in the indicated areas, and the conditions or requirements that might be associated with that development, are to be assessed and confirmed through the future site-specific studies.</p>
Yellow	Low Constraint	Development intrusion is not restricted by existing policies and regulations, but it is suggested that features be considered for incorporation into site-level plans where possible to avoid net loss of natural cover.	<p><u>Natural Features not Eligible for Inclusion in the NHS</u></p> <ul style="list-style-type: none"> Category 3 and 4 Hedgerows, and other hedgerows not assessed as part of the subwatershed study due to their lack of connectivity to other features (e.g., narrow windbreaks between agricultural fields) 	<p>Features may be considered for incorporation into site-level plans where possible (e.g., parks or SWM blocks, preservation of individual specimen trees, alignment with rear lot lines or trail routes, etc.).</p>

5 Recommendations for Further Study

The following section outlines recommendations for further study based on the findings of the work completed to date. Further recommendation(s) may be introduced following additional analysis during later phases of the Subwatershed Study.

As previously mentioned, **lands not accessed during this study will need to be evaluated as part of future studies**, as applicable (**Figure 4.10**). The constraints illustrated on lands not accessed as part of this study represent an assessment of the best available information at the time of this study. Where possible, features on inaccessible lands were evaluated from adjacent properties and/or roadsides plus a review of available background data. Additionally, since meander belt assessment was not included in this study, and HDF assessment was not feasible, these **will also have to be evaluated as part of future studies**. These study requirements are summarized below in more detail.

Table 5.1: Summary of Deferred Studies

Discipline	Study	Terms of Reference
Geomorphology	Meander Belt assessment	A meander belt assessment will be required for all unconfined reaches within the study area. This assessment should conform to accepted geomorphic practices, consistent with GRCA protocol for reaches SC-E, JC TRIB B-C, JC TRIB B-F, JC TRIB B-D, JC TRIB B-G, JC-I, JC-U, JC TRIB K, JC TRIB B-H, JC TRIB B-I, JC TRIB B-J, JC-S, JC-H, JC-R, JC-M, JC-K, JC-N, JC TRIB F, JC-G, LF-A, SC-B, JC-F, JC-B, JC-D, JC-A, LF-B, JC-E, JC, TRIB D, JC-C, JC TRIB B-A, JC TRIB B-B, SC-C, SC-D, SC-A, JC-J, JC-L, JC-P, JC-Q, JC-O, JC-T, LF TRIB B, SC, SC-A2, SC-A1.
Surface Water – Headwater Drainage Features	Headwater Drainage Feature Assessment	The potential features identified using the desktop analysis, along with those identified by GM Blue Plan in the Phase 1 Study, are to be assessed at a later stage following The Evaluation, Classification, and Management of Headwater Drainage Features Guidelines (CVC & TRCA, 2014).
Terrestrial Ecology	Vegetation Community Classification and Botanical Inventory	Vegetation surveys were completed at a high level and must be refined at the site development stage through the completion of an EIS. Vegetation communities should be mapped using ELC methodology. This should be completed in concert with a botanical inventory.
Terrestrial Ecology	Breeding Birds Surveys	Breeding bird surveys should be completed on all properties that did not permit site access during phase 1

Discipline	Study	Terms of Reference
		of this study. Surveys should be completed in accordance with OBBA guidelines (OBBA, 2001).
Terrestrial Ecology	Amphibian Calling Surveys	Amphibian calling surveys should be completed on any site that has wetlands mapped that did not give site access for either phase 1 or 2 of this study. Surveys should be completed in accordance to Marsh Monitoring Program Participant's Handbook for Surveying Amphibians (Bird Studies Canada, 2009).
Terrestrial Ecology	Targeted Species at Risk Surveys	Prior top development, all natural features should be screened for potential SAR species. This study is to be used as a guide of what SAR species were present or have the potential to be present at this time. Background resources should be rechecked for any additional species. All structures should be reviewed for potential Barn Swallow nests. Any site with trees should be reviewed for the potential of SAR bat habitat. All natural features should be screened for Butternut, Black Ash, or other SAR vegetation. Turtle searches may be required if any ponds or watercourses are located near the development to search for SAR turtles following the Survey Protocol for Blanding's Turtle (<i>Emydoidea blandingii</i>) in Ontario (OMNRF, 2015). Active visual searches should be completed if there is the potential for SAR snakes following Survey Protocol for Ontario's Species at Risk Snakes (OMNRF, 2016).
Terrestrial Ecology	Wetland boundary delineation	Wetland boundaries should be delineated in accordance to the rules described in the Ontario Wetland Evaluation System: Southern Manual (MNR, 2022) and agreed upon by the City.
Terrestrial Ecology	Wetland Evaluations	A complete wetland evaluation for any wetland patch currently designated PSW may be required. This includes 172.04, 172.05, 172.06, 175.05, 175.07, 177.01, 195.05, 195.05, 195.06, 196.02, 196.03, 196.05, 196.05, 206.03, 206.06, 206.11, 9999.03, 9999.05, W32, W33, W43, W44, W45, W46, W49, W50, W51, W52, W54, W55, W56, W57, W60, W73, and W74. Additionally, polygons 135.02, 172.09, 191.03, 206.12, and W48 are directly adjacent to the PSW and should be considered candidate PSW and may also require further evaluation. Several wetlands were identified as potentially locally significant. These

Discipline	Study	Terms of Reference
		wetlands include 115.03, 115.04, 131.09, 131.10, 155.06, 172.01, 172.02, 195.07, 195.08, 211.06, 232.01, 232.02, 259.03, W7, W8, W9, W10, W20, W23, W24, W25, W26, W27, W28, W29, W36, W53, W61, W63, W64, W65, W66, W67, W69, W70, W72, and W75. Further studies may be required to determine the local significance of these wetlands.
Terrestrial Ecology	Woodland dripline delineation	Woodland boundaries must be delineated and approved by the City.

5.1 Groundwater Recommendations

Maintenance of pre-development groundwater recharge will need to be considered. The magnitude of the impact of the effects of urbanization and potential measures to minimize the impact will be discussed during Phase 2 of the subwatershed study. Key findings from the Phase 1 Update will be used in Phase 2 to evaluate and identify the preferred stormwater management strategy.

5.2 Surface Water Recommendations

5.2.1 Hydrology and Hydraulic Modeling

The existing conditions hydrologic and hydraulic models have been described above, and the Phase 2 Subwatershed Study report will highlight the impact of future conditions on floodlines. It is recommended that climate change scenarios be incorporated into both single event and continuous hydrologic modelling for future scenarios in order to ensure community and infrastructure resiliency.

5.2.2 Erosion Hazard

The stable slope hazard component of the erosion hazard limit defined in Section 3.2.2.5.2 is based on a toe erosion limit defined by the bank material consistent with the provincial MNR (2002) guidelines, a stable slope allowance based on a 3:1 slope ratio and a provincial minimum erosion access allowance of 6m. Final LTSS setbacks should be confirmed based on detailed geotechnical field investigations commissioned by the development proponents. This could potentially reduce the stable slope ratio, and thereby the final offset. Additionally, while a 6m erosion access allowance is typically a provincial minimum, development policies may dictate an additional allowance where necessary. The following channel reaches have been shown to warrant a stable slope analysis prior to development approval:

- JC-H TRIB
- LF TRIB A

- LF TRIB A-H
- LF TRIB B

Meander belt considerations are warranted on all channelized reaches. In the case of HDF's, a meandering channel form was not observed and therefore do not warrant this analysis. The following reaches were determined, as a part of this study, to require a meander belt assessment to determine development limits:

- JC TRIB K-1C
- SC
- LF TRIB A
- LF TRIB B

The TRCA guidelines (2004) provide appropriate delineation procedures for this analysis and should be considered for determining a meander belt on der conditions where the hydrologic regime is subject to change, due to the anticipated development within the catchment. Such development will reduce infiltration and divert additional flow to these watercourses.

5.3 Natural Heritage System Recommendations

The North Brantford and Tutela Heights Subwatershed Study included a broad array of ecological field surveys. However, due to limitations in property access, project timing, and study scope, not all aspects of the natural environment that may pose constraints to development have been confirmed through this study.

5.3.1 Site-Specific Studies to Confirm Constraints

The following tasks may be warranted in certain locations during future planning phases to confirm and/or refine existing constraints:

- **Headwater Drainage Feature Assessments** – as project constraints did not permit HDF assessments as a part of this phase, it is recommended that further assessments occur in areas where land access restricted surveys from occurring as part of this subwatershed study (HDF assessment was already completed for land with access permission during Phase 1). Surveys should follow the same protocols that were used in the current study (CVC & TRCA, 2014).
- **Site-level Flora and Fauna Surveys** – Botanical inventories, breeding bird surveys, breeding amphibian surveys, and other field investigations were completed for this SWS and the prior Comprehensive EIS covering the entire SWS Study Area on a broad scale. For proposed site alteration or development, the associated site-specific studies completed at that time should complete appropriate detailed flora and fauna surveys such that the natural heritage features and functions of that site are comprehensively identified and evaluated and that current information is available to assess site conditions at that point in time. This will be of particular importance where Moderate Constraint features were identified for future study or where site access restrictions did not permit this SWS to collect site-specific data towards the study completion. A three-season inventory of plants is recommended for block plans. It

is recommended that vegetation and faunal surveys be conducted in accordance with provincial standards (e.g. ELC, OBBA, MMP).

- **Wetland Delineation** – Aquafor’s field investigations for this SWS attempted to confirm wetland boundaries within the SWS Study Area and to consolidate differing wetland mapping that was currently available from various sources. Not all target locations were reviewed due to site access restrictions. The ELC vegetation and wetland mapping provided with this report represents the results of that task. That said, wetland boundaries throughout the Study Area may be further confirmed/refined through site-level delineation (i.e., staking and survey) which is typically done in consultation with City staff. Additionally, full wetland evaluations may be required at the Block Plan or Site -specific planning stage.
- **Review and Confirmation of Restoration/Enhancement Opportunities** – Preliminary restoration and enhancement opportunities (including restoration and/or enhancement of linkages) were developed for this SWS as described in **Section 4.2.1.1.2**. It is acknowledged that the opportunities identified by this SWS do not necessarily represent the best or only opportunities that may be present in the Study Area, and therefore future site-specific studies should complete additional assessment of opportunities part of their scope of work, ensuring that the final restoration/enhancement opportunities provide a benefit to the NHS in keeping with the City’s policies and requirements, and that the landscape-level connections and functions discussed in this document are given due consideration.

Most, if not all, of the above ecological tasks are anticipated to occur as part of site-specific **Environmental Impact Studies (EIS)** that will confirm and refine Natural Heritage System components and other constraints in the Study Area as discussed previously in this document. The Terms of Reference (ToR) for work to be carried out as part of site-specific assessments should be scoped with the City and GRCA, plus any other applicable consultation with relevant agencies, prior to beginning work. The City’s Adjacent Lands overlay is intended to be used as a trigger for locations requiring an EIS.

6 References

- AquaResources Inc (ARI), 2009, Integrated water budget report - Grand River watershed: June 2009, Grand River Conservation Authority, Cambridge, Ontario.
- Armstrong, D.K. and Carter, T.R., 2010, The subsurface Paleozoic stratigraphy of southern Ontario: Ontario Geological Survey, Special Volume 7, 301 p.
- Arnaud, E., McGill, M., Trapp, A., and Smith, J., 2018, Subsurface heterogeneity in the geological and hydraulic properties of the hummocky Paris Moraine: Guelph, Can. J. Earth Sci. 00: 1–18 (0000) [dx.doi.org/10.1139/cjes-2016-0161](https://doi.org/10.1139/cjes-2016-0161)
- Bajc, A.F. and Dodge, J.E.P., 2011, Three-dimensional mapping of surficial deposits in the Brantford–Woodstock area, southwestern Ontario: Ontario Geological Survey, Groundwater Resources Study 10, 86p. [PDF document]
- Bayne, E., Habib, L., & Boutin, S. 2008. Impacts of Chronic Anthropogenic Noise from Energy-Sector Activity on Abundance of Songbirds in the Boreal Forest. *Conservation Biology*, 22(5), 1186-1193.
- Blackport Hydrogeology Incorporated and AquaResources Incorporated (ARI), 2009, Review of the state of knowledge for the Waterloo and Paris/Galt moraines: Ministry of the Environment Land and Water Policy Branch, Toronto, Ontario.
- Bird Studies Canada. 2009. Marsh Monitoring Program Participant’s Handbook for Surveying Amphibians, 2009 Edition. Bird Studies Canada in cooperation with Environment Canada and the US Environmental Protection Agency.
- Biron, P.M., Buffin-Bélanger, T., Larocque, M., Choné, G., Cloutier, C., Ouellet, M., Demers, S., Olsen, T., Desjarlais, C., & J. Eyquem. 2015. Freedom space for rivers: A sustainable management approach to enhance river resilience. *Environmental management*, 54: 1056–1073.
- Brotons, L., & S. Herrando. 2001. Reduced Bird Occurrence in Pine Forest Fragments Associated with Road Proximity in a Mediterranean Agricultural Area. *Landsc. Urban Plan.*, 57, 77-89.
- Brunton, F.R., Belanger, D., DiBase, S., Yungwirth, G., and Boonstra, G., 2007, Caprock carbonate stratigraphy and bedrock aquifer character of the Niagara Escarpment-City of Guelph region, southern Ontario: OttawaGeo2007 conference proceedings, p.371-377.
- Brunton, F.R., 2009, Update of revisions to the Early Silurian Stratigraphy of the Niagara Escarpment: integration of sequence stratigraphy, sedimentology and hydrogeology to delineate hydrogeologic units: in Summary of Field Work and Other Activities 2009, Ontario Geological Survey, Open File Report 6240, p.25-1 to 25-20.

Buffin-Bélanger, T., Biron, P.M., Larocque, M., Demers, S., Olsen, T., Choné, G., Ouellet, M., Cloutier, C., Desjarlais, C., & J. Eyquem. 2014. Freedom space for rivers: An economically viable river management concept in a changing climate. *Geomorphology*, 251: 137–148.

Chapman, L.J. and Putnam, D.F., 1984, The physiography of southern Ontario: Ontario Geological Survey, Special Volume 2, 270p.

City of Brantford. (2022, September). Official Plan. Brantford, Ontario, Canada.

Commission for Environmental Cooperation. 2009. Monarch Butterfly Monitoring in North America: Overview of Initiatives and Protocols.

COSEWIC. 2012. COSEWIC Assessment and Status Report on the Eastern Wood-pewee *Contopus virens* in Canada.

COSEWIC. 2012. COSEWIC Assessment and Status Report on the Wood Thrush *Hylocichla mustelina* in Canada.

COSEWIC. 2013. COSEWIC Assessment and Status Report on the Grasshopper Sparrow *pratensis* subspecies *Ammodramus savannarum pratensis* in Canada.

COSEWIC. 2016. COSEWIC Assessment and Status Report on the Blanding's Turtle *Emydoidea blandingii*, Nova Scotia population and Great Lakes/St. Lawrence population in Canada.

COSEWIC. 2016. Monarch (*Danaus plexippus*): COSEWIC Assessment and Status Report. Ottawa: Committee on the Status of Endangered Wildlife in Canada.

COSEWIC. 2017. Assessment and Status Report on the Butternut (*Juglans cinerea*) in Canada. Ottawa: Committee on the Status of Endangered Wildlife in Canada.

COSEWIC. 2018. COSEWIC Assessment and Status report on the Black Ash *Fraxinus nigra* in Canada.

Committee on the Status of Endangered Wildlife in Canada.

CVC & TRCA. 2014. Evaluation, Classification and Management of Headwater Drainage Features Guideline. Toronto, Ontario, Canada.

Earthfx, 2017, Wellhead Protection Area Delineation and Vulnerability Scoring for the Airport Wellfield, County of Brant, Ontario: prepared for Grand River Conservation Authority, September 2017

Earthfx, 2018, Whitemans Creek Tier Three Local Area Water Budget and Risk Assessment Model – Risk Assessment Report: prepared for Grand River Conservation Authority, October 2016

- Earthfx, 2018, Wellhead protection area delineation, vulnerability scoring and threats assessment for the St. George and Lynden Municipal Supply Wells: prepared for the Grand River Conservation Authority, May 2018, 214 p.
- Ebel, J. D., & Lowe, W. H. 2013. Constructed Ponds and Small Stream Habitats: Hypothesized Interactions and Methods to Minimize Impacts. Missoula, Montana, USA.
- Environment Canada. 2010. Recovery Strategy for the Butternut (*Juglans cinerea*) in Canada. Ottawa: Environment Canada.
- Environment Canada. 2013. How Much Habitat Is Enough? Third Edition. Environment Canada, Toronto, Ontario.
- Golder Associates Ltd., 2010, County of Brant Source Protection Vulnerability, Issues, and Threats Assessment: prepared for the Grand River Conservation Authority, July 2010 Government of Ontario. (2020, August). A Place to Grow: Growth Plan for the Greater Golden Horseshoe. Ontario, Canada.
- Government of Ontario. (2020, May 1). Provincial Policy Statement. Toronto, Ontario, Canada.
- Grand River Conservation Authority, 2008, Grand River Characterization Report (DRAFT): prepared by the Lake Erie Source Water Region Technical Team, 318 p.
- GRCA. (2019, June 25). Jones Creek Electrofish Survey Results, 2019. Cambridge, Ontario, Canada.
- Harbaugh, A.W., 2005, MODFLOW-2005, the U.S. Geological Survey modular ground-water model—the Ground-Water Flow Process: U.S. Geological Survey Techniques and Methods 6-A16.
- Hargreaves, G. H., & Samani, Z. A., 1982, Estimating potential evapotranspiration: Journal of the Irrigation and Drainage Division, 108(3), 225-230.
- Heagy, A., Badzinski, D., Bradley, D., Falconer, M., McCracken, J., Reid, R., & K. Richardson. 2014. Recovery Strategy for the Barn Swallow (*Hirundo rustica*) in Ontario. Ontario Recovery Strategy Series.
- Hvorslev, M.J., 1951, Time lag and soil permeability in ground-water observations: Bull. No. 36, Waterways Exper. Sta. Corps of Engrs, U.S. Army, Vicksburg, Mississippi, pp. 1-50.
- Johnson M.D., Armstrong, D.K., Sanford, B.V., Telford P.G., and Rutka, M.A., 1992, Paleozoic and Mesozoic geology of Ontario: in Geology of Ontario, Ontario Geological Survey, Special Volume 4, Part 2, p.907-1010.
- Jones, C., Somers, K. M., Craig, B., & T.B. Reynoldson. 2007. Ontario Benthos Biomonitoring Network: Protocol Manual. Toronto: Queen’s Printer for Ontario.

Geological Survey Geoscience Report 255, 94p.

Karrow, P.F., 2005, Quaternary geology of the Brampton area, southern Ontario: Ontario Geological Survey Geoscience Report 257, 59p.

Kassenaar, J.D.C. and Wexler, E.J., 2006, Groundwater modelling of the Oak Ridges Moraine area: YPDT-CAMC Technical Report #01-06: Available at <http://www.ypdt-camc.ca>.

Leavesley, G.H., Litchy, R.W., Troutman, B.M. and Saindon, L.G., 1986, Precipitation-Runoff Modeling System: User's Manual: Water Resources Investigations Report 83-4283, USGS Denver, Colorado.

Lee, H., Bakowsky, W., Riley, J., Bowles, J., Puddister, M., Uhlig, P., & S. McMurray. 1998. Ecological Land Classification for Southern Ontario, First Approximation and its Application. North Bay, Ontario: Ontario Ministry of Natural Resources.

Liberty, B.A., Bond, I.J., and Telford, P.G., 1976, Paleozoic geology of the Hamilton area, southern Ontario: Ontario Geological Survey. Map 2336, scale 1:50 000.

Longcore, T., & C. Rich. 2004. Ecological Light Pollution. *Frontiers in Ecology and the Environment*, 2(4), 191-198.

MacVeigh, B., T. Zammit and J. Ivey. 2016. Fairchild Creek Subwatershed Characterization Study. Version 1.0. Cambridge, ON: Grand River Conservation Authority.

Mandaville, S.M. 2002. Benthic Macroinvertebrates in Freshwaters – Taxa Tolerance Values, Metrics, and Protocols. Halifax, Nova Scotia, Canada.

Markstrom, S.L., Niswonger, R.G., Regan, R.S., Prudic, D.E., and Barlow, P.M., 2008, GSFLOW: Coupled ground-water and surface-water flow model based on the integration of the Precipitation-Runoff Modeling System (PRMS) and the Modular Ground-Water Flow Model (MODFLOW-2005): U.S. Geological Survey Techniques and Methods 6-D1, 240 p.

McCracken, J., Reid, R., Renfrew, R., Frei, B., Jalava, J., Cowie, A., & A. Couturier. 2013. Recovery Strategy for the Bobolink (*Dolichonyx oryzivorus*) and Eastern Meadowlark (*Sturnella magna*) in Ontario. Ontario Recovery Strategy Series.

Ministry of Environment (MOE). 1999. Revised Stormwater Management Guidelines Draft Report.

Ministry of Natural Resources (MNR). 2000. Significant Wildlife Habitat Technical Guide.

Ministry of Natural Resources (MNR). 2002. Technical Guide River & Stream Systems: Erosion Hazard Limit.

Ministry of Natural Resources (MNR). 2010. Natural Heritage Reference Manual for Natural Heritage Policies of the Provincial Policy Statement, 2005. Retrieved from

<https://dr6j45jk9xcmk.cloudfront.net/documents/3270/natural-heritage-reference-manual-for-natural.pdf>

- Ministry of Natural Resources (MNR). 2013. Barn Swallow General Habitat Description.
- Ministry of Natural Resources (MNR). 2013. Bobolink General Habitat Description.
- Ministry of Natural Resources (MNR). 2014. Ontario Wetland Evaluation System, Southern Manual, 3rd Edition, Version 3.3. Queen’s Printer for Ontario.
- Ministry of Natural Resources and Forestry (MNRF). 2015. Significant Wildlife Habitat Criteria Schedule for Ecoregion 7E.
- Ministry of Natural Resources and Forestry (MNRF). 2017. Survey Protocol for Species at Risk Bats within Treed Habitats Little Brown Myotis, Northern Myotis & Tri-Coloured Bat. Guelph: Guelph District Office.
- Moore, I.D., Grayson, R.B. and Ladson, A.R., 1991, Digital Terrain Modelling: A Review Of Hydrological, Geomorphological, and Biological Applications, in: Terrain Analysis And Distributed Modelling In Hydrology, edited By K.J. Beven And I.D. Moore, John Wiley & Sons.
- Niswonger, R.G., Panday, S., and Ibaraki, M., 2011, MODFLOW-NWT, A Newton formulation for MODFLOW-2005: U.S. Geological Survey Techniques and Methods 6–A37, 44 p.
- Oldham, M. J., Bakowsky, W. D., & D.A. Sutherland. 1995. Floristic Quality Assessment System For Southern Ontario. Peterborough: Natural Heritage Information Centre, Ontario Ministry of Natural Resources.
- Ontario Breeding Bird Atlas (OBBA). 2001. Ontario Breeding Bird Atlas Guide For Participants.
- MODFLOW-2005: U.S. Geological Survey Techniques and Methods 6–A37, 44 p.
- Ontario Geological Survey (OGS), 2010, Surficial geology of southern Ontario: Ontario Geological Survey, Miscellaneous Release—Data 128—Revised, attributed digital compilation map.
- Ontario Ministry of Natural Resources and Forestry (MNRF), 2015c. Southern Ontario Land Resource Information System (SOLRIS). Phase 2 – Data Specification Version 2.0, January 2015. 22 p.
- Ontario Ministry of Natural Resources and Forestry (OMNRF). 2015. Survey Protocol for Blanding’s Turtle (*Emydoidea blandingii*) in Ontario. Species Conservation Policy Branch. Peterborough, Ontario. li + 16 pp.

- OMNRF. 2016. Survey Protocol for Ontario's Species at Risk Snakes. Ontario Ministry of Natural Resources and Forestry, Species Conservation Policy Branch. Peterborough, Ontario. ii + 17 pp.
- Pidgeon, A., Radeloff, V., Flather, C., Lepczyk, C., Clayton, M., Hawbaker, T., & R. Hammer. 2007. Associations of Forest Bird Species Richness with Housing and Landscape Patterns Across the USA. *Ecological Applications*, 17(7), 1989-2010.
- Piégay, H., Darby, S.E., Mosselman, E., & N. Surian. 2005. A review of techniques available for delimiting the erodible river corridor: a sustainable approach to managing bank erosion. *River Research and Applications*, 21: 773-789.
- Poisson, G., & M. Ursic. 2013. Recovery Strategy for the Butternut (*Juglans cinerea*) in Ontario. Peterborough: Ontario Recovery Strategy Series. Prepared for the Ontario Ministry of Natural Resources.
- Reijnen, R., Foppen, R., & G. Veenbaas. 1997. Disturbance by Traffic of Breeding Birds: Evaluation of the Effect and Considerations in Planning and Managing Road Corridors. *Biodiversity and Conservation*, 6, 567-581.
- Schaub, A. E. 2009. Foraging Bats Avoid Noise. *Journal of Experimental Biology*, 212(18), 3036.
- Semlitsch, R., & J. Bodie. 2003. Biological Criteria for Buffer Zones Around Wetlands and Riparian Habitats for Amphibians and Reptiles. *Conservation Biology*, 17(5), 1219-1228.
- Southwestern Ontario Orthoimagery Project (SWOOP), 2015, Land Information Ontario, Ministry of Natural Resources.
- Stanfield, L. 2017. OSAP Version 10.
- Telford, P.G., 1976, Paleozoic geology of the Guelph area, southern Ontario: Ontario Geological Survey, Map 2342, scale 1:50,000.
- Varga, S., Leadbeater, D., Webber, J., Kaiser, J., Crins, B., Kamstra, J., & E. Zaic. 2000. The Distribution and Status of the Vascular Plants of the Greater Toronto Area. Aurora: Ontario Ministry of Natural Resources.