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**Date:** March 3, 2026

**Project #:** 60763197

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# Memorandum **Draft Final**

**Subject:** Background Review – Bear Brook Flood Mitigation Class Environmental Assessment and Preliminary Design

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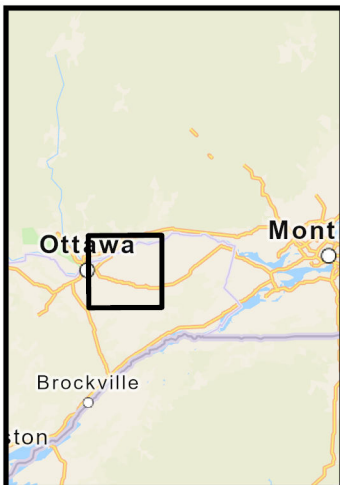
## 1. Introduction

The South Nation River Conservation Authority (SNC) has retained AECOM Canada ULC (AECOM) to carry out a Flood Mitigation Environmental Assessment and Preliminary Design Study for the Bear Brook watershed. The findings of this project will be used to assist SNC to complete a class environmental assessment (EA) for the Bear Brook watershed, and to identify and evaluate flood mitigation options for a defined reach of the Bear Brook watershed where flooding events are frequent and well documented.

The main objective of this study is to provide a sustainable approach to the protection and management of water resources in the watershed while minimizing the risk of flooding and erosion hazards to people, property and infrastructure.

Bear Brook is a tributary of the South Nation River and therefore falls within the jurisdiction of SNC. According to the Ontario Watershed Information Tool (OWIT, 2025), the Bear Brook watershed area is approximately 490 km<sup>2</sup> and encompasses parts of the City of Ottawa, as well as the United Counties of Prescott and Russell, as shown in **Figure 1**. For the purposes of the class environmental assessment the Bear Brook watershed is defined as the study area.

Furthermore, an analysis of flood mitigation options is also included as part of this project in response to persistent and well documented flooding for a reach of Bear Brook which is enclosed by Carlsbad Lane to the west (the upstream boundary) and Dunning Road to the east (the downstream boundary). This area is shown in **Figure 1** and has been defined as the flood mitigation assessment area.



	Municipal Boundary
	Bear Brook - Pour Point
	Bear Brook Watershed

**Data Sources:**  
Government of Ontario, South National Conservation Authority

<b>Bear Brook Watershed Flood Damage Assessment</b>	
<b>Study Area</b>	
<p>Kilometers Scale: 1:250,000</p>	
PN: 60763197	Figure 1
November 2025	<b>AECOM</b>

The purpose of this technical memorandum is to summarize AECOM's findings with respect to the tasks included in Task 1 of the Scope of Work for this project, which are:

- ◆ Complete a comprehensive review of historical data, watershed characteristics, and floodplain conditions, including available reports, flood mapping studies, numerical models, historical municipal drain reports, and geospatial layers.
- ◆ Prepare a summary of existing baseline site conditions with respect to geomorphological, geotechnical, and hydrotechnical conditions, as well as a high-level description of the natural habitat, cultural and socio-economic characteristics of the study area.
- ◆ Review the available hydrologic and hydraulic models provided by SNC and revise any identified land use changes in relevant areas that pertain to this project.
- ◆ Calculate to the extent possible flood damages under existing conditions with the available hydraulic models (1D and 2D) using a layer of existing buildings (provided by SNC) for the 2, 5, 10, 20, 50, 100, and 350-year return period flood events.
- ◆ Assess potential agricultural damages by identifying flooded agricultural areas for each modeled return period and applying high-level crop loss assumptions to estimate flood-related impacts.
- ◆ Identify and summarize data gaps in the reviewed information and provide SNC with a list of these data gaps as well as an opinion on their impact in the evaluation of flood mitigation options for this project.

Task 1 will provide the information required to define the extent of the flooding and potential opportunities that can be addressed by the class environmental assessment. Subsequent project tasks, which are presented in separate documents, include the development and evaluation of flood mitigation alternatives as well as a cost/benefit analysis of flood mitigation options.

## 2. Background Information Review

The following documents were reviewed to develop a comprehensive understanding of the Bear Brook watershed. Additionally, SNC provided a series of digital files, layers and models that were reviewed as part of the background review. This information is listed below.

- ◆ Bear Brook Watershed Study - Watershed Planning and Policy Framework Characterization Report, SNC. November 2024 [1].
- ◆ Bear Brook Watershed Study – Fluvial Geomorphology and Landslide Screening Characterization Report, Palmer. May 2024 [2].
- ◆ Bear Brook Watershed Study – Physical Setting Characterization Report, SNC. November 2024 [3].
- ◆ Bear Brook Watershed Study – Water Resources Characterization Report, SNC. November 2024 [4].
- ◆ Bear Brook Watershed Floodplain Mapping Report, SNC. February 2024 [5].
- ◆ Bear Brook Watershed Study – Surface Water Quality Characterization Report, SNC. November 2024 [6].
- ◆ Bear Brook and Tributaries 2D Hydraulic Modeling Report, SNC. February 2023 [7].
- ◆ One-dimensional model of the Bear Brook Watershed developed in HEC-RAS (Ver. 6.3.1), SNC. 2023-2024.
- ◆ Two-dimensional model of a section of Bear Brook developed in HEC-RAS (Ver. 6.3). SNC 2023.
- ◆ Updated hydrologic and hydraulic models (HEC-HMS and HEC-RAS) prepared by SNC in 2025, including refinements to model parameters, boundary conditions, and floodplain mapping.

- ◆ Spatial layers from SNC and the City of Ottawa, which include aerial photographs, hydraulic structures, building footprints, combined expansion areas, land cover areas, Manning’s coefficients, a digital elevation model, municipal drains, streams, waterbodies, and wetlands.

### 3. Summary of Existing Conditions

The Bear Brook watershed has a surface area of 490 km<sup>2</sup> at its confluence point with the South Nation River.

The Bear Brook watershed is contained within the administrative boundaries of the City of Ottawa and the United Counties of Prescott and Russell, which comprise 57% and 43% of the total watershed area, respectively. The predominant flow direction in Bear Brook is from west to east through a system of natural channels, wetlands and drainage channels around agricultural lands to its confluence point with the South Nation River at an area which is approximately 1.8 km upstream of the N. Dixon Bridge. The watershed is undergoing continued land use change, primarily due to urban expansion and associated development within previously rural areas. The following sections provide a summary of baseline conditions which describe the current condition of the watershed.

#### 3.1 Topography

As stated in the Bear Brook and Tributaries 2D Hydraulic Modeling Report [7], the topography of the Bear Brook watershed is considered relatively flat and encompasses urban areas, wetlands, forested areas, and agricultural lands. According to the available DEM which was generated from LiDAR data provided by the City of Ottawa (shown in **Figure 2**), the elevations within the Bear Brook watershed range between 43 m and 119 m.

A base digital terrain model (DTM) has been provided by SNC with a pixel resolution of 1 m by 1 m and projected to the spatial reference system NAD 1983 CSRS UTM Zone 18N and vertical datum CVGD28. The DEM consist of a combination of light detection and ranging (LiDAR) data from three datasets including the Riviere Outaouais (NRCan 2019), Ottawa-Gatineau (City of Ottawa 2020) and Eastern Ontario (SNC, 2022).

SNC conducted further studies to validate the accuracy of the three LiDAR data sources, which showed that the non-vegetated vertical accuracy (NVA) was calculated as +/- 10.8 cm at the 95% confidence interval, while vegetated vertical accuracy (VVA) was +/- 40.6 cm.

Additionally, the main topographic characteristics of Bear Brook, which were provided by the Ontario Water Information Tool (OWIT, 2025) are summarized in **Table 3.1**, showing the maximum and minimum elevations of the main channel (Bear Brook) and its watershed, as well as other relevant parameters.

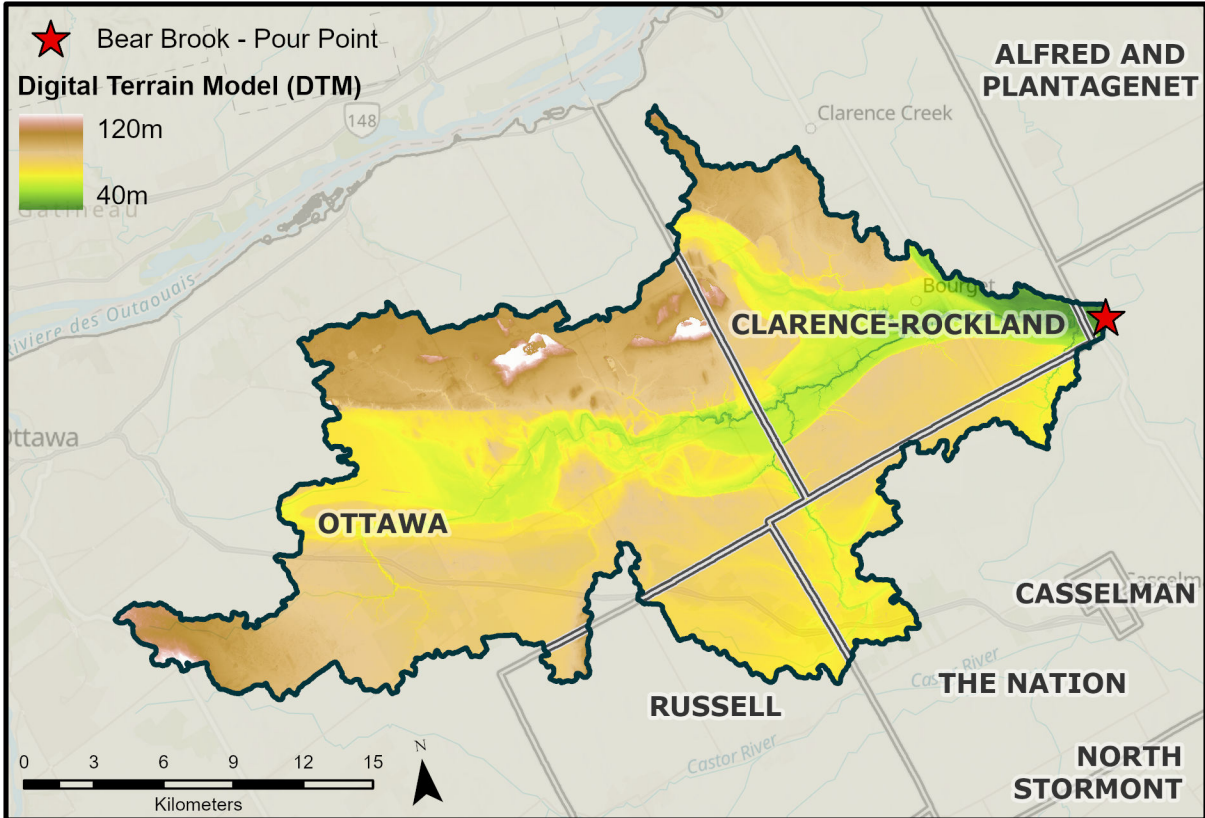
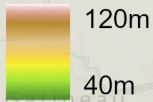
As shown, wetlands are an important land use feature in the watershed, and the average slope of the Bear Brook and its tributary areas are 0.7% and 1.7%, respectively.

**Table 3.1. Topographic Characteristics of Bear Brook from OWIT**

Parameter	Value	Parameter	Value
Drainage Area (km <sup>2</sup> )	490	Area Lakes (km <sup>2</sup> )	0.6
Length of Main Channel (km)	77.9	Area Wetlands (km <sup>2</sup> )	92.7
Max. Channel Elevation (m)	98.9	Mean Elevation (m)	74.9
Min. Channel Elevation (m)	44.9	Max. Elevation (m)	116.8
Slope of Main Channel (%)	0.7	Mean Slope (%)	1.7
Area Lakes/Wetlands (km <sup>2</sup> )	93.3	Annual Precipitation (mm)	999.0

★ Bear Brook - Pour Point

Digital Terrain Model (DTM)



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### 3.2 Subwatershed Elements

The Bear Brook watershed can be divided into six subwatershed areas that contain Bear Brook and its main tributaries [3]. The characteristics of each area are presented below.

- ◆ Bear Brook Main Channel: The subwatershed that contains Bear Brook has a surface area of 176.1 km<sup>2</sup>. The channel begins near Carlsbad Springs and flows east across the City of Ottawa, continuing south of Navan and Bourget to its confluence point with the South Nation River.
- ◆ South Bear Brook: this subwatershed is located within the City of Ottawa on the western edge area of the Bear Brook watershed and has a surface area of 60.9 km<sup>2</sup>. South Bear Brook begins north of Findlay Creek and flows towards the east across Highway 417 discharging into Bear Brook at a point south of Carlsbad Springs. This subwatershed includes portions of Carlsbad Springs, the Leitrim and Findlay Creek communities as well as designated urban expansion areas for the future Tewn community.
- ◆ Mer Bleue: This subwatershed has a surface area of 46.7 km<sup>2</sup> and consists of three tributaries of Bear Brook including McKinnons Creek, East Savage Creek and the McFadden Municipal Drain. A significant portion of the Mer Bleue bog is also contained within this area, as well as urban areas that include a portion of Orleans, the east-west corridor of Navan Road, and designated urban expansion areas in Orleans.
- ◆ Shaws Creek: This creek is a major tributary of Bear Brook and flows northward, crossing Highway 417 and joining Bear Brook east of Milton Road. The surface area of this subwatershed is 35.3 km<sup>2</sup> and includes portions of the Vars community to the east.
- ◆ South Indian Creek: This creek flows north across Highway 417 and continues east of the Town of Limoges to its confluence point with Bear Brook near the Town of Cheney. The subwatershed of South Indian Creek includes the Town of Limoges and portions of the Larose Forest and has a surface area of 96.3 km<sup>2</sup>.
- ◆ North Indian Creek: This creek flows southeasterly, to an area north of Hammond and discharges into Bear Brook west of Bourget. This subwatershed, which has a surface area of 62.2 km<sup>2</sup> includes the Hammond Swamp which is a designated Provincial Significant Wetland (PSW), as well as the community of Hammond.

### 3.3 Land Cover

Following a detailed review of available information, the available land cover types provided by the City of Ottawa were reorganized by SNC [3]. The land use categories were combined into nine categories which include aggregate, settlement (urban), transportation, water, wetland, wooded area, crop/pasture, grassland, and tiled drained land. The land cover types for the Bear Brook watershed are summarized in **Table 3.2** and shown in **Figure 3**.

**Table 3.2. Land Covers of Bear Brook Watershed**


Land Cover Type	Percentage of Land Cover by Subwatershed (%) <sup>1</sup>						Total
	South Bear Brook	Mer Bleue	Shaw's Creek	South Indian Creek	North Indian Creek	Main Bear Brook	
Aggregate	0.63	0.97	0.30	0.00	1.03	0.80	0.63
Settlement	10.46	12.48	7.89	8.08	7.65	7.24	8.43
Transportation	4.21	4.88	3.76	3.41	2.65	2.94	3.41
Water	0.43	0.27	0.41	0.31	0.29	0.69	0.46
Wetland	27.17	29.00	17.57	30.55	23.56	14.15	22.06
Wooded Area	28.77	12.33	15.73	28.74	27.49	26.68	25.27
Crop/Pasture	22.82	32.47	49.05	24.52	33.03	43.30	34.91
Grassland	6.15	7.61	5.29	3.99	4.31	4.20	4.83
Tile Drained Land	6.55	13.16	31.06	11.12	13.03	22.18	16.52


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
1. The total percentages add to more than 100% because there is overlapping of certain land cover layers.


★ Bear Brook - Pour Point

**Land Cover**


 Crop and Pasture


 Meadow Thicket


 Sand and Gravel

 Settlement

 Transportation

 Water

 Wetlands

 Wooded Area

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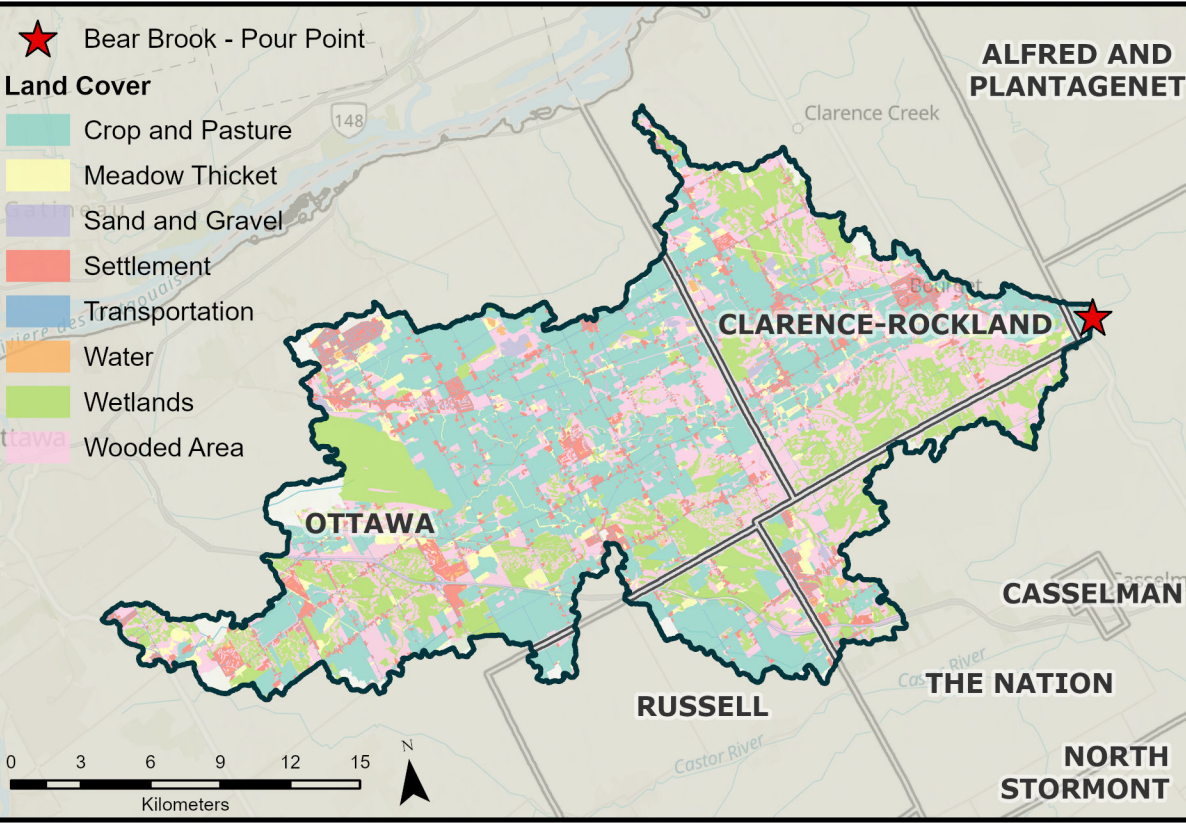
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### 3.4 Hydrologic Soil Groups

Soil characteristics such as texture, composition, and particle size distribution play a crucial role in the processes that drive the transformation of precipitation into runoff. **Table 3.3.** presents the percentages for each hydrologic soil group (HSG) in the Bear Brook subwatersheds and as a total for the entire watershed.

A summary of the four hydrologic soil groups based on the definitions provided in Chapter 7 of the National Engineering Handbook [8] are presented below.

- ◆ Soil Group A: “Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments”.
- ◆ Soil Group B: “Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand and have loamy sand or sandy loam textures. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments”.
- ◆ Soil Group C: “Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand and have loam, silt loam, sandy clay loam, clay loam, and silty clay loam textures. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments.
- ◆ Soil Group D: “Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted. Group D soils typically have greater than 40 percent clay, less than 50 percent sand, and have clayey textures. In some areas, they also have high shrink-swell potential. All soils with a depth to a water impermeable layer less than 50 centimeters of the surface are in this group, although some may have a dual classification, if they can be adequately drained”.

In the Bear Brook watershed there is a wide range of infiltration capacity within the soils as both clay and sandy soils are present. The clays in the watershed consist of Leda Clay which is an unstable type of clay that can behave like a liquid when disturbed, and such material was deposited during the last ice age in eastern Canada. Other soil types with clays present poor natural drainage characteristics and seasonal flooding, noting that they are rich in minerals and have high crop yields when drained.

On the other hand, sandy soils are largely covered by upland forest and treed swamps across the watershed. These soils drain well; however, they generally contain low nutrient levels and are easily erodible by wind, rain and stream flows.

There are landform features of interest within the Bear Brook watershed, such as the Vars-Winchester Esker which is a 50 km long, highly permeable ridge as well as a sandy-fan carapace that surrounds the esker which has moderate permeability. The Vars-Winchester Esker is a productive groundwater feature and provides municipal water for seven villages in the Bear Brook watershed.

Additionally, the Mer Bleue Bog is a large wetland within the watershed with low drainage capacity. The wetland covers approximately 3,500 hectares and it is considered one of the largest peat bogs in southern Ontario.

**Table 3.3. Hydrologic Soil Groups within the Bear Brook Watershed**

Hydrologic Soil Group	Infiltration Rate	Percentage Hydrologic Soil Group by Subwatershed						Total Percentage
		South Bear Brook	Shaw's Creek	Mer Bleue	Bear Brook	South Indian Creek	North Indian Creek	
A	High	6	4	11	16	25	9	14
B	Moderate	6	12	7	43	43	60	32
C	Slow	74	58	11	27	27	4	28
D	Very Slow	6	22	69	3	3	25	22
No Data	N/A	n/a	8	3	1	2	2	3

### 3.5 Municipal Drains

There are multiple designated municipal drains within the Bear Brook watershed, which must be maintained by the City of Ottawa and the United Counties of Prescott and Russell to fulfill the legislative requirements of the Drainage Act.

A layer showing designated municipal drains was extracted from the City of Ottawa geospatial portal (geoOttawa, 2025). There are 80 municipal drains located inside the Bear Brook watershed shown in this layer. The municipal drains were organized in alphabetical order and are presented in [Table 3.4](#) with their corresponding length. Other details of these drains are presented in the Bear Brook Watershed Floodplain Mapping Report [5].

As part of the flood mitigation study, the location and conveyance capacity of municipal drains will be explored to identify options which include but are not limited to increasing the conveyance capacity of municipal drains, redirecting flows at identified bypass locations, and extending municipal drains.

**Table 3.4. Municipal Drains located within the Bear Brook Watershed**

Municipal Drain Name	Length (km)	Municipal Drain Name	Length (km)	Municipal Drain Name	Length (km)	Municipal Drain Name	Length (km)
Aldema Cleroux	0.12	Dutrisac	4.86	Lalonde Cleroux	1.39	Rudolph Brisson	10.23
Antoine Cleroux	0.47	Edna Griffith	1.86	Leduc	8.27	Salomon Award	1.17
Aristide Cleroux	0.60	Eduoard Cleroux	0.35	Leo Robinson	1.65	Savage	13.73
Ashton Griffith	2.10	Emmet Garland	3.54	Lepage Charbonneau	1.21	Schnupp	3.22
Bear Brook	15.22	Ewart Watson	3.36	Lortie	0.99	Scott	3.04
Beauchamp	1.60	Frank Johnston	2.85	Louis Lafleur	4.57	Simpson	5.78
Bickerton	3.05	Frank McNeely	1.29	Lowe Armstrong	4.21	Smith-Gooding	14.66
Bourdeau	0.96	Gascon	1.04	M. Phillip	0.90	Smith-Staal	1.86
Brady	3.84	George Birch	1.67	Marcel Racine	1.48	South Morrow	0.28
Charlebois Vinette	5.95	Germain Lapalme	0.02	McFadden	3.03	Stanley Edwards	1.88
Chartrand Shaw	1.60	Griffith Lacroix	0.78	McWilliams	4.71	Sylvio Pilon	0.57

Childs Lacroix	1.19	H. Cleroux	0.85	Nelson Charlebois	2.17	Tasse Regimbald	1.54
Christie Dashney	3.14	Hammond	2.45	North Indian Creek	5.53	Tessier	0.94
Clark Rothwell	1.94	Harold Shaw	1.79	Patenaude	3.54	Thibodeau Toonders	1.32
Daoust	2.97	Henry Hill	1.07	Raymond Bouvier	0.88	Van Vliet	1.85
David Cleroux	2.35	Hupe	3.34	Regimbald	7.24	Vas Trudeau	1.11
Denis Perrault	0.65	John MacDonald	3.35	Richard Clark	3.56	Vinette	5.23
Desjardins-Morris	2.33	Johnston	6.85	Robert Walsh	2.13	Walsh Hayes	2.31
Devine	4.26	Labelle	8.30	Rochon	2.86	Walter Henn	1.82
Dubois	0.71	Labreche	4.83	Royal Goudreau	1.77	Wilson Johnston	7.85

## 4. Natural Environment

### 4.1.1 Natural Heritage Features

Natural heritage features include wetlands, fish habitat, woodlands, and habitats for wildlife. Designated natural heritage features include areas recognized for their unique ecological values by municipal and provincial governments, and/or the public. These are protected through legislations, policies or approved management plans. Designated natural heritage features identified within the Study Area, with available open mapping data, are shown in **Figure 4** and include the following:

**Municipal Natural Heritage Systems:** Municipal Natural Heritage Systems (NHS) are identified in the Official Plans and Schedules of both the City of Ottawa and United Counties of Prescott and Russell (UCPR). Within the City of Ottawa, the NHS is outlined in Section 4.8.1 of the Official Plan and depicted on Schedule C11 [9]. The City of Ottawa NHS consists of protected core areas and connecting linkages that support ecological integrity and biodiversity. Components of the NHS identified by the City of Ottawa include significant wetlands; habitat for Endangered and Threatened species; Significant Woodlands, Significant Valleylands, Significant Wildlife Habitat (SWH), Areas of Natural and Scientific Interest (ANSIs), Urban Natural Features, Natural Environment Areas, natural linkage features and corridors, groundwater features, surface water features including fish habitat, and landform features [10].

The UCPR NHS is made up of “Regional Cores”, which are large areas of natural cover that are connected by corridors. Components of the UCPR NHS include provincially significant wetlands (PSW), ANSIs, habitat of Endangered or Threatened species, SWH, natural sites of county significance, Significant Woodlands, fish habitat, Significant Valleylands, groundwater recharge areas and river corridors [11]. As per the UCPR Official Plan, significant natural heritage features are illustrated in Schedule B2, with the exception of significant wetlands that are shown on Schedule A2 [11]. Additionally, natural features that are not identified as significant but that form part of the UCPR NHS are identified on Schedule B1 [11].

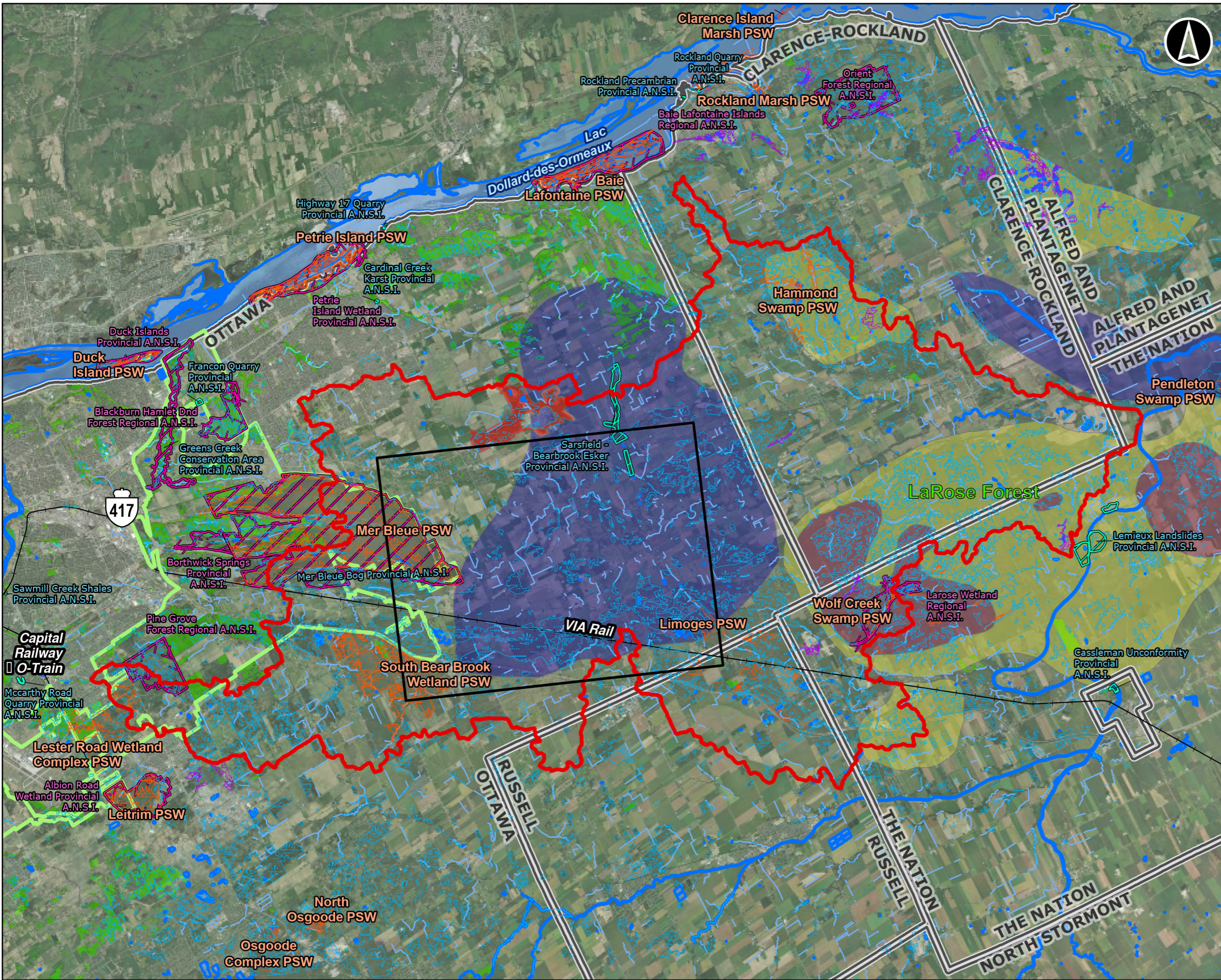
Portions of Ottawa’s Greenbelt also fall within the watershed. Situated south of Ottawa and managed by the National Capital Commission, this 20,000-hectare horseshoe-shaped Greenbelt contributes farms, forests, and natural areas to the headwaters of Bear Brook [12].

**Provincially Significant Wetlands:** Bear Brook Watershed contains six PSWs, including Hammond Swamp, Lester Road Wetland Complex, Limoges Swamp, Mer Bleue Bog, South Bear Brook Swamp and Wolf Creek Swamp [13].

**Areas of Natural and Scientific Interest:** There are two ANSIs in the Bear Brook Watershed; these are the Mer Bleue Bog Life Science ANSI and the Sarsfield-Bear Brook Esker Earth Science ANSI. The Mer Bleue Bog Life Science ANSI encompasses the entirety of the Mer Bleue Bog PSW. The Sarsfield-Bear Brook Esker Earth Science ANSI, a portion of the Vars-Winchester Esker, extends north to south along much of the eastern edge of the City of Ottawa. This ANSI is geologic in nature and is representative of a significant landform and geologic process that has occurred within the Bear Brook watershed.

**Conservation Lands:** A collection of Conservation Lands has been identified in the Watershed including lands identified by the UCPR, National Capital Commission, South Nation Conservation Lands, City of Ottawa Lands and Crown Lands [13]. These areas are managed for conservation purposes and contribute significantly to the integrity of the core natural heritage areas and ecological linkages throughout the watershed.

**Significant Wildlife Habitat:** The Ministry of Natural Resources (MNR) has identified and mapped White-tailed Deer Wintering Areas (Stratum 2), Moose Early Wintering Areas and Waterfowl Staging Areas within the watershed. These mapped areas are considered confirmed Significant Wildlife Habitat.



**Legend**

- Approximate Focus Area
- Project Study Area (Bear Brook Watershed)
- Ottawa Greenbelt

Area of Natural and Scientific Interest (A.N.S.I.)

- Candidate Life Science
- Earth Science
- Life Science

Wildlife Activity Type

- Moose Early Wintering Area
- Waterfowl Staging Area
- White-tailed Deer Wintering Area (Stratum 2)
- White-tailed Deer Yard (Stratum 1)

Wetland Types

- Provincially Significant Wetland (PSW)
- Unevaluated Wetland
- Evaluated-Other Wetland

Other Features

- Waterbody
- Watercourse
- Wooded Area
- Municipal Boundary

0 1,250 2,500 5,000 7,500 10,000  
Metres

BEARBROOK EA

Natural Heritage Features

November 2025	1:152,000 <small>* when printed 11"x17"</small>	Datum: NAD 1983 UTM Zone 17N Source: LIO, Ottawa Open Data Portal Ontario. Image: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAF, NRCan World Imagery: Earthstar Geographics
P#: 60763197		<b>Figure 4</b>

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### 4.1.2 Ecosystem and Habitat

The Bear Brook watershed is located within Ecoregion 6E (Lake Simcoe - Rideau), which extends from Lake Huron to the Ottawa River and encompasses much of the Lake Ontario shoreline and the Ontario portion of the St. Lawrence River Valley. The bedrock is primarily Paleozoic dolomite and limestone of Ordovician and Silurian ages, with the Frontenac Axis containing a complex mix of Precambrian granites and gneisses alongside Ordovician limestone and sandstone [14]. Vegetation across the ecoregion is diverse, with upland hardwood forests dominated by sugar maple (*Acer saccharum*), American beech (*Fagus grandifolia*), white ash (*Fraxinus americana*), and eastern hemlock (*Tsuga canadensis*). Lowland and floodplain forests support green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinum*), red maple (*Acer rubrum*), eastern white cedar (*Thuja occidentalis*), yellow birch (*Betula alleghaniensis*), balsam fir (*Abies balsamea*), and black ash (*Fraxinus nigra*) [14].

Additionally, the Bear Brook watershed encompasses a varied landscape of agriculture, meadow, wetland, watercourses, forests, and developed areas. Approximately 38.8 percent of its land base is forested, representing an estimated 18,655 hectares [13]. Much of this cover is concentrated in large, continuous natural heritage features that provide core areas of wildlife habitat. The Larose Forest, half of which lies within the watershed, contributes over 10,944 hectares of forest and wetlands [15], with its northern portion near the outlet of Bear Brook forming one of the largest contiguous natural areas in the watershed [13]. The Cumberland Forest, consisting of three City of Ottawa properties, provides an additional 600 hectares of protected forest and serves as a linkage between the Larose Forest and the Mer Bleue wetland complex [13].

Wetlands are a predominant land cover type across the Bear Brook Watershed, occupying approximately 10,600 hectares, or 33 percent of the total area [13]. Numerous evaluated and unevaluated wetlands are located within the watershed, six of which are provincially designated. The Mer Bleue Bog, with a surface area of more than 3,300 hectares, is southern Ontario's second largest domed bog and has been recognized internationally for its ecological significance under the Ramsar Convention [16]. Ground cover of the bog is dominated by *Sphagnum* ssp. moss, and the vegetation cover consists of open heath vegetation, dominated by Labrador tea (*Ledum groenlandicum*), leather leaf (*Chamaedaphne* sp.) and small cranberry (*Vaccinium oxycoccus*), as well as black spruce (*Picea mariana*) forest [17].

### 4.1.3 Biodiversity

The varied habitats within the Bear Brook Watershed support a high diversity of wildlife. Over 4,000 research-grade species observations have been recorded in the Bear Brook Watershed through iNaturalist, highlighting its rich biodiversity. A 2010 bioblitz within the Larose Forest alone, for example, identified 743 species across eight taxonomic groups [18].

For the purposes of this memorandum, Species at Risk (SAR) are defined as those listed as Threatened or Endangered provincially under the *Endangered Species Act* (ESA), 2007, or federally under Schedule 1 of the *Species at Risk Act* (SARA), 2002. A review of secondary sources, including the Species at Risk in Ontario List [19], Species at Risk Public Registry [20], Bat Conservation International [21], Natural Heritage Information Centre (NHIC), Ontario Breeding Bird Atlas [22], Ontario Reptile and Amphibian Atlas [23], eBird [24], and iNaturalist [25], identified records of 32 different SAR within or near the watershed.

These included one amphibian, Western Chorus Frog – Great Lakes St. Lawrence Population (*Pseudacris maculata* pop. 1); three aquatic species, Hickorynut (*Obovaria olivaria*), American Eel (*Anguilla rostrata*), and Lake Sturgeon (*Acipenser fulvescens* pop. 3); 14 birds, Bank Swallow (*Riparia riparia*), Bobolink (*Dolichonyx oryzivorus*), Chimney Swift (*Chaetura pelagica*), Eastern Meadowlark (*Sturnella magna*), Eastern Whip-poor-will (*Antrostomus vociferus*), Henslow's Sparrow (*Centronyx henslowii*), Least Bittern (*Ixobrychus exilis*), Loggerhead Shrike (*Lanius ludovicianus*), Red-headed Woodpecker (*Melanerpes erythrocephalus*), Short-eared Owl (*Asio flammeus*), Golden-winged Warbler (*Vermivora chrysoptera*), Barn Swallow (*Hirundo rustica*), Wood Thrush (*Hylocichla mustelina*) and Canada Warbler (*Cardellina canadensis*); two trees, Black Ash (*Fraxinus nigra*) and Butternut (*Juglans cinerea*); two reptiles, Blanding's Turtle (*Emydoidea blandingii*) and Spotted Turtle (*Clemmys guttata*), three insects, Monarch (*Danaus plexippus*), Skillet Clubtail (*Gomphurus ventricosus*) and Transverse Lady Beetle (*Coccinella transversoguttata*); and Ontario's seven bat SAR: Little Brown Myotis

(*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), Eastern Small-footed Myotis (*Myotis leibii*), Tri-coloured Bat (*Perimyotis subflavus*), Eastern Red Bat (*Lasiurus borealis*), Silver-haired Bat (*Lasionycteris noctivagans*), and Hoary Bat (*Lasiurus cinereus*).

Known SAR hotspots include the Mer Bleue Bog and Larose Forest. Additionally, the Mer Bleue Bog provides habitat for Blanding's Turtle and Spotted Turtle with nesting and juvenile Spotted Turtles documented through long-term monitoring studies [26]. Larose Forest has been known to host Eastern Whip-poor-will, Wood Thrush, and Canada Warbler [18]. During the 2010 Larose Forest bioblitz, eight Eastern Whip-poor-wills were recorded in areas of open conifer plantations and early successional forest [18]. Black Ash was also recorded within the South Bear Brook Swamp PSW during a 2020 wetland evaluation, along with observations of Monarch and Wood Thrush [27].

In addition to SAR, a review of secondary sources indicates that there are records for 74 Species of Conservation Concern (SOCC) within the Bear Brook Watershed, defined as species with Provincial S-rank assigned by the NHIC as S1 (critically imperilled), S2 (imperilled) or S3 (vulnerable) and species listed as Special Concern (SC) under the ESA and SARA. Of the 74 SOCC, these included 1 amphibian, 13 birds, six fish, 15 insects, 33 plants, lichens and moss, and 6 reptiles.

Many of the provincially rare (S1 – S3) plant species are known to occur in the Mer Bleue Bog. The bog hosts a high diversity of flora and fauna because of its relatively undisturbed natural habitat and its uniqueness in representing a boreal habitat which is normally found much farther north [17].

At least 22 mammal species have been documented in or near the bog, including aquatic furbearers such as American Beaver (*Castor canadensis*), Muskrat (*Ondatra zibethicus*), and Mink (*Neogale vison*), and terrestrial species including Eastern Red Fox (*Vulpes vulpes*), White-tailed Deer (*Odocoileus virginianus*), Coyote (*Canis latrans*), and Raccoon (*Procyon lotor*) [17].

Numerous bird species, including SOCC such as Black-crowned Night Heron (*Nycticorax nycticorax*), Eastern Wood-pewee (*Contopus virens*), Common Nighthawk (*Chordeiles minor*), and Olive-sided Flycatcher (*Contopus cooperi*) (eBird, 2025) have been noted in the bog, in addition to regionally rare insects and plants [17].

The Mer Bleue Conservation Area, encompassing the Mer Bleue Bog, has been nominated under the Important Amphibian and Reptile Areas (IMPARA) Program by the Canadian Wildlife Federation and the National Capital Commission due to providing habitat for a diverse number of reptiles and amphibians, including the two SAR turtle species [28].

With the exception of MNR data noted in the section above, no other official SWH mapping exists for the full watershed, but it is likely numerous SWH occurs throughout. The NHIC identified the presence of two Wildlife Concentration Areas in the watershed, a Colonial Waterbird Nesting Area and Mixed Wader Nesting Colony, both of which are considered as SWH. Great Blue Heron (*Ardea Herodias*) was noted to be nesting in the South Bear Brook Swamp PSW during the wetland evaluation, which indicates the potential presence of a Colonial Waterbird Nesting Area and would be considered as SWH [27]. The habitats for any of the 74 SOCC identified within the watershed would also be considered SWH. Mer Bleue Bog is also known to provide hibernaculum for Spotted Turtle [26].

## 4.2 Climate Change

The climate regime within the watershed includes cold, snowy winters and warm, humid summers [3]. Mean temperatures vary significantly by season with slightly higher precipitation occurring between April and October. The same report also notes that based on the latest statistics of Climate Normals, which were calculated from data for the period of 1991 to 2020 at the Ottawa International Airport weather station (ECC, 2024), the region shows a long-term warming trend, where temperatures have been steadily rising during ice-free months as well as during the winter season.

Furthermore, a climate projection study done by the National Capital Commission (NCC) and the City of Ottawa [29], indicates that under both Representative Concentration Pathways (RCP) 4.5 (moderate emissions) and RCP 8.5 (high emissions), the climate patterns are projected to become warmer and wetter. These projections suggest a shift in seasonal timing, with increased precipitation in all seasons except summer. Rainfall is

expected to increase in both volume and intensity, while annual snowfall may decrease, leading to a shorter snow season.

## 5. Geotechnical Background

The Bear Brook Watershed lies primarily within the Ottawa Valley Clay Plains physiographic region, with portions extending into the Prescott and Russell Sand Plains (Chapman and Putnam, 2007). Supporting data from South Nation Conservation (SNC 2024) indicates that the watershed is characterized by extensive marine clay deposits (Leda clay) derived from post-glacial Champlain Sea sediments, which overlie deltaic sands, silts, and glaciofluvial materials.

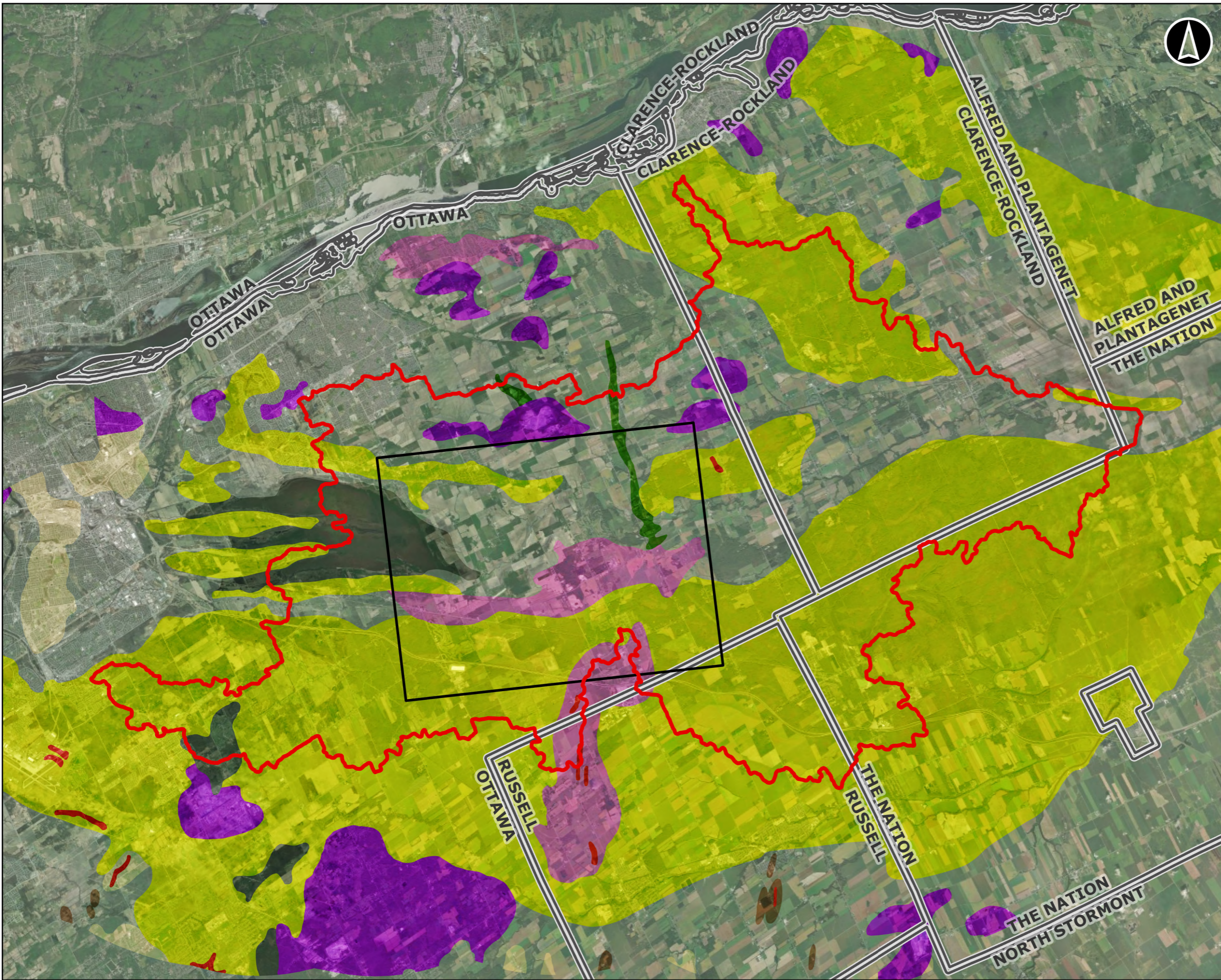
These deposits exhibit high plasticity, low permeability, and sensitivity to disturbance, rendering them susceptible to instability, retrogressive landslides, and differential settlement, particularly along the Bear Brook valley and its tributaries. Localized areas of sand and gravel, including those associated with the Vars–Winchester Esker, provide more permeable soils that serve as groundwater recharge zones and contribute to local hydrogeologic connectivity. The variable stratigraphy of soft clays interbedded with coarser sediments creates complex geotechnical conditions influencing drainage, slope stability, and foundation design across the watershed.

Once specific mitigation areas and design locations are confirmed, a detailed geotechnical investigation will be required to assess subsurface conditions, material properties, slope stability, and bearing capacities. This investigation will inform the flood mitigation feasibility study, structural design, and erosion hazard management, and must be completed in accordance with Ontario Regulation 41/24 and relevant geotechnical and environmental assessment standards.

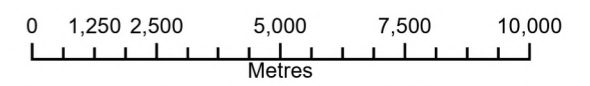
At the time of this assessment, the geotechnical information available is limited to regional and desktop-based datasets. Site-specific geotechnical investigations will need to be undertaken following the completion of the Environmental Assessment and the start of detailed design activities, once preferred flood mitigation alternatives and specific construction footprints have been identified.

### 5.1.1 Hydrogeology/Groundwater

As discussed in the geotechnical background, the predominant physiographic region in the Study Area is the Ottawa Clay Plain. The Physiographic landforms within the watershed are shown in **Figure 5**. Within the watershed, these landforms include peat and muck on the western side, sand plains along the southern boundary in the northeast corners and along the northwest quadrant with till plains through the central area. An esker (a portion of the Vars-Winchester esker) is identified trending north to south along the eastern half of the watershed. Surficial geology mapping (**Figure 6**) shows a central area of stone-poor, sandy silt to silty sand-textured till with areas of glaciomarine deposits, both fine-textured and coarse textured.



- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
- Physiography Description**
- 17: Peat And Muck
  - Beaches
  - 6: Till Plains (Drumlinized)
  - 13: Eskers
  - Sand Plains
  - 9: Limestone Plains
  - 7: Drumlins
  - 5: Till Plains (Undrumlinized)



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Physiographic Landforms

November 2025	1:152,000 <small>* when printed 11"x17"</small>	Datum: NAD 1983 UTM Zone 17N Source: LIO, OGS, Chapman and Putnam, 1984 : The Physiography of Southern Ontario. Image: World Topographic Map; Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAFIC, NRCAN World Imagery: Earthstar Geographics
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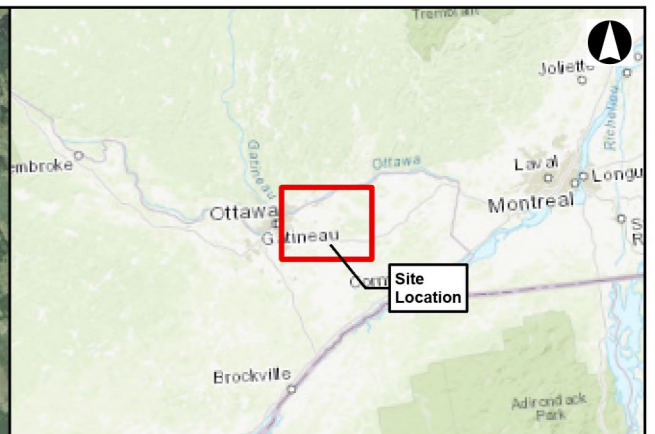
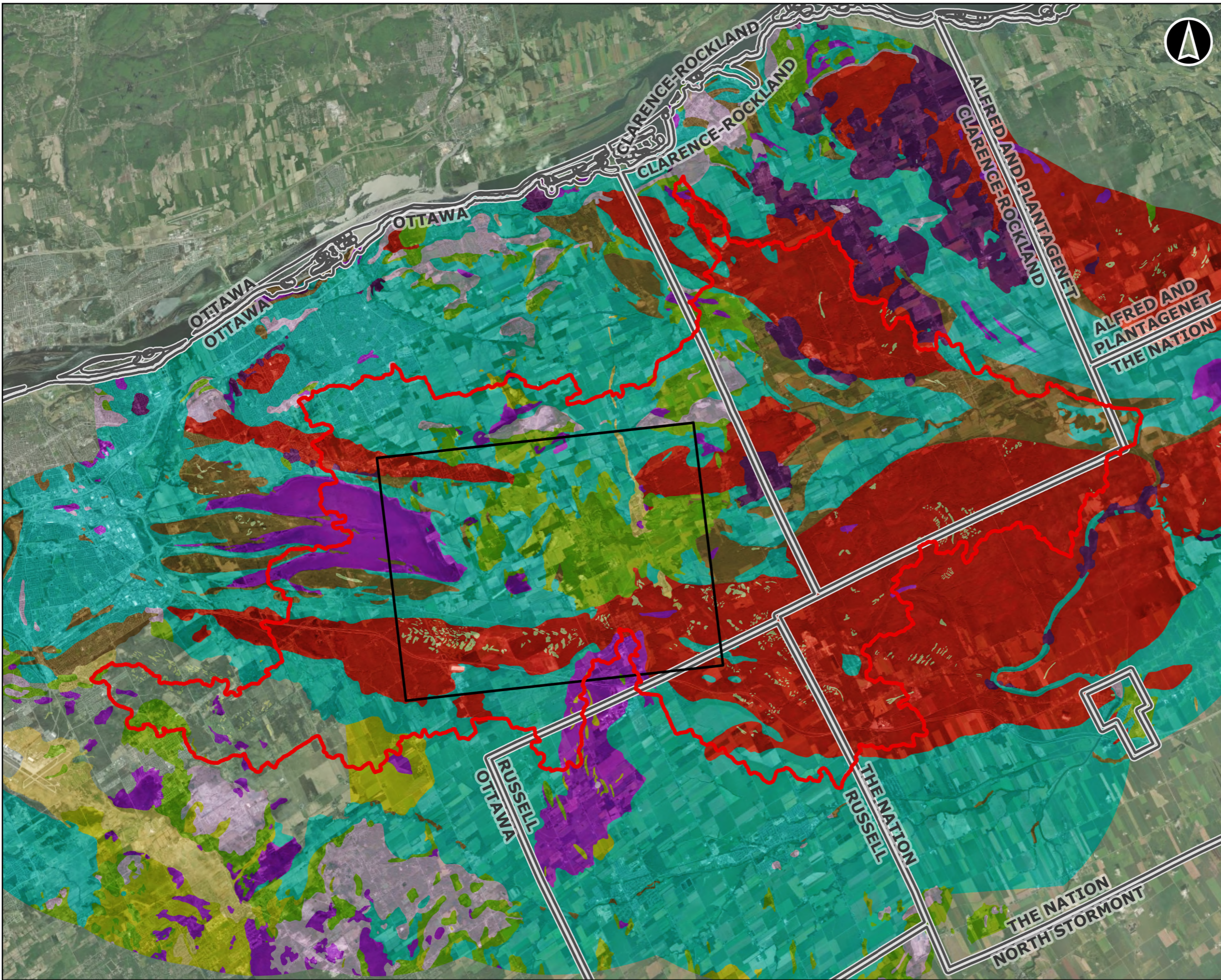
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Figure 5

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**Legend**

- Project Study Area (Bear Brook Watershed)
- Approximate Focus Area

**Surficial Geology Material Description**

- 1: Precambrian bedrock
- 3: Paleozoic Bedrock
- 5b: Till (Stone-poor, sandy silt to silty sand-textured till on Paleozoic terrain) 10a Fine-textured glaciomarine deposits)
- 7: Glaciofluvial deposits (river deposits and delta topset facies)
- 10a: Massive-well laminated
- 11a Coarse-textured glaciomarine deposits (sand, gravel, minor silt and clay)
- 11b: Coarse-textured glaciomarine deposits (sand, gravel, minor silt and clay)
- 11c: Coarse-textured glaciomarine deposits (sand, gravel, minor silt and clay Foreshore and basal deposits)
- 12: Older alluvial deposits
- 17: Eolian deposits
- 18: Colluvial deposits
- 19: Modern Alluvial Deposits (clay, silt, sand, gravel, may contain organic remains)
- 20: Organic deposits (peat, muck and marl)

0 1.25 2.5 5 7.5 10  
km

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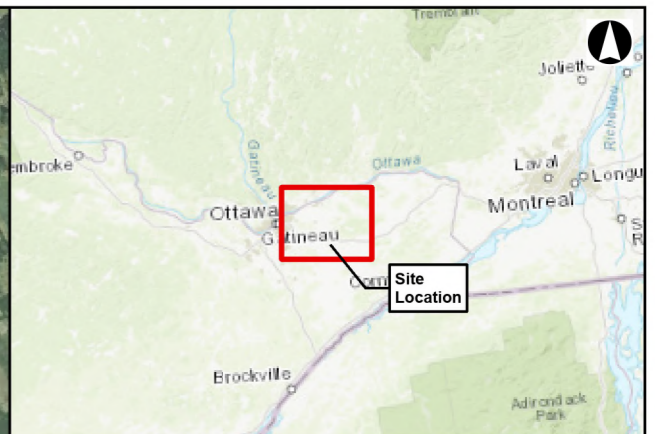
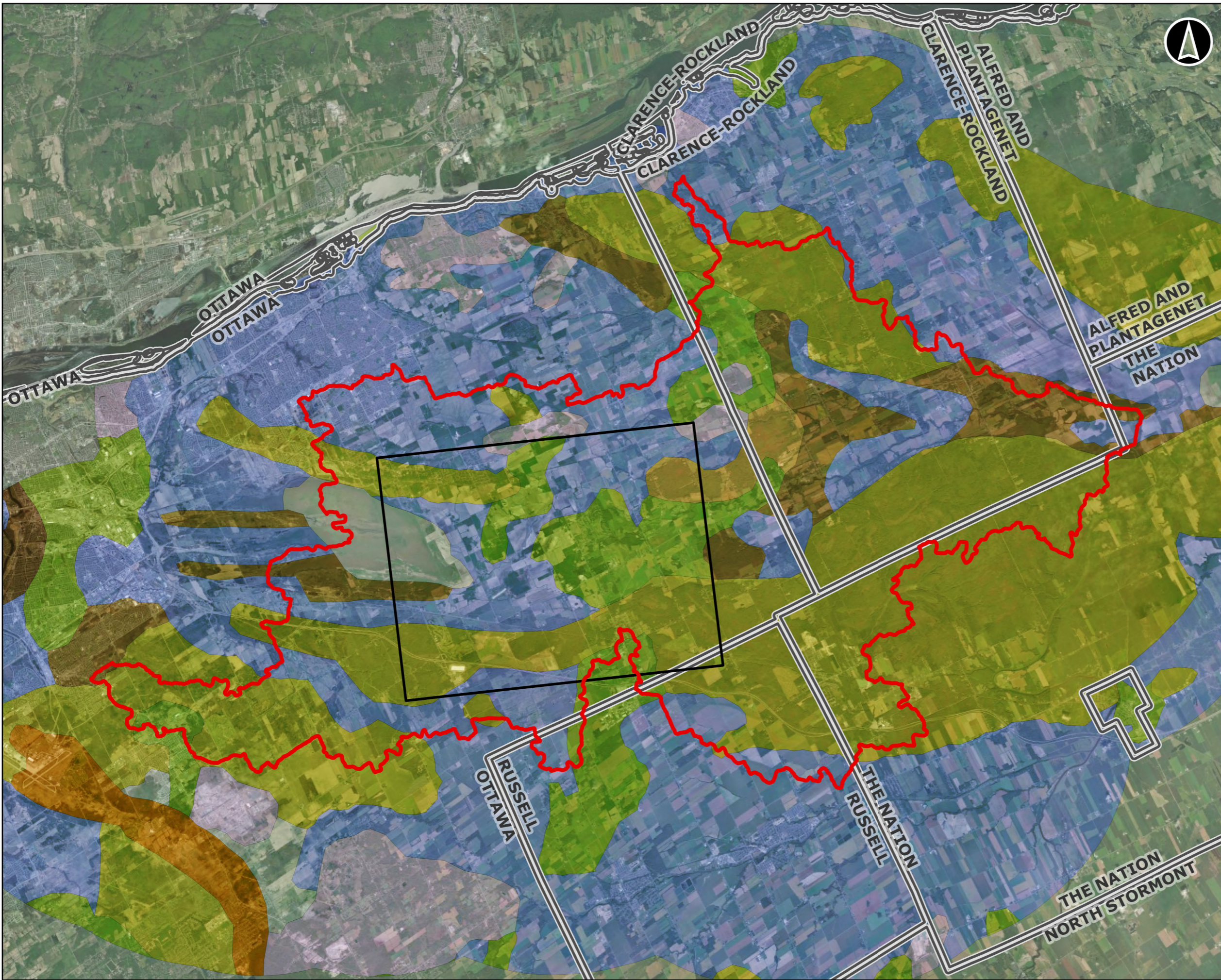
Surficial Geology

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P#: 60763197		<b>Figure 6</b>

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The Flood Mitigation Assessment area contains deposits from the Pleistocene Epoch (Figure 7), a mix of organics (western watershed area), undifferentiated till that is of a predominantly sandy silt to silt matrix with glaciomarine deposits of silt and clay in the central area, and glaciomarine and marine deposits (sand, gravelly sand and gravel) on the north and south boundaries. The underlying bedrock is primarily comprised of the Carlsbad Formation, which contains shale and limestone, with an area of Billings shale in the north and a portion of Lindsay Formation Limestone in the northeast corner (Figure 8).

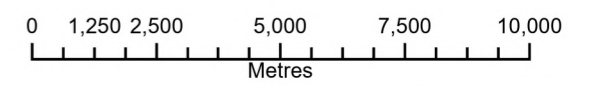


**Legend**

- Project Study Area (Bear Brook Watershed)
- Approximate Focus Area

**Quaternary Geology Description**

- 2: Paleozoic Bedrock (Undifferentiated Carbonate and Clastic Sedimentary Rock, Exposed at Surface or Covered by a Discontinuous, Thin Layer of Drift)
- 19: Till (undifferentiated, predominantly sandy silt to silt matrix, commonly rich in clasts, often high in total matrix carbonate content)
- 22: Glaciofluvial Ice
- 23: Glaciofluvial Outwash deposits
- 26: Glaciomarine and marine deposits (silt and clay, basin and quiet water deposits)
- 27: Glaciomarine and marine deposits (sand, gravelly sand and gravel, nearshore and beach deposits)
- 28: Fluvial deposits (gravel, sand, silt and clay)
- 31: Fluvial deposits (gravel, sand, silt and clay, deposited on modern flood plains)
- 32: Organic deposits



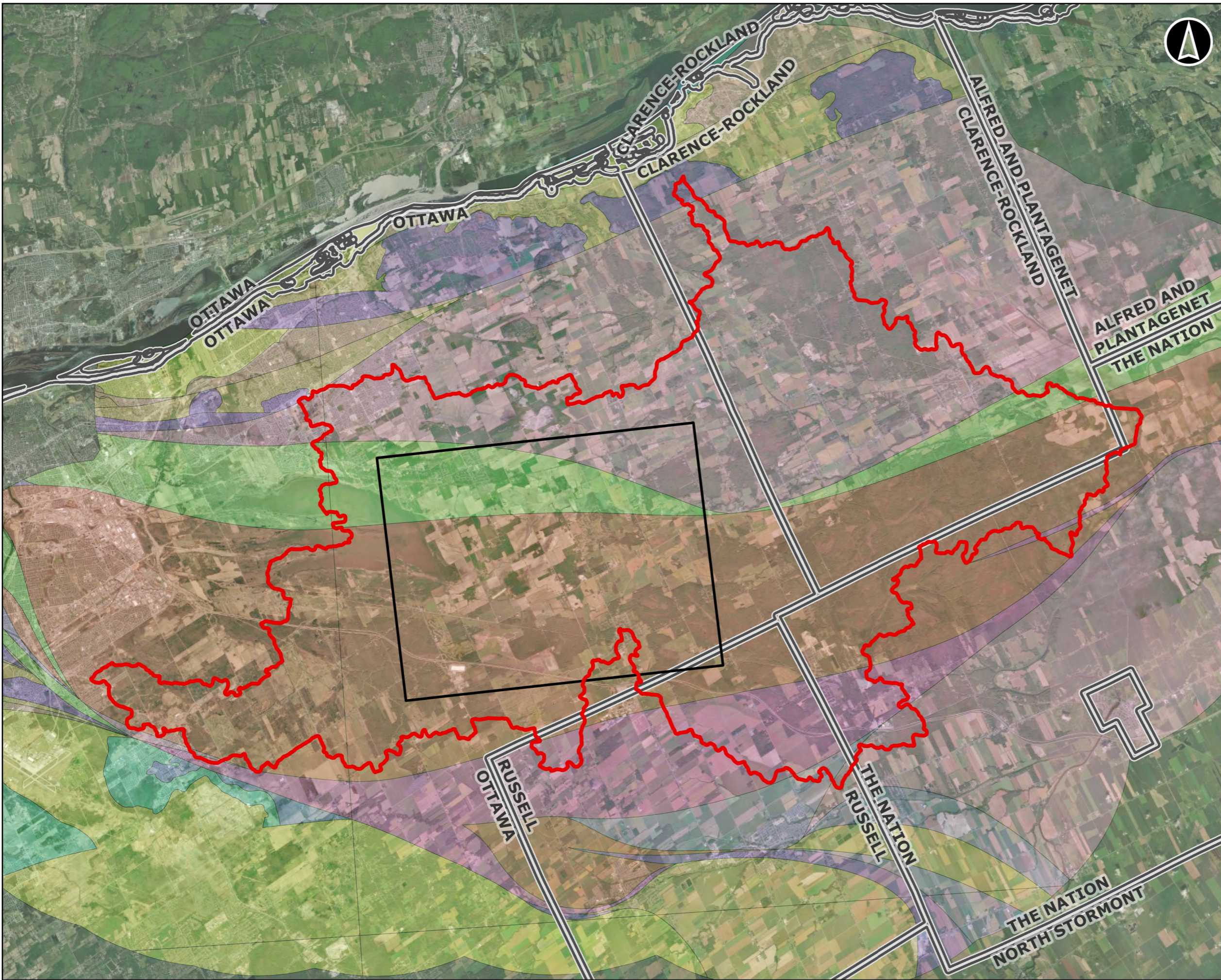
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**Quaternary Geology**

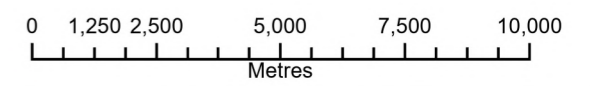
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P#: 60763197	<b>Figure 7</b>	

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- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
- Bedrock Formation Description**
- Billings: shale, minor limestone
  - Bobcaygeon
  - Carlsbad: shale and limestone
  - Covey Hill
  - Gull River
  - Lindsay: limestone; nodular to black laminated (Collingwood)
  - March
  - Nepean
  - Oxford
  - Precambrian
  - Queenston
  - Rockcliffe
  - Verulam



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Bedrock Geology

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P#: 60763197		<b>Figure 8</b>



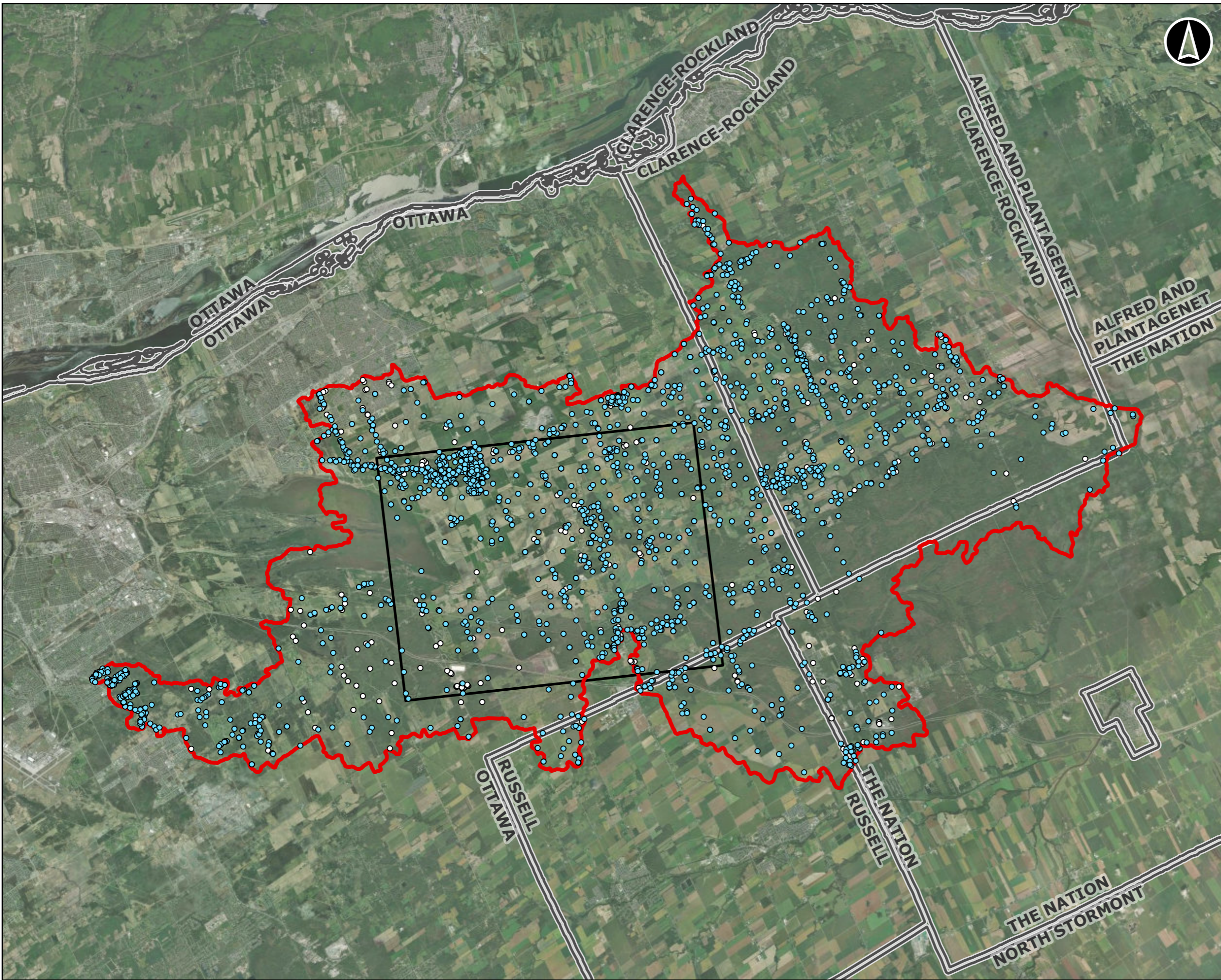
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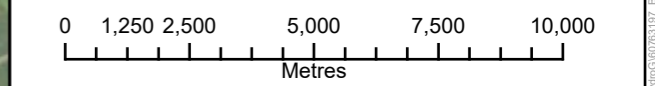
Additionally, within the Bear Brook watershed, the MECP database of Water Well Records identified 3,432 points in total, with 2,900 identified as water supply wells or unclassified (**Figure 9**). Within the watershed there are two public groundwater supplies (Vars/Limoges Municipal wells), each having their corresponding wellhead protection areas (WHPA-A through WHPA-D)<sup>1</sup> in the south-central portion of the watershed (**Figure 10**). Most of the watershed is identified as a Highly Vulnerable Aquifer (HVA) by the South Nation Source Water Protection Area (**Figure 11**) and is also identified as a Significant Groundwater Recharge Area (**Figure 12**).

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<sup>1</sup> WHPA-A is a circle with a radius of 100 m that surrounds a water supply well. WHPA-B, C, and D, represent the surface and subsurface areas within which the time of travel to the well is less than or equal to two, five, and twenty-five years, respectively.



- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
- Water Well Use**
- No Data
  - Water Supply



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**MECP Water Well Records**

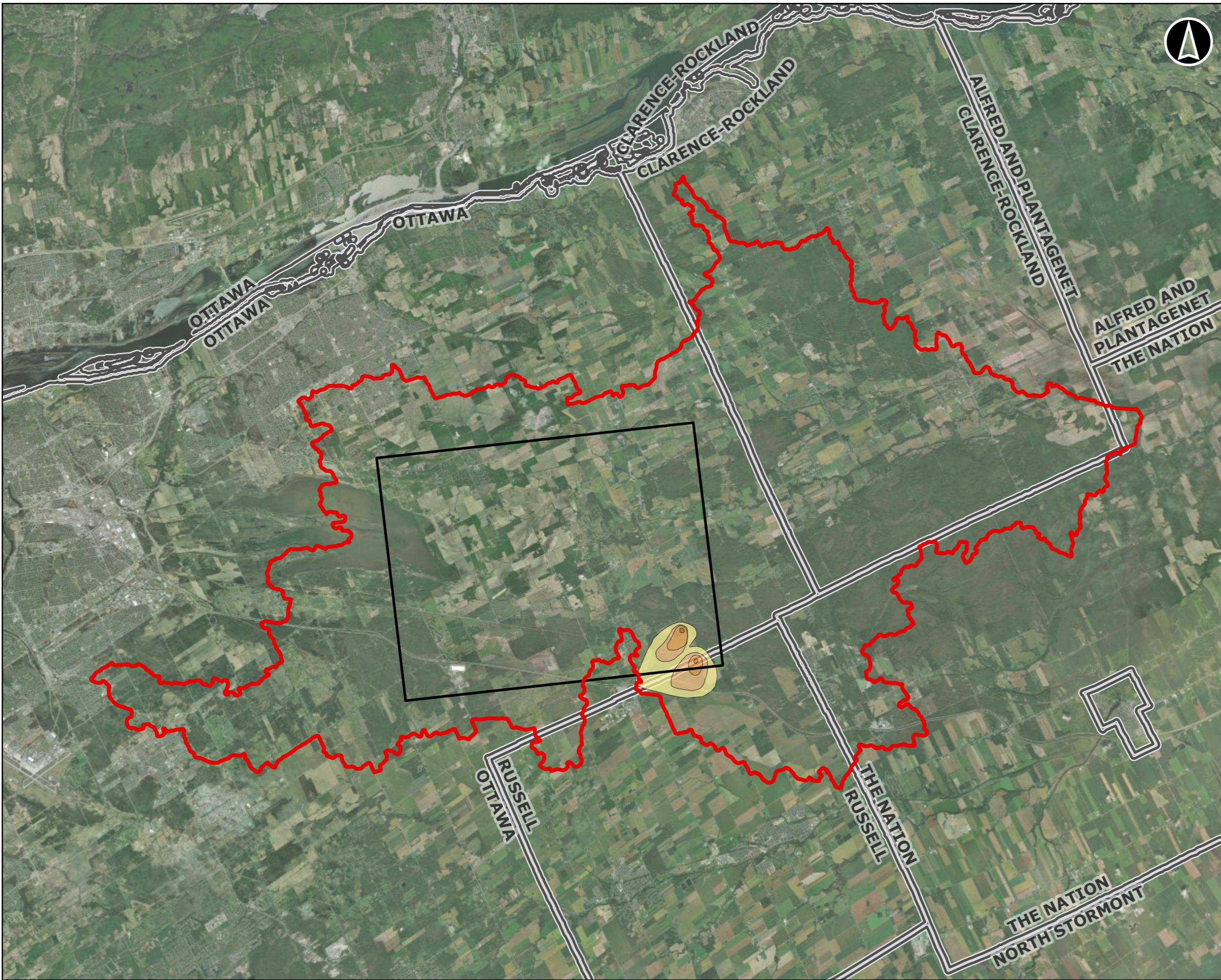
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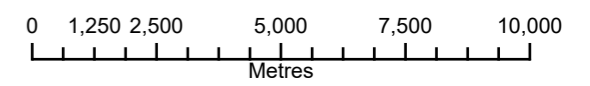
Figure 9

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- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
- Wellhead Protection Areas
- A
  - B
  - C
  - D
- Municipal Boundary



BEARBROOK EA

Wellhead Protection Areas

November 2025	1:152,000 <small>* when printed 11"x17"</small>	Datum: NAD 1983 UTM Zone 17N Source: LIO, MCEP Image: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAF, NRCAN World Imagery: Earthstar Geographics
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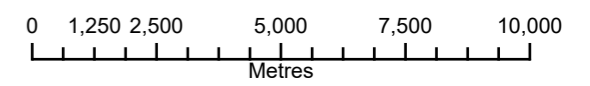
<b>AECOM</b>	<b>Figure 10</b>
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- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
  - Highly Vulnerable Aquifers (TRSPA)
  - Municipal Boundary



BEARBROOK EA

Highly Vulnerable Aquifers

November 2025	1:152,000 <small>* when printed 11"x17"</small>	Datum: NAD 1983 UTM Zone 17N Source: LIO, MCEP Image: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAFC, NRCAN World Imagery: Earthstar Geographics
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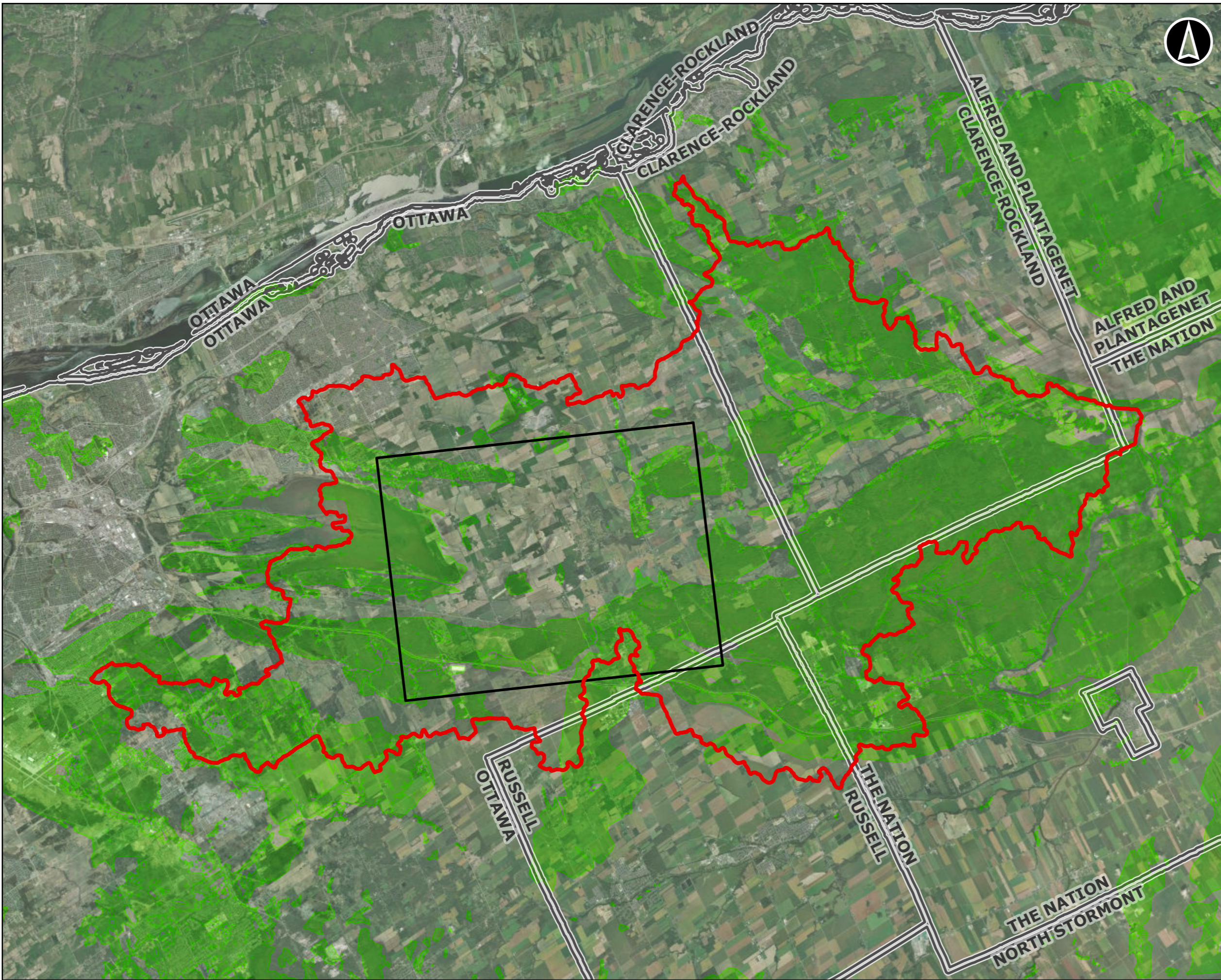
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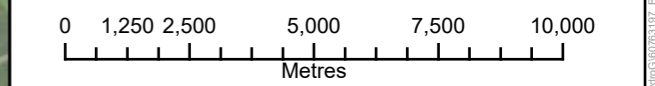
**Figure 11**

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Map Source: C:\00\SAC\Projects\60763197\Bearbrook\Map\60763197\_Bearbrook\_HighlyVulnerableAquifers.aprx  
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- Legend**
- Project Study Area (Bear Brook Watershed)
  - Approximate Focus Area
  - Significant Groundwater Recharge Area
  - Municipal Boundary



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Significant Groundwater Recharge Area

November 2025	1:152,000 <small>* when printed 11"x17"</small>	Datum: NAD 1983 UTM Zone 17N Source: LIO, MCEP Image: World Topographic Map: Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS, AAF, NRCAN World Imagery: Earthstar Geographics
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Figure 12

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Additionally, the Sarsfield-Bear Brook Esker Earth Science ANSI, a portion of the Vars-Winchester Esker, extends north to south along much of the eastern edge of the City of Ottawa. This ANSI is geologic in nature and is representative of a significant landform and geologic process that has occurred within the Bear Brook watershed. This esker is the water source for the Vars/Limoges Municipal wells, and it runs approximately north/south right through the eastern portion of the Flood Mitigation Assessment Area.

Protection of groundwater resources should be considered in any proposed works within the watershed.

## 6. Cultural Heritage

### 6.1.1 Archaeology

True North Archaeological Services Inc. completed an Archaeological Screening Report in 2024 as a land planning tool for the Bear Brook watershed [30]. The report identifies areas with prior archaeological assessments and highlights areas retaining archaeological potential. Once the specific areas of proposed impacts are determined, a Stage 1 Archaeological Assessment must be conducted for all proposed lands to be impacted, and the report must be submitted to the Ministry of Citizenship and Multiculturalism (MCM) for review and approval.

The Archaeological Screening Report serves as a preliminary planning resource, while the Stage 1 Assessment is required for regulatory compliance during project design.

### 6.1.2 Built Heritage

A desktop review was undertaken to identify known cultural heritage resources within the Bear Brook watershed (**Figure 1**). Generally, when conducting a preliminary identification of known cultural heritage resources, several stages of research and data collection are completed to adequately establish the existence of known cultural heritage resources in a geographic area. Therefore, a review of sources to screen for known cultural heritage resources within the study area is provided below:

- ◆ A review of online searchable databases including:
  - Municipal Heritage Registers [31]: City of Ottawa, Township of Russell, Municipality of the Nation, and City of Clarence-Rockland;
  - Ontario Heritage Trust: Conservation Easements [32], Places of Worship Inventory [33], Plaque Program [34], and *Ontario Heritage Act* Register [35];
  - Ontario Historical Society: Ontario Heritage Directory and Map [36];
  - Ontario Genealogical Society: Cemetery Index [37];
  - Parks Canada Agency [38]: National Historic Sites, Canadian Register of Historic Places, Directory of Federal Heritage Designations, Directory of Designated Heritage Railway Stations and Heritage Lighthouses of Canada;
  - Canadian Heritage River System website [39]; and,
  - United Nations Educational, Scientific and Cultural Organization (UNESCO): World Heritage Sites [40].
- ◆ Correspondence with the municipal heritage department of the City of Ottawa, along with planning staff from the Township of Russell, Municipality of the Nation, and City of Clarence-Rockland; and
- ◆ Correspondence with staff at the Ministry of Citizenship and Multiculturalism (MCM) and the Ontario Heritage Trust (OHT).

The status and results of the correspondence with MCM, OHT, and the municipalities is presented below:

- ◆ MCM confirmed that no properties in the study area have been designated by the Minister and that MCM has no records of a provincial heritage property within or adjacent to the study area.
- ◆ OHT confirmed the OHT has a conservation easement agreement to protect a natural heritage property called “Garlandside Road” in the City of Ottawa. Details on the property are provided below.

- ◆ Heritage planners from the City of Ottawa provided a list of properties in the Bear Brook watershed identified by the municipality as Designated Part IV, listed on the heritage register (non-designated), and properties formerly listed on the municipal heritage register. Several properties were noted by the heritage planners as being adjacent to the study area and have been noted below.
- ◆ The Township of Russell confirmed that no properties from the municipal heritage register are located within the study area.
- ◆ The Municipality of the Nation confirmed that no properties from the municipal heritage register are located within the study area.
- ◆ The City of Clarence-Rockland confirmed that no properties from the municipal heritage register are located within the study area.

### **Results of the Desktop Review**

The following known cultural heritage resources were identified during the desktop review:

#### **City of Ottawa**

The OHT confirmed through correspondence that the following natural heritage property is protected by a conservation easement agreement:

- ◆ Garlandside Road: Located on east half of Lot 23 & 24, Concession 3, Part 1 on R-Plan 4R-9684, PIN 1455-0006. A 200-acre property located off Garlandside Road, north of Devine Road, owned by the South Nation Conservation Authority.

The following known cultural heritage resources within the study area in the City of Ottawa are Designated Part IV under the *Ontario Heritage Act* and are included on the municipal heritage register:

- ◆ 8 Robert Kemp Street; and
- ◆ 4971 Dunning Road, Andrew Wilson House/Hayes House.

The following known cultural heritage resources within the study area in the City of Ottawa are listed (non-designated) on the municipal heritage register:

- ◆ 24 Kemp Drive;
- ◆ 19 Melva Avenue;
- ◆ 8908 Mitch Owens Road;
- ◆ 6260 McVagh Road, McVeigh House, Veighton P.O.;
- ◆ 1428 Devine Road;
- ◆ 5790 Buckland Road, Paroisse Catholique Saint-Guillaume (also listed on the Places of Worship Inventory);
- ◆ 1954 Farista Drive;
- ◆ 5281 Clayton Road;
- ◆ 8785 Russell Road, Trinity Anglican Church (also listed on the Places of Worship Inventory);
- ◆ 4399 Leitrim Road (adjacent to the study area);
- ◆ 3390 Dessaint Street;
- ◆ 3464 Sarsfield Road, Paroisse Saint-Hugues (also listed on the Places of Worship Inventory);
- ◆ 4036 Spring Street, Thomas Boyd House;
- ◆ 5958 Piperville Road, Paroisse Saint-Laurent (also listed on the Places of Worship Inventory);
- ◆ 1255 Colonial Road;
- ◆ 3480 Trim Road, St. Mary's Anglican Church (also listed on the Places of Worship Inventory);

- ◆ 3494 Trim Road;
- ◆ 3539 Trim Road;
- ◆ 3551 Trim Road;
- ◆ 3615 Trim Road;
- ◆ 1145 Smith Road;
- ◆ 1129 Smith Road, Navan United Church (also listed on the Places of Worship Inventory); and
- ◆ 1119 Smith Road.
- ◆ The following properties were identified by the City of Ottawa as properties formerly on the municipal heritage register as listed (non-designated) properties:
  - ◆ 4540 Bank Street (adjacent to the study area);
  - ◆ 4570 Bank Street;
  - ◆ 5876 Buckland Road;
  - ◆ 5886 Buckland Road;
  - ◆ 5904 Buckland Road;
  - ◆ 5918 Buckland Road;
  - ◆ 4532 Carlsbad Lane;
  - ◆ 1203 Colonial Road;
  - ◆ 1764 Colonial Road;
  - ◆ 2883 Colonial Road;
  - ◆ 2955 Colonial Road;
  - ◆ 2955 Colonial Road;
  - ◆ 1875 Division Street (adjacent to the study area);
  - ◆ 4967 Dunning Road;
  - ◆ 4978 Dunning Road;
  - ◆ 5348 Dunning Road;
  - ◆ 6205 Frontier Road;
  - ◆ 4865 McNeely Road;
  - ◆ 8847 Mitch Owens Road;
  - ◆ 9074 Mitch Owens Road;
  - ◆ 3890 Navan Road;
  - ◆ 3 Orville Kemp Street;
  - ◆ 5950 Piperville Road;
  - ◆ 3664 Ramsayville Road (adjacent to the study area);
  - ◆ 5936 Rockdale Road (adjacent to the study area);
  - ◆ 5039 Russell Road (adjacent to the study area);
  - ◆ 5520 Russell Road;
  - ◆ 6247 Russell Road;

- ◆ 8253 Russell Road;
- ◆ 8852 Russell Road;
- ◆ 3611 Sarsfield Road;
- ◆ 1023 Smith Road;
- ◆ 1060 Smith Road;
- ◆ 1151 Smith Road;
- ◆ 5490 Thunder Road;
- ◆ 3470 Trim Road;
- ◆ 4065 Trim Road; and
- ◆ 1458 Wall Road (adjacent to the study area).

The following Ontario Heritage Plaque within the City of Ottawa was identified within the study area:

- ◆ Carlsbad Springs: located in the picnic area by NCC Greenbelt Parking Lot 24 on south side of Russell Road, between Leitrim Road and Bear Brook.

The following cemeteries within the City of Ottawa were identified within the study area:

- ◆ 5958 Piperville Road, St. Laurent Roman Catholic Cemetery/Carlsbad Springs Roman Catholic Cemetery;
- ◆ Division Street (west end), St. Guillaume Catholic Cemetery;
- ◆ 2459 Forced Road, Vars United Cemetery;
- ◆ Forced Road (south side, west of Vars United Cemetery), Patterson Presbyterian Cemetery;
- ◆ 8785 Russell Road, Trinity Anglican/Bearbrook Parish Cemetery;
- ◆ 3641 Trim Road, St. Mary's Anglican Cemetery;
- ◆ 1700 Colonial Road, Wilson Memorial/Navan United Church Cemetery; and
- ◆ 3295 Sarsfield Road, Paroisse Saint-Hugues Roman Catholic Cemetery.

### **Township of Russell**

No known cultural heritage resources within the Township of Russell were identified as being within the study area.

### **Municipality of the Nation**

The following known cultural heritage resource in the Municipality of the Nation from the Places of Worship Inventory has been identified within the study area:

- ◆ 156 Rue Mabel, Saint Viateur Roman Catholic Church.

The following cemeteries within the Municipality of the Nation have been identified within the study area:

- ◆ 13 Main Street, Saint Viateur Cemetery; and
- ◆ Grant Road (east side, south of Clarence Cambridge Boundary Road), Grant Baptist Cemetery.

### **City of Clarence-Rockland**

The following known cultural heritage resources in the City of Clarence-Rockland from the Places of Worship Inventory have been identified within the study area:

- ◆ 3130 Gendron Road, St. Mathieu Roman Catholic Church; and
- ◆ 3765 Champlain Road, Sacre-Coeur de Bourget.

The following cemeteries within the City of Clarence-Rockland have been identified within the study area:

- ◆ Butler Road (east side, south of Prescott-Russell Recreational Trail), Hammond Protestant Cemetery;
- ◆ 1248 Lacroix Road, St. Mathieu Roman Catholic Cemetery; and
- ◆ 2302 Dollard Street, Saré-Coeur Roman Catholic Cemetery.

## 7. Hydrologic and Hydraulic Assessments

Subsequent to the development of the 2022 and 2024 hydrologic and hydraulic models described below, SNC completed updates to both the HEC-HMS hydrologic model and the HEC-RAS hydraulic models in 2025. These updates incorporated refinements to hydrologic inputs, model boundary conditions, and hydraulic representation based on additional review and technical feedback. The flood extents and water levels applied in this memorandum reflect the most recent (2025) model outputs provided by SNC. Previous hydrologic and hydraulic assessments have been completed for the Bear Brook watershed. An initial study entitled “The South Bear Brook” was completed in 1978 by Crysler and Lathem Ltd. and then updated in 1991 by Ecos Garatech Associates Ltd. The extent of the 1991 study begins at the headwaters of Bear Brook within the former boundaries of the Township of Gloucester and continues along Bear Brook into the South Nation River to its confluence with the Ottawa River near the Town of Wendover.

Furthermore, in 1997 a study conducted by SNC and J.F. Sabourin and Associates Inc. entitled “Bear Brook Floodplain Mapping Study – City of Gloucester” added more details to the area located in the former Township of Gloucester (South Bear Brook subwatershed).

In 2019, the “South Bear Brook Flood Risk Mapping” study by SNC was completed, focusing on the eastern portion of the City of Ottawa and former Townships of Gloucester and Cumberland. The purpose of this study was to define the flood boundary associated with the 1:100-year flood event for a portion of Bear Brook.

To update the flood hazard limits a subsequent study entitled Bear Brook Watershed Floodplain Mapping Report [41] included the development of a one-dimensional hydraulic model of Bear Brook and North Indian Creek. As part of the findings of this study, the hydraulic simulations revealed that sections of Bear Brook between Carlsbad Lane to Dunning Road spill outside the channel and into adjacent lands even during low magnitude flood events.

Therefore, a subsequent study was completed by SNC to develop a two-dimensional hydraulic model using HEC-RAS to assess the hydraulic characteristics of Bear Brook during the 100-year storm event for areas where flows spills were identified between Carlsbad Lane and Dunning Road, which is defined in this project as the Flood Mitigation Assessment Area.

In 2024, the previous Bear Brook Flood Hazard Mapping Study (2022) was extended down to the confluence with the South Nation River. In this study, the hydrology and hydraulic models were updated to develop flood hazard maps for the entire Bear Brook Watershed.

### 7.1 Hydrologic Models

As per the information provided by SNC, the ‘original model’ is the hydrologic model of a portion of the Bear Brook watershed that was developed in 2022 while the ‘extended model’ is the hydrologic model that was developed in 2024, for which the results are included in the report Bear Brook Watershed Flood Mapping Report [5]. Both models (original and extended) were developed with the software HEC-HMS (version 4.9), which is available to the public and is regularly updated by the U.S. Army Corps of Engineers. A summary of both hydrologic models is included in the following sections.

#### 7.1.1 Original Model

The original HEC-HMS model has 267 basin elements which cover the Bear Brook watershed to an outlet point at the Bourget hydrometric station, with a drainage area of 448 km<sup>2</sup>. The subcatchment boundaries for this

model were delineated using the Arc-Hydro extension included in the GIS software ArcMap, and further refined by comparing the boundaries with aerial imagery and land use data. Watercourse centerlines were drawn based on a hill shade representation of the available digital terrain model and verified with the most recent aerial imagery (2019).

Land cover types were developed from a base layer from the Ontario Land Cover Compilation (OLCC) and refined manually by adjusting land cover types from aerial imagery and LiDAR derived hill shade images. The percentage of land use for each catchment was used to determine a composite curve number (CN) coefficient which is used to calculate infiltration rates for each land cover type.

The uplands method was used to calculate the time of concentration, as it showed the greatest correlation to magnitude and peak arrival times compared to other methods such as the SCS lag method. The time of concentration is the maximum time that it takes surface runoff to move from the furthest point of a watershed to its outlet and is used by the hydrologic model to define the shape of the hydrograph as precipitation is converted into runoff.

The selected methods to run the simulations include the SCS curve number to account for soil infiltration, the Clark unit hydrograph to transform precipitation into runoff, and the Muskingum-Cunge to route runoff along the stream network. Both summer and spring rain and snow events were considered to determine the dominant runoff scenario. Two prominent precipitation flow events were measured at the Bourget station and used to calibrate and validate the model.

The applied design storms included the 12 and 24-hour SCS Type II and the 3 and 6-hour Chicago distributions. For each storm event the CN values with AMC III (antecedent moisture condition) were added as a conservative approach. The intensity-duration-frequency (IDF) data was taken from the Environment and Climate Change Canada (ECCC) rain gauge at the McDonald Cartier Airport in Ottawa. The results of the simulations showed that the dominant summer design storm was the 24-hour SCS Type II distribution.

Additionally, rain on snow hydrographs were developed based on the data from the Meteorological Service of Canada to analyze spring floods. A sine curve distribution was used to distribute the snowmelt + rainfall volume on a 15-minute basis for each day on a 12-hour snow melting period. The CN value was converted from AMC II to AMC III to account for snowmelt runoff conditions.

The hydrologic model results were compared with the results of a statistical analysis carried out on observed flow data derived from the Bourget stream gauge station. The results developed from the model were also compared to the index flood method and the primary regression method from the Ontario Flow Assessment Tool (OFAT) provided by the Ministry of Natural Resources (MNR, 2018).

The simulations showed that the 10-day snow and rainfall event generated the maximum peak flows, and this event was selected as the design flow to be carried forward into the hydraulic modelling for flood hazard mapping.

### **7.1.2 Extended Hydrologic Model**

The extended hydrologic model included 34 additional basin elements to the original model, adding 40 km<sup>2</sup> of drainage areas, 301 basin elements, and a drainage area of 488 km<sup>2</sup>, which covered the entirety of the Bear Brook watershed [5].

The input model parameters were consistent with the original model and included the CN value, the Clark unit hydrograph and Muskingum-Cunge routing method. Given that the limit of the extended model is located downstream of the Bourget stream gauge station, the calibration of the model was not possible for the new added section. Hence a transfer function was used to calibrate model parameters in the extended model.

The resultant flows at the outlet of the extended model were compared with other methods such as station frequency analysis, the unified Ontario flood method (UOFM), the modified index flood method (MIFM) and MNR flood index method.

Based on the results, the 10-day snow and rain event was maintained as the design flow to be carried forward for hydraulic modeling to determine flood boundaries. The peak flow values for the 2, 10, 20, 50, 100, and 350-

year return period for the 10-day snow and rain were extracted at specified junction elements for input into the hydraulic model.

## 7.2 Hydraulic Models

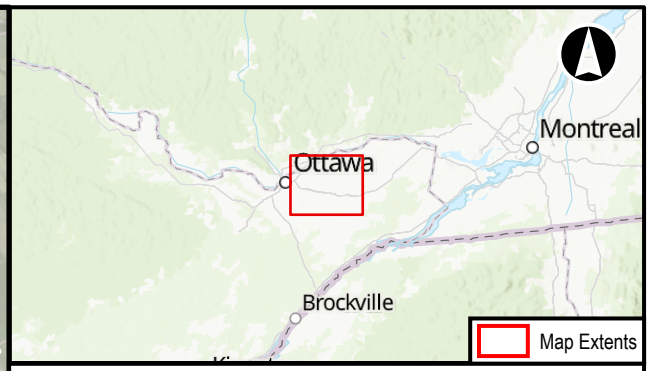
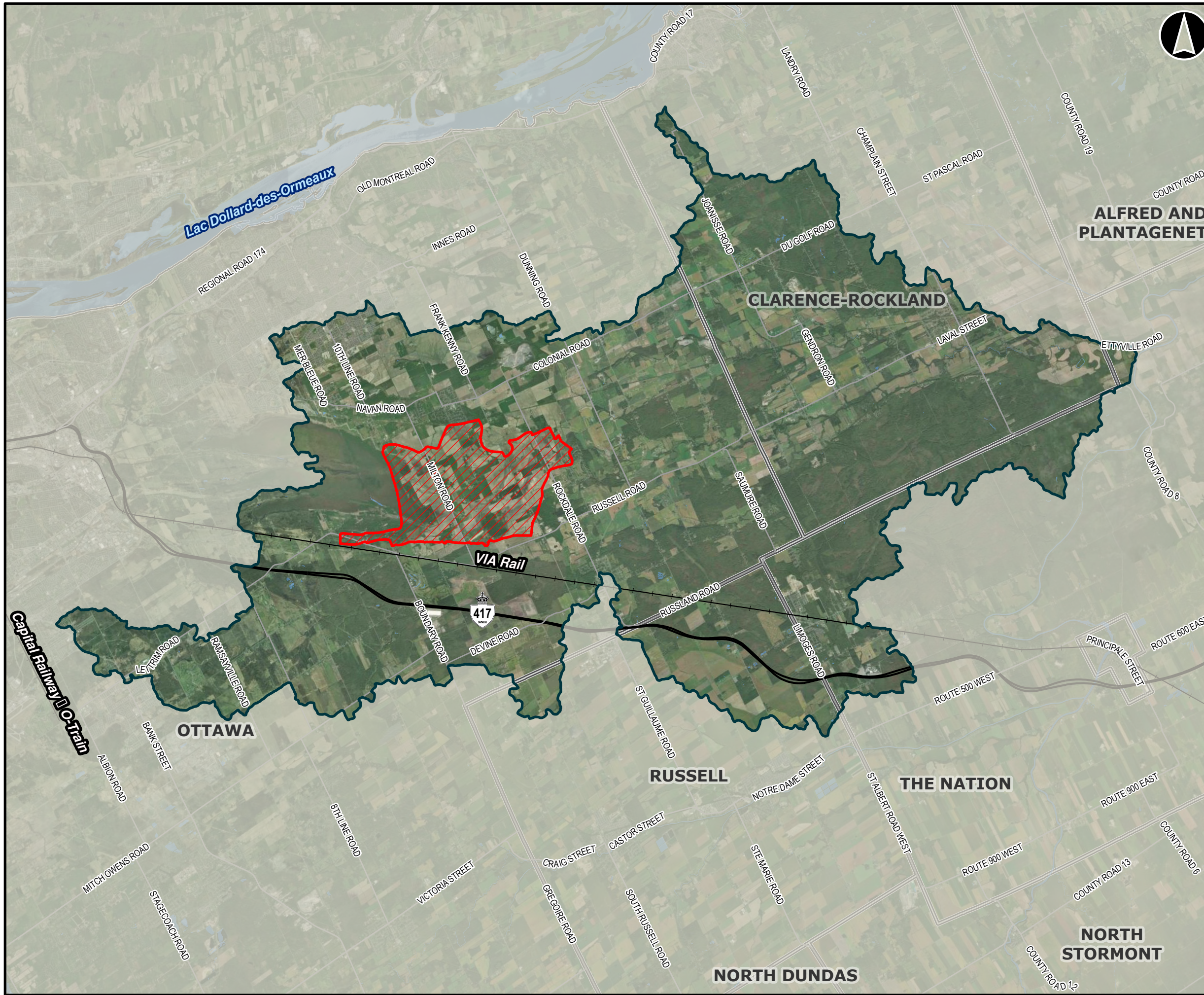
As indicated in the Bear Brook Watershed Floodplain Mapping Report [5], the one-dimensional (1-D) hydraulic model of Bear Brook and tributaries was developed with GeoHECRAS, which is a graphical user interface software that externally controls HEC-RAS (version 6.3.1). The 1-D steady state model developed in 2022 was used as the base model and extended to the Bear Brook confluence with the South Nation River.

The updated HEC-RAS model includes 2,566 cross sections which were generated from the available digital terrain model and bathymetric survey completed by SNC. There are 140 culverts and 60 bridges in the updated hydraulic model. Their physical dimensions were collected by SNC staff based on field surveys, external sources and estimations using aerial imagery when appropriate.

The simulations in the 1-D hydraulic model were set as steady-state flow under a subcritical flow regime. The downstream boundary condition added in the model was set to a known water elevation which was extracted from the results previous hydraulic modelling (Ecos Garatech Associates, 1991).

Furthermore, and as reported by SNC, no calibration was completed due to the lack of historical streamflow and water level data for Bear Brook, however, a detailed sensitivity analysis was performed on the hydraulic model, and the results were compared with the previous study prepared by Ecos Garatech Associates Ltd. (1991).

Based on the findings of the 1-D model, a localized 2D HEC-RAS model was developed to cover a section of Bear Brook where flood spill locations were identified. Along with Bear Brook, the 2D model includes the Savage Municipal Drain, East Branch of Savage Municipal Drain, McFadden Municipal Drain, Richard Clark Municipal Drain, Bickerton Municipal Drain, McWilliams Municipal Drain, Shaw's Creek, David Cleroux Municipal Drain, and Bear Brook Municipal Drain. The total length of these channels is 42.66 km, and the 2-D model covers a total area of 26.13 km<sup>2</sup>. The extent of the 2-D model is shown in **Figure 13**.

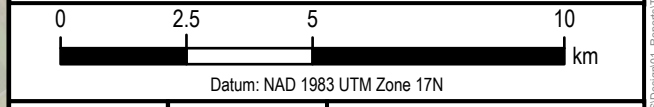


- Legend**
- Extent of 2D Hydraulic Model
  - Bear Brook Watershed
  - Waterbody
  - Municipal Boundary
  - Main Railway
  - Primary or 400 Series Highway
  - District, County, and Regional Roads

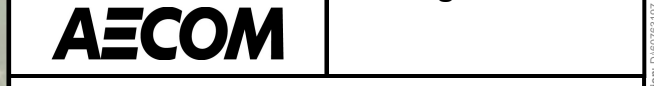
**Data Sources:**  
 Contains Information licensed under the Open Government License Ontario.  
 Basemaps provided by: Earthstar Geographics, Province of Ontario, Esri, TomTom, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Esri, USGS

**Bear Brook  
 Environmental Assessment**

**Extent of the 2-D Hydraulic Model**



Nov, 2025	1:150,000	<b>Figure 13</b>
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Input flows were imported from the 2022 hydrologic model at selected boundary condition lines which were added to the computational mesh. The mesh has 66,059 cells with variable sizes. A total of 31 culverts were modeled, based on information from available LiDAR for most culverts while three culverts were added with survey information. Bridge structures were not included in the 2-D model because it was determined that the water did not reach the soffit of the structures during the 100-year flood event.

Two scenarios were developed for the 2-D model under steady and unsteady state conditions. The steady state model uses constant peak flows from the hydrologic model at selected locations, and the unsteady state model uses 19 hydrographs from the hydrologic model, while the downstream boundary condition was set as a normal depth.

## 8. Fluvial Geomorphology

As part of the Bear Brook Watershed Study, Palmer/SLR Consulting Canada Ltd. was retained by South Nation Conservation (SNC) to complete a fluvial geomorphic assessment of Bear Brook and assess landslide distribution across the watershed [2].

The following datasets were provided to AECOM based on the work done by Palmer/SLR Consulting Canada Ltd.:

- ◆ Channel\_Cutoffs (point).
- ◆ Channel\_Planform\_Pre\_1945 (line).
- ◆ Channel\_Planform\_Year (line).
- ◆ Esker (polygon).
- ◆ Landslides\_Points (point).
- ◆ Meander\_Migration\_Lines (line).
- ◆ Reach\_Breaks (line).

River\_Chainage\_1000m (point).

Key findings from the assessment include the following:

- ◆ Natural erosion processes, such as meander migration and cut-offs occur at a slow rate along Bear Brook due to its gentle to flat-lying slope (0.04%) and the stable material in its bed and banks. The area is still strongly influenced by the effect of the Champlain Sea, which existed between 13,900 and 11,500 years before present. However, human activities (including riparian vegetation removal, straightening tributaries, excavation of drains, urbanization, changing climate conditions and landslides have notably altered these processes and contributed to the development of related hazards.
- ◆ The following features or mechanisms were identified as being largely responsible for geomorphological processes within Bear Brook:
  - **Vars-Winchester Esker** – The Vars-Winchester Esker has a sand and gravel core and is a prominent grade control feature for Bear Brook.
    - Due to the relatively low erosive energy of Bear Brook, upstream of the esker, the watercourse is unable to entrain the esker sediments and therefore has not incised into the Champlain Sea sediments. The bed of the channel is only slightly below its floodplain. In this area Bear Brook is unconfined and is well connected to its broad floodplain.
    - Downstream of the esker, Bear Brook has incised into the more clay-rich sediments of the Mer Bleue formation/paleochannel until its confluence with the South Nation River. Channel incision has resulted in entrenchment and the formation of a contemporary valley, which contains flood flows and appears prone to small landslides.

- **Channel Straightening** – Anthropogenic channel straightening that occurred prior to 1945 largely for agricultural purposes reduced the overall channel length and locally steepened the watercourse. Channel alteration and straightening largely occurred in the upper reaches of Bear brook (i.e., upstream of the esker), where the channel is connected to its floodplain.
  - **Riparian Vegetation** – The riparian vegetation along Bear Brook has been altered over the past century, especially in the upper reaches (Reaches 2, 3, and 4) where the river is unconfined and vegetation has been extensively cleared. A vegetated riparian buffer was present for Reach 1 and Reaches 5 to 9.
  - **Landslides** – Evidence of landslides of varying sizes and ages were noted throughout the Bear Brook watershed, with a notable concentration downstream of the Vars-Winchester Esker. Several large retrogressive landslides occurred millennia ago along escarpments of the Ottawa River paleochannels, well back from contemporary fluvial processes (Alysworth et al., 2000). These landslides were likely triggered by seismic activity. More recent and smaller landslides are evident along the banks and valley slopes of Bear Brook and its tributaries. If degradation of the system continues, further landslides are expected, particularly where clay exposures increase along the lower valley walls.
- ◆ For the purposes of the assessment, nine reaches were delineated over a channel length of 59.4 km from a tributary confluence upstream of Highway 417 to the South Nation River confluence. The delineation was based on the degree of channel confinement, channel gradient, history of anthropogenic modification, and landslide activity. Additionally, a summary of characteristics for delineated geomorphic reaches is presented in **Table 8.1** and **Table 8.2**.

**Table 8.1. Summary of Delineated Geomorphic Reaches along Bear Brook (Reproduced in part from Palmer, 2024 [2])**

Reach	Upstream Chainage (km) <sup>1</sup>	Downstream Chainage (km) <sup>1</sup>	Upstream Reach Break Rationale	Reach Length (km) <sup>2</sup>	Slope (%) <sup>3</sup>
1	0.0	3.7	Confluence with major tributary	3.7	0.06
2	3.7	11.2	Channel becomes less confined, notable anthropogenic straightening.	7.5	0.04
3	11.2	19.0	Channel unconfined, drastic increase in flood hazard extent, lack of riparian buffer.	7.8	0.02
4	19.0	24.5	Reduction in flood hazard extent, increase in meander radii and amplitudes.	5.5	0.02
5	24.5	30.5	Increase in slope downstream of Vars-Winchester Esker, onset of channel incision, onset of more widespread landsliding.	6.0	0.16
6	30.5	33.7	Upstream extent of large retrogressive landslide, increase in contemporary valley relief.	3.2	0.03
7	33.7	40.7	Downstream extent of large retrogressive landslide, South Indian Creek confluence.	7.0	0.03
8	40.7	49.1	North Indian Creek confluence.	8.4	0.03
9	49.1	59.4	Channel descends into a Bourget paleochannel, onset of tortuously meandering planform.	10.3	0.04

Notes:

1.Length along 2019 centreline starting from upstream limit of Study Area.

2.Reach length (m) = downstream chainage (m) – upstream chainage (m).

3.Reach-averaged slope determined from 2019/2020 LiDAR-derived longitudinal profile.

**Table 8.2. Summary of Delineated Geomorphic Reaches along Bear Brook (cont'd, reproduced in part from Palmer, 2024)**

Reach	Bankfull Width (m) <sup>1</sup>	Sinuosity <sup>2</sup>	General Reach Characteristics	RGA Results	Dominant Geomorphic Process
1	11	1.28	Has a natural, irregular meandering planform and flows within a defined valley, formed through channel incision into near-shore and deltaic sand deposits	In Regime	Widening
2	13	1.29	Flows within the Mer Bleue paleochannel. Has been locally straightened and has good access to the floodplain (not entrenched)	Transitional	Widening
3	17	1.29	Flows within the Mer Bleue paleochannel. Has been locally straightened and has good access to the floodplain (not entrenched)	Transitional	Widening
4	17	1.14	Flows within the Mer Bleue paleochannel. Has been locally straightened and has good access to the floodplain (not entrenched)	Transitional	Widening
5	19	1.41	Has incised into the former paleochannel and Champlain Sea deposits, creating a contemporary valley	Transitional	Degradation
6	20	1.32	Has incised into the former paleochannel and Champlain Sea deposits, creating a contemporary valley	Transitional	Widening
7	22	1.17	Has incised into the former paleochannel and Champlain Sea deposits, creating a contemporary valley	Transitional	Widening
8	23	1.42	Has incised into the former paleochannel and Champlain Sea deposits, creating a contemporary valley	Transitional	Widening
9	24	3.08	Has incised into the former paleochannel and Champlain Sea deposits, creating a contemporary valley.	Transitional	Widening

Notes:

1. Bankfull width was averaged by reach measurements over 1,000 m using 2019 orthophotographs and LiDAR data.

2. Sinuosity (m/m) = 2019 channel length (m) / valley length (m).

## 9. Surface Water Quality

Approximately 37% of the Bear Brook watershed is used for agricultural purposes, which has contributed to increased sedimentation and nutrient loading in surface waters [6]. These processes have elevated phosphorus levels, increased the risk of eutrophication and oxygen depletion in local water bodies. In addition, urban expansion has led to higher concentrations of chlorides, nutrients, E. coli, and metals, particularly in areas where natural habitats have been disturbed or removed.

Currently, the Canadian Water Quality Index (WQI) scores for the Bear Brook watershed indicate frequent impairments in water quality. Chloride levels continue to rise across the watershed, with the highest concentrations observed in urbanized regions. As per the SNC 2024 report [6], the Black Creek subwatershed

remains in excellent ecological condition and could serve as a reference site for environmental indicators within the Bear Brook watershed.

## 10. Flood Damage Assessment - Existing Conditions

The available data provided by SNC was used to determine preliminary calculations of flood damages within the flood mitigation assessment area, which contains Bear Brook and its tributaries, and is delineated by Carlsbad Lane to the west and Dunning Road to the east. These limits also correspond to the extents of the hydraulic model provided by SNC. The flood extents, flood depths, and inundation characteristics used in this assessment were derived from the most recent HEC-RAS hydraulic models provided by SNC. For the 2-, 5-, 10-, 20-, 50-, and 350-year return period events, results from the 2D HEC-RAS model prepared by SNC were used. In the SNC modeling framework, flow inputs derived from the HEC-HMS hydrologic model (including the 10-day rain-on-snow event used to define peak flows) were applied at selected upstream boundary locations within the 2D computational domain. These inflows were routed through the 2D mesh, which represents both the main channel and floodplain storage areas, allowing for simulation of overbank flow, floodplain spreading, and hydraulic attenuation within the Flood Mitigation Assessment Area. The resulting maximum water surface elevations and depth grids produced by the 2D model were used directly for the flood damage assessment. No adjustments were made by AECOM to flow magnitudes, routing assumptions, or return period designations; all hydraulic results reflect the finalized model outputs provided by SNC. For the 100-year return period event (regulatory flood), the one-dimensional (1D) HEC-RAS model results were applied to ensure consistency with the approved regulatory floodplain mapping used by SNC. All model outputs were used as provided by SNC without modification by AECOM.

This analysis is based on the guidelines presented in the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure [42], which provides general guidance on how to evaluate and calculate potential economic losses which can be generated from flood events, noting that these guidelines are focused on the estimation of flood damages to buildings and infrastructure even when other damages are also mentioned (i.e., indirect and intangible damages).

For the purposes of this assessment, a summary of relevant definitions which are included in the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure [42] are included in **Table 10.1**.

**Table 10.1. Relevant Definitions for the Flood Damage Assessment**

Parameter	Definition
Contents Damage	Damages to moveable contents within a structure.
Direct Damages	Damages that occur immediately as a direct result of flood inundation, these include damages to public infrastructure and private properties.
First Floor Height	The assumed elevation of the first floor of a building above grade.
Grade elevation	The highest elevation of a property which can be defined from LiDAR data, topographic surveys or detailed topographical maps.
Tangible Damages	Damages to which a direct dollar value may be assigned.
Intangible Damages	Damages that are more difficult to assess on a monetary basis such as emotional stress, illness, disruptions to daily life, and loss of life.
Stage Damage or Depth-Damage Curve	A direct mathematical relationship between the depth of water above (or below) the first floor of a building and the amount of damage that can be attributed to that level of water. In Canada it is common to refer to damages in the form of a currency value (i.e., dollars per square metre).

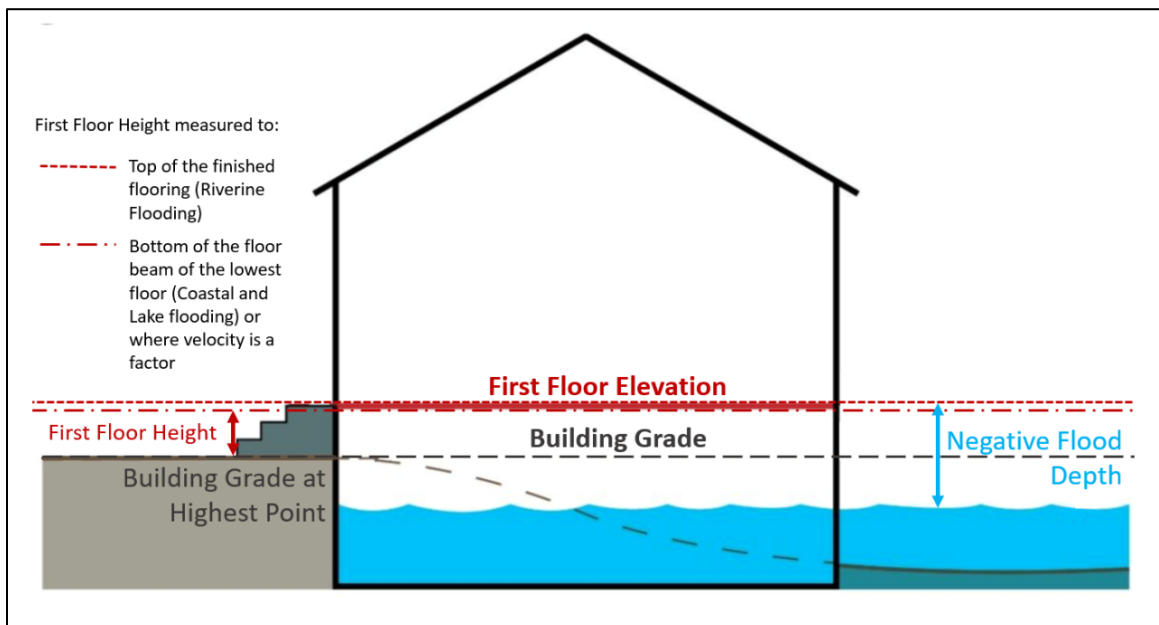
## Structure Damage

Damages to a building and its attached components which are not taken when the occupants move such as furnace, hot water heater, air conditioner, built-in fireplace.

Furthermore, as shown in the Federal Flood Damage Estimation Guidelines, the determination of flood depths for buildings is based on the elevation of the top of the finished flooring (i.e., for riverine flooding), at which point direct damages can be applied. This is depicted in **Figure 14**.

For the purposes of this flood damage assessment, even when it is recognized that there are different types of flooding, the calculation of damages is based on riverine (fluvial) flooding, as a product of an increase in water levels beyond the conveyance capacity of the channels extending towards flood prone areas. The damages from a flood event are therefore estimated when it is determined that an exposure of infrastructure, buildings, and other assets is occurring during a flood event.

The inundation characteristics that can influence the impacts of fluvial flooding include but are not limited to the extent of flooding, the maximum water depth, the rate of water rise, time of occurrence, and exposure to sources of contamination (i.e., flood impacts to septic, fuel and oil tanks) [42].



**Figure 14. Building Measurements Used in Determining Flood Damage Calculations**

## 10.1 Flood Damage Estimation Procedure for Riverine Flooding

The procedure to calculate flood damages can be summarized in five steps [42] and include the following:

- ◆ Develop the flood hazard mapping, which will be the base to identify impacts during different flood events. For this task the calculations rely on the results of the hydraulic models provided by SNC, specifically the latest versions of the HEC-RAS models which are summarized in **Section 7.2** of this memo.
- ◆ Compile an inventory of features that could be affected by exposure to floods. These features include but are not limited to buildings, infrastructure, and population.
- ◆ Calculate direct damages using available stage-damage curves for the selected building classes, noting that local curves may not be available. Based on the calculations, develop a curve of total damage as a function of return period, where the estimated annual damages (EAD) are extrapolated from this curve.
- ◆ Evaluate indirect damages. These are normally difficult to estimate and therefore it is common practice to assign a percentage of direct damages in the range of 20% to 40% [42]. Other damages could also be assigned using first principles or as a percentage of direct damages (i.e., damages to roads, hydraulic crossings, utilities).

Calculate total damages for each flood event as the sum of direct damages and indirect damages.

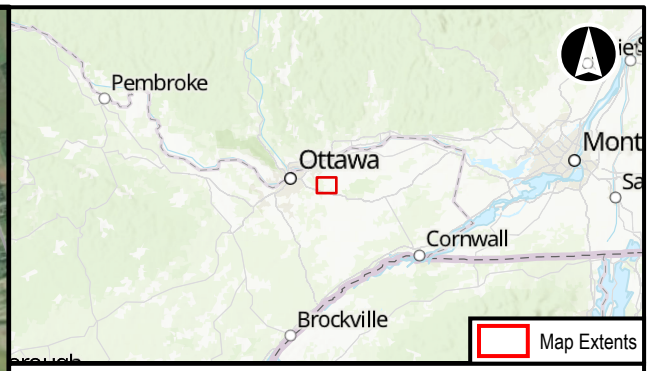
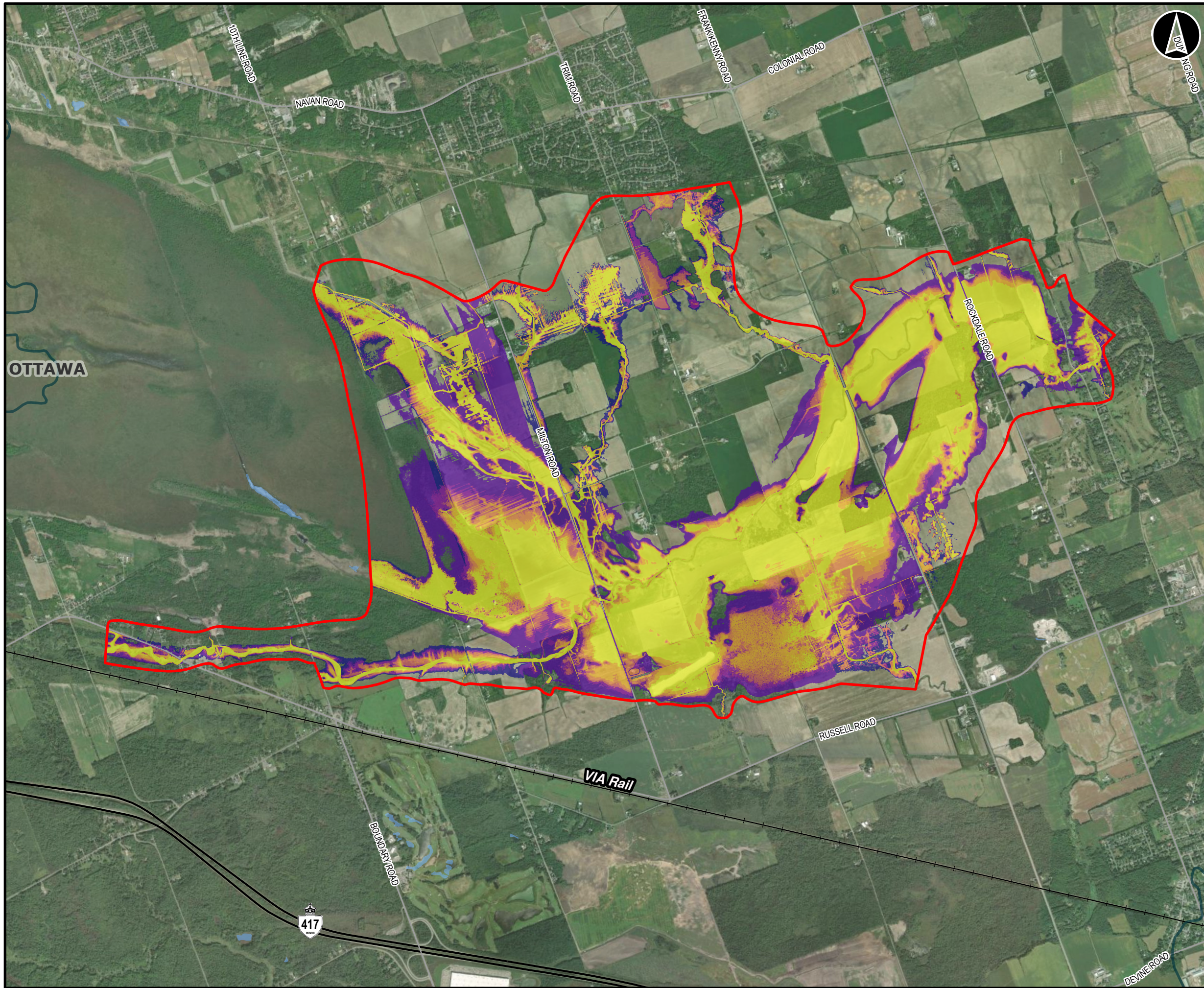
Details of each step are provided in the following sections.

### **10.1.1 Flood Hazard Mapping**

A geodatabase that contains geospatial layers such as buildings, infrastructure, land cover types, transportation networks, streams and waterbodies, wetlands, floodplain boundaries, and water elevations for available flood events was generated for this assessment.

Specifically, the data used to calculate flood damages was extracted from the most recent (2025) HEC-RAS hydraulic model provided by SNC. The model represents the updated regulatory flood mapping for the Bear Brook watershed and incorporates refinements to hydraulic inputs and boundary conditions relative to earlier versions (2022 and 2024). Flood lines and flood depths were extracted for the 2, 5, 10, 20, 50, 100, and 350-year return period events within the Flood Mitigation Assessment Area. The flood boundaries are shown in **Figure 15**.

AECOM did not undertake calibration, re-parameterization, or structural revisions to the SNC-provided HEC-RAS model as part of this assignment; the model outputs were applied as supplied for the purposes of estimating flood damages under existing conditions.



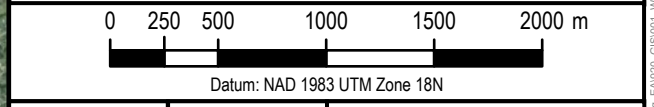
**Legend**

- Extent of 2D Hydraulic Model
- 2 Year Return Period Flood Boundary
- 5 Year Return Period Flood Boundary
- 10 Year Return Period Flood Boundary
- 20 Year Return Period Flood Boundary
- 50 Year Return Period Flood Boundary
- 100 Year Return Period Flood Boundary
- 350 Year Return Period Flood Boundary
- Bear Brook Watershed
- Waterbody
- Municipal Boundary
- Main Railway
- Primary or 400 Series Highway
- District, County, and Regional Roads

**Data Sources:**  
 Contains Information licensed under the Open Government License Ontario.  
 Basemaps provided by: Vantor, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Esri, USGS

**Bear Brook  
 Environmental Assessment**

**Flood Boundaries in Bear Brook Watershed for  
 Different Return Period Events**



Feb, 2026	1:35,000	<b>Figure 15</b>
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**Figure 15** presents the flood extents derived from the 2D HEC-RAS hydraulic model for the modeled return period events. No post-processing adjustments or exclusions were applied to the model outputs. It is noted that the 2D hydraulic model was used for all return period events up to and including the 350-year event, while the 100-year regulatory floodplain was derived from the 1D hydraulic model to maintain consistency with SNC’s approved regulatory mapping.

### 10.1.2 Inventory of Affected Features

An inventory of affected features was generated with available geospatial layers by calculating intersection of the building layer provided by SNC with the flood boundaries extracted from the updated 2D HEC-RAS hydraulic model. Additionally, the findings of the flood vulnerability analysis [5] were reviewed during this task.

It is also noted that a sub-set of the available building layer was generated for the flood mitigation assessment area, and therefore the results do not match with the findings of the Bear Brook Watershed Floodplain Mapping Report [5], which uses a larger area.

It was confirmed that, as indicated by SNC, there are no critical buildings located within the floodplain for any analyzed flood event, where critical buildings include but are not limited to hospitals, schools and retirement homes, and non-critical buildings include residential dwellings, garages, barns, sheds, and commercial buildings. A summary of affected features within the flood mitigation assessment area is provided in **Table 10.2**.

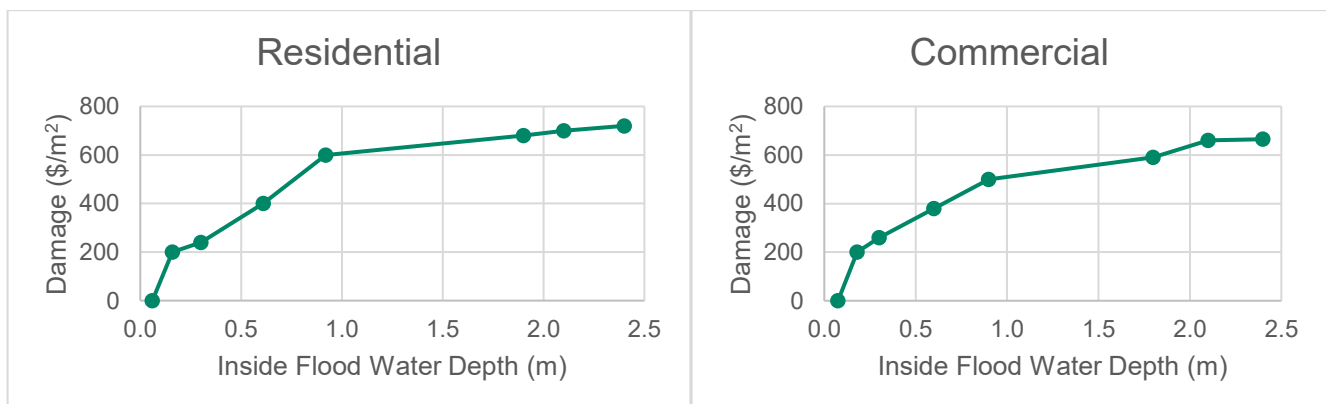
**Table 10.2. Affected Features during selected Flood Events**

Return Period	Non-Critical Buildings in Floodplain
2	0
5	0
10	0
20	0
50	2
100	7
350	9

### 10.1.3 Calculation of Total Flood Damages

The calculation of total flood damages includes direct damages to buildings and infrastructure, as well as intangible damages such as disruption of normal activities, temporary relocation, and road closures.

In the absence of local data, the direct damages were calculated with the stage-damage curves [42], specifically residential and commercial stage-damage curves that were obtained from the Provincial Flood Damage Assessment Study (IBI and Golder, 2015). These curves are included in **Figure 16** and show the estimated cost of damages per square metre for different water depths, where damage (y axis) is a function of water depth (x axis).



### Figure 16. Stage-Damage Curves

For each building, the depth above ground was obtained from the results of the hydraulic simulations and used to obtain an average damage cost from the stage-damage curves, where the damage for each structure is the cost multiplied by its surface area. The area of each impacted building was calculated by using the building polygon layer and confirmed with aerial images to review their rooftop footprint. The buildings were also reviewed to confirm their building type (i.e., residential and commercial).

The calculations also assume that damage to basements are not considered, and as recommended by NRCan [42], the indirect damages were calculated as 40% of the direct damages which corresponds to the conservative end of the suggested range of 20% to 40%. The calculation of damages is presented in **Table 10.3**.

**Table 10.3. Direct Damage Calculations**

Return Period	Probability	Direct Damages	Indirect Damages	Total Damages
2	0.50	0.00	0.00	0.00
5	0.20	0.00	0.00	0.00
10	0.10	0.00	0.00	0.00
20	0.05	0.00	0.00	0.00
50	0.02	\$31K	\$13K	\$44K
100	0.01	\$62K	\$25K	\$87K
350	0.003	\$79K	\$32K	\$111K

#### 10.1.4 Agricultural Damage Assessment

While structural damages were evaluated for return period events equal to or greater than the 2-year event, the agricultural damage assessment also considers higher-frequency (below 2-year) events. Due to the very flat topography within the Flood Mitigation Assessment Area, overbank flooding can occur during events smaller than the 2-year discharge. A review of the 71-year discharge record at the Bourget gauge indicates that 2-year and larger events occur almost exclusively during the spring freshet (March–April) and do not occur as isolated events during summer months (May–August). However, SNC has documented summer flooding events (including August 2024) that resulted in agricultural damages. To better reflect observed conditions and account for crop exposure during the growing season, AECOM incorporated four sub-2-year discharge thresholds corresponding to 20%, 35%, 50%, and 75% of the 2-year flow. These thresholds represent smaller, more frequent flood events that are capable of producing shallow overbank flooding under flat terrain conditions. The lower bound of 20% of the 2-year discharge was selected as a practical minimum threshold. This threshold was selected based on review of hydraulic model outputs, which indicated negligible floodplain inundation below this flow level.

Agricultural damages were assessed separately from structural damages due to the large agricultural footprint within the Flood Mitigation Assessment Area and the strong dependence of crop losses on both flood timing and flood magnitude. Unlike buildings and infrastructure, agricultural impacts vary significantly throughout the year based on crop type and stage of growth.

The agricultural damage assessment integrates information on when flooding is most likely to occur, how susceptible crops are during different months of the growing season, and the estimated value of crops located within flooded areas. By combining these elements, the analysis estimates the portion of crop value expected to be damaged during flood events of different magnitudes.

Specifically, crop-damage severity varies by month and crop type, reflecting differences in vulnerability throughout the growing season. This seasonal vulnerability is considered alongside the likelihood of flooding in each month for a given flood magnitude. These two components are then applied to the estimated value of crops located within the inundated area to determine the expected agricultural damage attributable to each flood event.

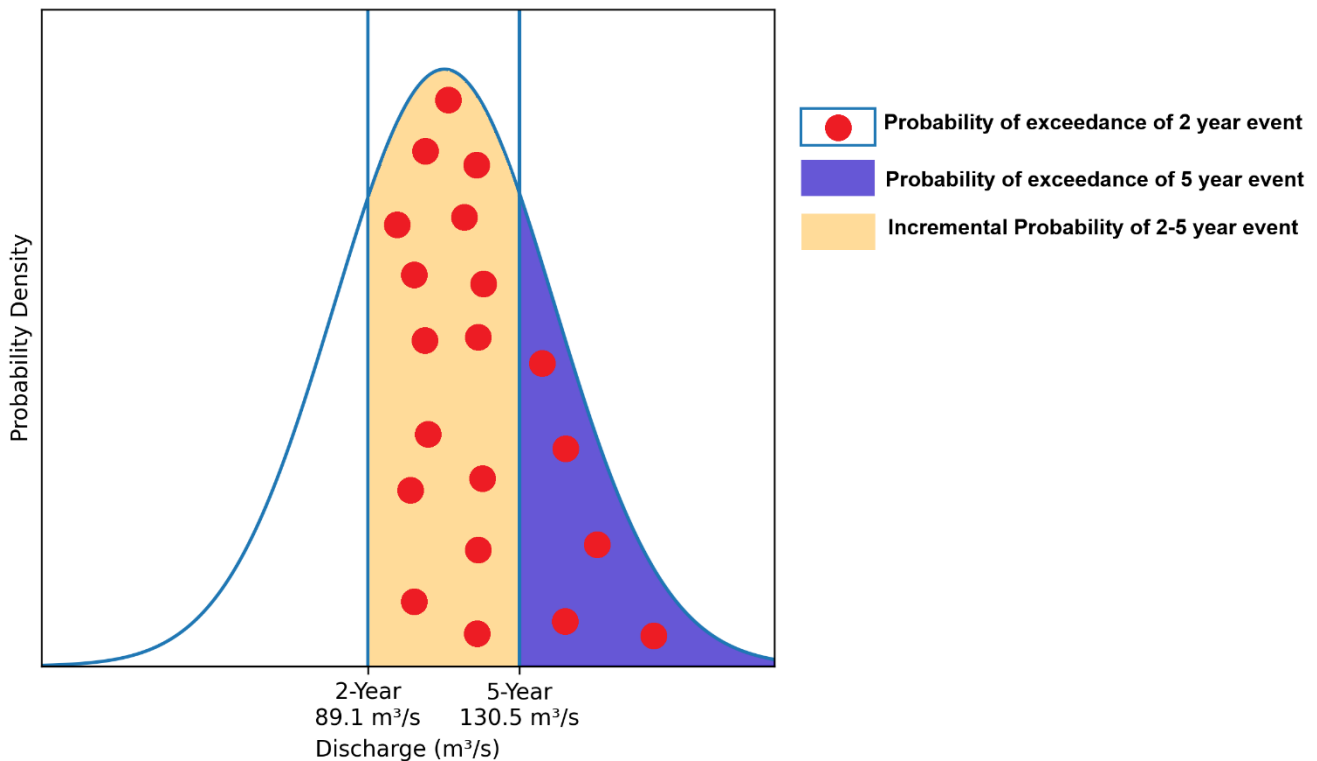


<b>5</b>	130.5	0	2	4	9	0	0	0	0	0	0	0	0
<b>10</b>	160.8	0	2	3	4	0	0	0	0	0	0	0	0
<b>20</b>	192.3	0	2	3	3	0	0	0	0	0	0	0	0
<b>50</b>	236.8	0	2	1	0	0	0	0	0	0	0	0	0
<b>100</b>	273.1	0	0	0	0	0	0	0	0	0	0	0	0
<b>350</b>	345.7	0	0	0	0	0	0	0	0	0	0	0	0

Because the exceedance probabilities shown in **Table 10.5** are cumulative by definition, the probability associated with a given threshold includes all larger events. To estimate expected annual agricultural damages without double counting, the cumulative values were converted to incremental probabilities, representing the probability of flows occurring within specific discharge ranges (e.g., between the 2-year and 5-year events).

**Figure 17** illustrates the relationship between cumulative exceedance probability and incremental probability for two return-period thresholds. The shaded area between the 2-year and 5-year thresholds represents the incremental probability of events occurring within that discharge range (e.g., for March, 19% minus 4% equals 15%).

### Conceptual Illustration of Cumulative and Incremental Probability



**Figure 17. Conceptual Illustration of Cumulative and Incremental Exceedance Probabilities - March**

**Figure 17** conceptually illustrates the relationship between cumulative and incremental probabilities of exceedance for the month of March. The probability of exceeding the 2-year discharge is 19%, while the probability of exceeding the 5-year discharge is 4%. The probability of occurrence of flows between the 2-year and 5-year events is therefore 15%, which represents the incremental probability used in the agricultural damage calculations.

**Table 10.6** presents the incremental monthly probabilities derived from the cumulative exceedance values shown in **Table 10.5** as well as the average flooding depth for each of the storm events.

**Table 10.6. Incremental Monthly Probability of Exceeding Event-Specific Discharges**

Storm Events	Average Flooding Depth (m)	Probability (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
<b>20% of 2</b>	0.22	23	19	12	15	25	10	12	6	2	27	31	31
<b>35% of 2</b>	0.28	11	6	12	12	4	8	6	8	0	6	13	15
<b>50% of 2</b>	0.33	2	2	28	24	10	6	0	0	4	4	4	6
<b>75% of 2</b>	0.42	0	0	13	13	0	4	0	0	2	0	0	0
<b>2</b>	0.50	2	0	14	24	0	0	0	0	0	0	0	0
<b>5</b>	0.62	0	0	1	4	0	0	0	0	0	0	0	0
<b>10</b>	0.69	0	0	0	1	0	0	0	0	0	0	0	0
<b>20</b>	0.76	0	0	1	3	0	0	0	0	0	0	0	0
<b>50</b>	0.86	0	2	1	0	0	0	0	0	0	0	0	0
<b>100</b>	1.10	0	0	0	0	0	0	0	0	0	0	0	0
<b>350</b>	1.10	0	0	0	0	0	0	0	0	0	0	0	0

Including both modeled return-period events and sub-2-year thresholds allows the monthly probability distribution to capture the full range of flood conditions, from frequent low-magnitude overbank events to rare high-magnitude floods. The flow data at the Bourget gauge confirms that annual peak flows occur primarily in March and April, and the derived monthly probabilities reflect this seasonal pattern.

**10.1.4.3 Flooded Agricultural Area and Crop Values**

For each modeled event, the spatial extent of flooding within agricultural lands was derived from the maximum depth grids generated by the SNC 2D HEC-RAS hydraulic model. Flow inputs for these simulations were based on hydrographs obtained from the SNC HEC-HMS hydrologic model. For sub-2-year events (20%, 35%, 50%, and 75% of the 2-year event), flow magnitudes were defined as proportional fractions of the modeled 2-year peak flow and applied as upstream boundary conditions in the 2D domain. The 2D model routed these inflows through the channel and floodplain, inherently accounting for hydraulic attenuation and floodplain storage. The resulting simulated flood extents were then intersected with the agricultural land cover layer to determine the total flooded agricultural area for each event. No adjustments were made to return-period classifications following hydraulic routing.

The extent of flooded agricultural land for each event was determined using the land cover layer provided by SNC, which classifies agricultural lands as a combined “crop + pasture” category without distinguishing between cultivated fields and pasture. To estimate how much of this area is actively farmed, AECOM applied event-specific crop ratios based on both the 2024 Federal Annual Crop Inventory [44] and a review of high-resolution aerial imagery.

For sub-2-year events, flooding is generally confined to areas immediately adjacent to the channel. Based on aerial imagery review, these areas include a higher proportion of pasture and non-cultivated land. Accordingly, 40% of the flooded agricultural area was assumed to be cropland and 60% pasture for sub-2-year events.

For the 2-year and larger return-period events, flooding extends further into upland agricultural fields where cultivated land is more prevalent. For these events, 75% of the flooded agricultural area was assumed to be cropland and 25% pasture

Within the cultivated portion, the crop area was divided equally among the three major field crops grown in the region (i.e. soybeans, grain corn, and winter wheat) to align with available yield and market price data. These crop-specific areas were then paired with representative yields and commodity prices to determine the total value of crops potentially exposed to flooding for each event. The resulting crop-value estimates are summarized in **Table 10.7**.

**Table 10.7. Agricultural Value Calculations within the Flooded Area**

Return Period	Flooded Area (ha)	Assumed Flooded Crop Area (ha)	Crop Yields in Flooded Area (bushels) <sup>1,2</sup>			Crop Value in Flooded Area <sup>3</sup>		
			Soybeans	Grain Corn	Winter Wheat	Soybeans	Grain Corn	Winter Wheat
<b>20% of 2</b>	120.4	48.2	1,666	6,867	2,928	25k	35k	19k
<b>35% of 2</b>	228.3	91.3	3,159	13,021	5,551	47k	65k	36k
<b>50% of 2</b>	306.9	122.8	4,247	17,505	7,463	64k	87k	48k
<b>75% of 2</b>	414.8	165.9	5,740	23,659	10,087	86k	118k	66k
<b>2</b>	494.8	371.1	12,838	52,913	22,559	193k	265k	147k
<b>5</b>	605.7	454.3	15,716	64,774	27,616	236k	324k	179k
<b>10</b>	680.8	510.6	17,664	72,800	31,038	265k	364k	202k
<b>20</b>	747.2	560.4	19,386	79,899	34,064	291k	399k	221k
<b>50</b>	829.5	622.1	21,523	88,704	37,818	323k	443k	246k
<b>100</b>	960.2	720.2	24,914	102,680	43,777	374k	513k	284k
<b>350</b>	1004.5	753.4	26,063	107,416	45,796	391k	537k	298k

Notes:

1. Based on data from (OMAFRA, 2025) the average yields for Prescott and Russel in 2022 were 42 bushels/acre for soybeans, 173 bushels/acre for grain corn and 74 bushels/acre for winter wheat.
2. For sub-2-year events, 40% of the flooded agricultural area was assumed to be cash crop agriculture, reflecting flooding confined near the channel. For the 2-year and larger events, 75% of the flooded agricultural area was assumed to be cash crop agriculture. Within the cultivated portion, the area was divided equally among soybeans, grain corn, and winter wheat [44]
3. The total value assumes the average market prices of \$15/bushel for soybeans, \$5/bushel for grain corn and \$6.5/bushel for winter wheat (OMAFRA, 2025).

#### 10.1.4.4 Monthly Agricultural Damage Calculations

Monthly agricultural damages were estimated by combining:

- ◆ crop-specific damage severity factors (**Table 10.4**),
- ◆ the incremental monthly probability of exceeding each discharge range (**Table 10.6**), and
- ◆ the total crop value within the inundated agricultural areas (**Table 10.7**).

The crop-damage severity factors describe the vulnerability of each crop type during different stages of the growing season. These severity factors were applied together with the incremental monthly probabilities to calculate a monthly damage factor for each crop type and each modeled discharge threshold.

The monthly damage factor was then multiplied by the corresponding total crop value within the flooded area to estimate monthly monetary losses. Summation of monthly losses provides the expected annual agricultural damage associated with each discharge threshold.

This framework captures two key controls on agricultural flood damages:

- ◆ Seasonality of crop exposure, which governs whether crops are present and vulnerable at the time of flooding; and
- ◆ Flood magnitude and frequency, which control the extent of inundation but not necessarily crop presence.

As shown in **Table 10.8**, agricultural damages are driven primarily by sub-2-year discharge thresholds (20%, 35%, 50%, and 75% of the 2-year flow). These lower-magnitude, higher-frequency events occur more commonly during the growing season (May through November), when soybeans and grain corn are present and sensitive to inundation.

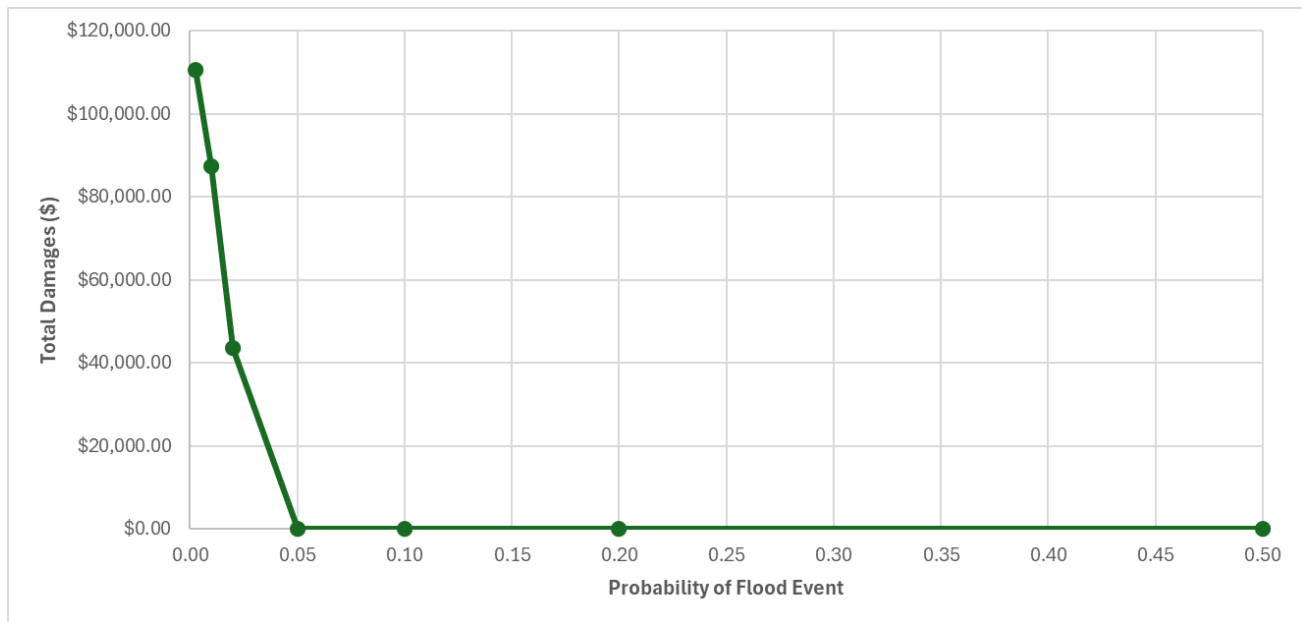
In contrast, return-period events equal to or greater than the 2-year discharge occur predominantly during March and April based on the historical discharge record. During this period, annual crops such as soybeans and corn are not present on the landscape, and damages are largely limited to winter wheat. As a result, the modeled  $\geq 2$ -year events contribute relatively small agricultural losses compared to the more frequent sub-2-year events.



			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Winter Wheat	\$202,000	Damage Factor (%)	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$1,206	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
20	Soybeans	\$291,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Grain Corn	\$399,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$2,639
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Winter Wheat	\$221,000	Damage Factor (%)	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$2,639	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
50	Soybeans	\$323,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Grain Corn	\$443,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Winter Wheat	\$246,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
100	Soybeans	\$374,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Grain Corn	\$513,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Winter Wheat	\$284,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
350	Soybeans	\$391,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Grain Corn	\$537,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	\$0
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
	Winter Wheat	\$298,000	Damage Factor (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
			Damage (\$)	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	
<b>Annual Average Agricultural Damage</b>															<b>\$138,766</b>	

The total expected annual agricultural damage is estimated at approximately \$140,000 (2026 dollars). The majority of this value is attributable to crop losses associated with high-frequency flooding during the growing season, rather than rare, high-magnitude flood events.

The total structural damages (direct and indirect) were plotted against flood frequency in **Figure 18**. The damages shown represent the estimated structural losses that would occur if the specified flood event were to occur. As shown in **Figure 18**, structural damages remain negligible for lower return period events and begin to increase substantially beyond the 50-year return period, when floodplain extents expand to impact buildings and associated infrastructure. The sharp increase at higher return periods reflects the inclusion of building impacts and corresponding indirect damages.



**Figure 18. Total Structural Damages for Different Flood Events**

## 11. Summary of Constraints and Critical Areas

The following constraints and critical areas were identified through the background review and should be considered in subsequent planning and design stages:

- ◆ Designated natural areas and environmental constraints are shown in **Figure 4**. Key constraints in the Focus Area include Mer Bleue Bog PSW and Provincial ANSI, Limoges PSW and the Sarsfield-Bearbrook Esker Provincial ANSI. Mer Bleue Bog is also known habitat for SAR. Development would need to avoid or mitigate impacts on these natural heritage features, and any others identified through future targeted studies.
- ◆ Additional development pressures within upstream headwaters.
- ◆ Moraine features that restrict grading and servicing options.
- ◆ Agricultural land use that may limit flood storage availability.
- ◆ The focus area is within the South Nation Source Water Protection Area. As discussed in Section 5, portions are identified as Highly Vulnerable Aquifers as well as Wellhead protection areas. Development and infrastructure within these areas are required to adhere to the SWP Area's relevant policies dependant on the work undertaken.
- ◆ Flat grades across portions of the flood mitigation assessment area.
- ◆ Flat watercourse slope (0.04%).

- ◆ Human influences (riparian vegetation removal, straightening tributaries, excavation of drains, urbanization, climate change conditions, and landslides).
- ◆ Influences from Vars-Winchester Esker including channel incision and erosion.
- ◆ Impacts from landslides.
- ◆ Transitional RGA rating for majority of reaches delineated within the Study Area.

## 12. Data Gaps and Limitations

### 12.1 Fluvial Geomorphology Potential Data Gaps

- ◆ The existing report [2] does not consider the impacts on aquatic habitats and species that may arise from two causes: (1) direct impact of changes in flow frequency and potential revised velocity profiles (the main interest is the complete flow range but with lesser interest for large return period events), and (2) indirect impact from changes in river and floodplain morphology on habitat availability. The impact to habitat is difficult to predict but broadly, if suitable habitats are available, it is likely that supported species would also be provided for
- ◆ Assessment of swales, undefined reaches, or tributaries to Bear Creek that may occur within the Bear Creek Subwatershed were not conducted. Based on Figure 5 in Appendix A of Palmer, 2024 [2], there are a significant number of tributaries to Bear Brook of varying sizes.
- ◆ No inventory of in-channel structures (culverts/ bridges), bank treatment structures, weirs, ponds, or outfalls were considered although crossings, weirs, and stormwater ponds were noted to be present in the assessment report [2].
- ◆ The field reconnaissance completed by Palmer was limited to public watercourse crossings or where Bear Brook flowed near public property. Therefore, reach descriptions and stability assessments (RGA, RSTAT) may not be representative of each reach
- ◆ Land use changes were noted in the Palmar report as part of the historical aerial imagery assessment however, land use mapping was not conducted
- ◆ The Assessment of Fluvial Geomorphology and Landslide Distribution along Bear Brook report [2] mentions large landslides were mapped as polygons. This data does not appear to be in the dataset provided. 104 small data points were provided but not the larger polygons.
- ◆ Historical aerial Imagery (should be some from 2019, 2008, 1975, 1945) was referred to in the existing report [2], but this data was not provided to AECOM
- ◆ Subwatershed boundaries were used in the existing report [2], but this data was not provided to AECOM

### 12.2 Natural Environment

Natural Environment data has been pulled from desktop sources. Targeted field studies specific to the Project Study Area and approximate focus area have not been completed.

### 12.3 Geotechnical Data Gaps and Limitations

- ◆ Stratigraphic and geomorphological information is available for the Bear Brook watershed, but with no site-specific geotechnical investigations having been completed at this time. The SNC Quaternary geology mapping illustrates a complex subsurface environment composed of Champlain Sea clays, glaciomarine silts, deltaic and nearshore sands, fluvial and glaciofluvial outwash, organic deposits, and the prominent sand-and-gravel Vars–Winchester Esker that bisects the system. Channel assessments completed for the watershed identify bank materials dominated by cohesive clay, silt, and fine sand, with localized gravel and cobble lag deposits near the esker, and extensive clay-rich valley walls in downstream reaches where sensitive (Leda) clays contribute to landsliding [2], [45]. Supplementary MECP (Ministry of the Environment, Conservation and Parks) Water Well Records within and near the study area further demonstrate the degree of heterogeneity, documenting abrupt shifts in stratigraphy, such as sand over clay over shale, sand over clay over gravel, and soft clay deposits exceeding 40 m in thickness, over relatively short distances [2] [45].

- ◆ The geotechnical information available at this stage of the study consists primarily of regional and desktop-based datasets, which are appropriate for an EA-level assessment but are not sufficient to support detailed design. Site-specific geotechnical investigations such as boreholes, test pits, laboratory testing, groundwater monitoring, and slope stability assessments have not been completed as part of this phase of work. These investigations are typically undertaken during later stages of the EA or during detailed design, once specific mitigation alternatives and locations are confirmed. Regional geology and geomorphology provide valuable context at the EA stage; however, site-specific investigations will be required to support detailed engineering design. Accordingly, targeted geotechnical investigations will be required during subsequent phases of the EA and detailed design to confirm subsurface conditions, evaluate slope stability, and support the feasibility and design of preferred flood mitigation alternatives.

## 13. Conclusions and Recommendations

### 13.1 General

Bear Brook experiences constant and well documented flooding which has triggered an effort by SNC with support from other stakeholders to study the area in detail and work towards the completion of a class environmental assessment (EA). As part of this study there is a requirement to identify and evaluate flood mitigation options for a defined area between Carlsbad Lane to the west (the upstream boundary) and Dunning Road to the east (the downstream boundary).

A review and assessment of background information which includes available reports and numerical models was completed to consolidate and integrate the data for further analysis. The Bear brook watershed has a total area of 490 km<sup>2</sup> and includes a portion of the City of Ottawa (57%) and the United Counties of Prescott and Russell (43%).

The predominant flow direction of Bear Brook is west to east with a stream network of tributaries and designated drainage channels to its confluence point with the South Nation River. The watershed is undergoing continued land use changes which include urban and per-urban development, which is concentrated mostly in the outskirts of the City of Ottawa and within the United Counties of Prescott and Russell.

The topography of the Bear Brook watershed is relatively flat and encompasses urban areas, wetlands, forested areas, and agricultural lands. Six subwatersheds were identified based on the properties of the stream network and include the Bear Brook Main Channel, South Bear Brook, Mer Bleue, Shaw's Creek, South Indian Creek, and North Indian Creek.

The land cover types for these subwatersheds as well as the entire Bear brook Watershed were defined with available geospatial land cover layers provided by the City of Ottawa. The predominant land cover types within the watershed include crop/pasture, and wooded area. Other land cover types include tile drained land and settlement.

Furthermore, the assigned hydrologic soil groups are a function of inferred soil characteristics and define indirectly the infiltration capacity of the soils within the watershed. The available information shows that a wide range of infiltration capacities is present within the watershed because of the presence of both clay and sandy soils. The clays in the watershed consist of Leda Clay which is unstable and can behave like a liquid when disturbed. Other soil types with clays have poor natural drainage characteristics and contribute to seasonal flooding, noting that they are rich in minerals and have high crop yields when drained. On the other hand, sandy soils are largely covered by upland forest and treed swamps across the watershed.

Based on available information from the City of Ottawa, 80 municipal drain segments were found within the Bear brook Watershed with a total combined length of 252 km. This reflects the nature of the land use as agricultural and pasture areas are present mostly in rural areas towards the east and south of the watershed.

### 13.2 Geotechnical Considerations

From a geotechnical perspective, the watershed's underlying materials present significant engineering constraints for future flood mitigation design. The presence of extensive Champlain Sea (Leda) Clay across

much of the watershed indicates a high potential for sensitive clay behavior, including loss of strength upon disturbance, retrogressive landsliding, and slope instability along entrenched reaches. Downstream of the Vars–Winchester Esker, channel incision into these clays has already created numerous documented landslides and steep valley walls. Upstream areas contain sand, gravel, and esker-derived deposits that exhibit very different infiltration, scour, and erosion characteristics. At the time of this assessment, site-specific geotechnical investigations such as boreholes, test pits, strength testing, and groundwater monitoring had not been completed, which is typical for this stage of a Class EA. As the EA progresses and preferred flood mitigation alternatives are identified, site-specific geotechnical investigations will be required to characterize subsurface conditions, assess slope stability, and support subsequent stages of detailed design.

The geotechnical information presented herein is considered appropriate for the purpose of identifying constraints and considerations at the EA level.

### 13.3 Natural Environment

The Bearbrook watershed Study Area contains municipally, provincially and federally designated natural areas including:

- ◆ City of Ottawa Natural Heritage System including the Greenbelt
- ◆ United Counties of Prescott and Russell Natural Heritage System,
- ◆ 2 Areas of Natural and Scientific Interest (ANSIs) - Mer Bleue Bog Life Science ANSI and the Sarsfield-Bear Brook Esker Earth Science ANSI,
- ◆ 6 Provincially Significant Wetlands (PSWs) - Hammond Swamp, Lester Road Wetland Complex, Limoges Swamp, Mer Bleue Bog, South Bear Brook Swamp and Wolf Creek Swamp,
- ◆ Conservation Lands - UCPR, National Capital Commission, South Nation Conservation Lands, City of Ottawa Lands and Crown Lands

The Study Area also contains:

- ◆ Significant Wildlife Habitat (SWH) - White-tailed Deer Wintering Areas, Moose Early Wintering Areas and Waterfowl Staging Areas
- ◆ 32 Species at Risk (SAR) identified under the provincial *Endangered Species Act (ESA)* and the federal *Species at Risk Act (SARA)*

Flood mitigation options should be evaluated for the potential to affect the above noted natural areas, habitats and SAR. The recommended preferred option will require a detailed assessment of impacts, the development of mitigation measures and possible compensation measures. The potential environmental permitting requirements for the preferred option will then be based on this assessment. Targeted field investigations may also be required to identify potential impacts on natural heritage features and functions.

### 13.4 Archaeology

A Stage 1 Archaeological Assessment must be completed for all proposed lands to be impacted determined during project design. The report must be submitted to the Ministry of Citizenship and Multiculturalism (MCM) for review and approval [46].

### 13.5 Cultural Heritage

It is recommended that a Cultural Heritage Report: Existing Conditions and Preliminary Impact Assessment (CHR) be completed for all proposed lands determined to be impacted during project design as part of the EA process. The CHR will document known and potential cultural heritage resources, assess potential impacts resulting from the proposed works, and provide recommendations for further reporting or mitigation measures to minimize adverse impacts on potential and known cultural heritage resources.

### 13.6 Hydrologic and Hydraulic Assessments

Previous hydrologic and hydraulic assessments have been completed for the Bear Brook watershed and include work by Chrysler and Lathem Ltd. in 1978 and then updated in 1991 by Ecos Garatech Associates Ltd. A study conducted by SNC and J.F Sabourin and Associates Inc. in 1997 entitled “Bear Brook Floodplain Mapping Study – City of Gloucester” added more details to the area of the South Bear Brook subwatershed.

In 2019, the “South Bear Brook Flood Risk Mapping” study by SNC was completed focusing on the eastern portion of the City of Ottawa.

An extended hydrologic model of the Bear Brook Watershed was developed with HEC-HMS and includes 301 basin elements and a total drainage area of 488 km<sup>2</sup>. The input model parameters included the CN curve number for infiltration, the Clark Unit hydrograph to represent runoff transformation, and the Muskingum-Cunge routing method to model channel storage effects.

Based on the results of the hydrologic simulations, the 10-day snow and rain event was selected to be carried forward for hydraulic modeling to determine flood boundaries. The peak flow values for the 2, 10, 20, 50, 100 and 350-year return period for the 10-day snow and rain were extracted at specified junction elements for input into the hydraulic model.

To update the flood hazard limits a subsequent study entitled Bear Brook Watershed Floodplain Mapping Report (SNC, 2022) included the development of a one-dimensional hydraulic model of Bear Brook and North Indian Creek. As part of the findings of this study, the hydraulic simulations revealed that sections of Bear Brook between Carlsbad Lane to Dunning Road spill outside the channel and into adjacent lands even during high frequency flood events.

To corroborate these findings and obtain more details, a two-dimensional hydraulic model was developed using HEC-RAS to assess the hydraulic characteristics of Bear Brook during the 100-year storm event, and flood prone areas were identified.

It is noted that SNC completed updates to the hydrologic and hydraulic models in 2025, and the flood extents and water levels used in this memorandum are based on those most recent model outputs.

### **13.7 Fluvial Geomorphology**

Fluvial geomorphology provides a critical link between hydraulic modelling and the natural environment. Results provided by both disciplines will need to feed into the fluvial geomorphic assessment to provide a comprehensive look at impacts natural watercourse processes could have. Care has been taken to obtain all information to date from reliable sources and has been verified where possible. Data gaps identified in this report are required to complete the comprehensive Environmental Study Report to support the development and evaluation of flood mitigation alternatives. All analyses and deliverables will be completed using publicly available data sources, including LiDAR, geospatial datasets, and previously published reports. No fieldwork or site visits will be undertaken as part of this project. Any need for field verification or outstanding data gaps will be identified as a recommendation in the final report.

### **13.8 Flood Damages Assessment**

Preliminary calculations of riverine flood damages within the Flood Mitigation Assessment Area were completed for Bear Brook and its tributaries between Carlsbad Lane and Dunning Road. The flood damage assessment was completed using the approved regulatory flood extents and water levels obtained from the most recent (2025) HEC-RAS hydraulic model developed and updated by SNC.

The analysis is based on the guidelines presented in the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure (NRCan, 2021), which provides general guidance on how to evaluate and calculate potential economic losses which can be generated from flood events, noting that these guidelines are focused on the estimation of flood damages to buildings and infrastructure even when other damages are also mentioned (i.e., indirect and intangible damages).

A geodatabase that contains geospatial layers such as buildings, infrastructure, land cover types, transportation networks, streams and waterbodies, wetlands, floodplain boundaries, and water elevations for available flood events was generated for this assessment. The data was used to calculate flood damages for flood events corresponding to the 2, 5, 10, 20, 50, 100, and 350-year return periods.

An inventory of affected features was generated with available geospatial layers by calculating intersection of the building layer provided by SNC with the flood boundaries extracted from the updated HEC-RAS hydraulic

model. Additionally, the findings of the flood vulnerability analysis presented in the Bear Brook Watershed Floodplain Mapping Report (SNC, 2024) were reviewed during this task.

The findings show that flooding affects buildings within the Flood Mitigation Area only during the 50, 100, and 350-year return period events (2, 7 and 9 buildings, respectively), however, crop and pasture lands are affected by all events that were considered in the assessment.

The calculation of direct damages to structures included the use of stage-damage curves included in the Federal Flood Damage Estimation Guidelines for Buildings and Infrastructure (NRCAN, 2021), specifically residential and commercial stage-damage curves that were obtained from the Provincial Flood Damage Assessment Study (IBI and Golder, 2015). Additionally, in the absence of local data indirect damages were calculated as 40% of direct damages.

The results show that the rounded costs of direct and indirect damages to the features are \$44,000 (50-year), \$87,000 (100-year) and \$111,000 (350-year). These costs grow exponentially with the flood event magnitude.

Agricultural damages were assessed for both return period events equal to or greater than the 2-year event and selected higher-frequency (sub-2-year) discharge thresholds. Inclusion of sub-2-year events was necessary to reflect the flat topography of the Flood Mitigation Assessment Area and documented summer flooding events that affect crops during the growing season. While larger return-period events occur predominantly in early spring, smaller and more frequent events occur during the growing season and contribute substantially to agricultural losses. Incorporating these higher-frequency events results in a more representative estimate of expected annual agricultural damages. Based on the analysis presented in **Section 10**, the estimated annual agricultural damage is approximately \$140,000 (2026 dollars), driven primarily by crop losses associated with frequent, low-magnitude overbank flooding during the growing season.



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