3.0 WATERSHED HYDROLOGIC CHARACTERIZATION

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The project study area is the watershed under the jurisdiction of the Niagara Peninsula Conservation Authority (NPCA) with a total area of 2,424 km^2.

3.1 Climate

The climate of Southern Ontario is characterized as having warm summers, mild winters, a long growing season, and usually reliable rainfall. The climate within southern Ontario differs somewhat from one location to another and from one year to the next. Spatial variations are generally caused by the topography and varying exposure to the prevailing winds in relation to the Great Lakes (Schroeter et al, 1998). According to Brown et al. (1980), the NPCA watershed is located in the Niagara Fruit Belt climatic region.

Average annual precipitation is least along the shore of Lake Ontario (less than 850 mm) and greatest (more than 1,000 mm) in the Fort Erie area on the shore of Lake Erie (NPCA, Aqua Resource Inc, 2009). Average annual snow water equivalent shows large differences: greater than 175 mm in Fort Erie and Grimsby, to less than 125 mm in the Niagara-on-the-Lake (NOTL), Haldimand and Pelham areas. Snow water equivalent is the amount of water contained within a snow pack (i.e. the depth of water that would result if a snowpack was melted instantaneously).

The mean annual temperature ranged from 8^{o}C at Hamilton Airport to 9.5^{o}C at Vineland and Port Dalhousie. Mean temperatures are generally warmer moving from the west towards the center of the NPCA's watershed and lower elevations.

Other general observations include, 14-17% of precipitation is generally snow, the month with the lowest monthly precipitation is February and the greatest monthly precipitation occurs in September.

3.2 Topography

The topography in the Niagara Peninsula ranges from its highest elevation of 260 metres above sea level (m ASL) at the Fonthill Kame-Delta Complex to its lowest at Lake Ontario at 75 m ASL.

Escarpments play a large role in drainage boundaries. For example, the Niagara Escarpment forms the east-west topographic northern boundary of Twenty Mile Creek, as well as the southern boundary of Niagara-on-the-Lake creeks. The Niagara Escarpment decreases in elevation from about 210 m ASL in Hamilton to the west, and 200 m ASL in Niagara Falls in the east, towards Twelve Mile Creek at about 160 m ASL. The much less prominent, but also east-west trending, Onondaga Escarpment, at about 180-190 m ASL, largely defines the northern boundary of Lake Erie Northern Shore creeks.

Many of the other major drainage boundaries are much less distinct because of the relatively flat central area associated with the Haldimand Clay Plain.

The three (3) main drainage basins are Lake Ontario, the Niagara River, and Lake Erie.

There are 146 subwatersheds with a total of 4,898 kilometres of stream length, which drain to these primary outlets.

3.2.1 Lake Ontario Drainage Basin

Lands in the northern portion of the watershed drain into Lake Ontario.
The drainage to Lake Ontario generally starts above the Niagara Escarpment and flows easterly before turning north, flowing over the Escarpment, and into the lake.

The most significant drainage to Lake Ontario comes from Twenty Mile Creek with a total drainage area of 291 km^2, Twelve Mile Creek with a total drainage area of 178 km^2, and Forty Mile Creek with a total drainage area of 64.8 $km^{2.}$ (Niagara Peninsula Conservation Authority, 2007, 29)

The total length of Lake Ontario shoreline within the NPCA jurisdiction is 50 kilometres. (Regional Municipality of Niagara, 2003, 4-8)

3.2.2 Niagara River Drainage Basin

Lands in the central portion of the watershed drain to the Niagara River.

The two largest tributaries of the Niagara River are the Welland River and Black Creek. The headwaters of the Welland River are located in the City of Hamilton and it has a drainage area of approximately 1,050 km^2. Black Creek has a total drainage area of approximately 70.3 km^2. (Niagara Peninsula Conservation Authority, 2007, 33)

The total length of shoreline within the NPCA jurisdiction is 60 kilometres. (Regional Municipality of Niagara, 2003, 4-8)

3.2.3 Lake Erie Drainage Basin

Lands in the southern portion of the watershed drain to Lake Erie.

The drainage to Lake Erie is by small streams or tile drains that have been dredged and straightened to drain the Haldimand Clay Plain. These watersheds have less than 20 km^2 total area and generally flow south from the Onondaga Escarpment to the lake. The largest of these systems include Six Mile Creek, Wignell Drain and Lowbanks Drain. (Niagara Peninsula Conservation Authority, 2007, 33)

The total length of shoreline within the NPCA jurisdiction is 60 kilometres. (Regional Municipality of Niagara, 2003, 4-8)

Within the watershed, the two largest drainage areas occur in the Welland River and Twenty Mile Creek. The Welland River falls approximately 82 metres in elevation over its entire course. The most significant vertical drop is a 78 metres drop which occurs over the first 55 kilometres with only a 4 metre drop on the lower 80 kilometers of the River. This slight gradient results in a meandering, sluggish river from Port Davidson downstream (approximate intersection of the Welland River and Haldimand County boundary).

Twenty Mile Creek begins adjacent to the Welland River with rolling topography and fairly steep slopes in the headwaters. The middle and lower portions of the Twenty Mile Creek watershed have a gently rolling to flat topography before the creek bed drops almost 100 metres at the Niagara Escarpment. Most of Twenty Mile Creek above the Escarpment flows over bedrock, or is controlled by bedrock ridges.

3.3 Streamflow

An analysis of baseflow separation and streamflow recession was completed for six (6) stations (shown below) in the NPCA watershed (AquaResource Inc., 2007). Four (4) of the stations had extensive records, while two (2), 02HA030 and 02HA031, had very limited records, presenting a limitation of the streamflow data for these two (2) stations which may have affected the results.

Table - Streamflow Gauges

WSC ID	Description	Drainage Area (km^2)	Data Start Date	Data End Date
02HA006	Twenty Mile Creek At Balls Falls	293	3/1/1957	12/31/2005
02HA007	Welland River Below Caistor Corners	230	7/1/1957	12/31/2005
02HA020	Twenty Mile Creek Above Smithville	168	1/1/1987	12/31/2005
02HA024	Oswego Creek At Canboro	81	9/1/1988	12/31/2005
02HA030	Four Mile Creek Near Virgil	13	4/1/2006	10/2/2007
02HA031	Twelve Mile Creek Near Power Glen	47	4/1/2006	10/2/2007

3.3.1 Twenty Mile Creek, the Welland River and Oswego Creek

The flow regime observed at these four (4) stations is typical of Southern Ontario. Due to spring freshet, annual peak flows are observed during the month of March. The flows quickly decline through the months of April, May and June, reaching summer low flows by July. Low to no flow remains until mid to late fall, where lower evaporation and more regional rainfall allow streamflow to recover.

There is a significant difference between median flows and 10th percentile flows during the spring months. The 10th percentile flows are on average approximately five times the median flow for the month of March. This suggests the flow regime is extremely flashy, as peak flows are not sustained for large periods of time. Soon after a precipitation event, flows quickly return to baseflow conditions. This is indicative of a well-drained watershed dominated by tight surficial materials. There does not seem to be any evidence of significant depression storage on the landscape.

Summer low flows are lower than in many other regions of Southern Ontario.

- Welland River below Caistor Corners has monthly median summer flows below 0.1 m^3/s indicating that there are no areas with significant groundwater discharge within the catchment.
- Ball's Falls has monthly median summer flows (July – August) below 0.1 m^3/s indicating that there are no areas with significant groundwater discharge within the gauged catchment.

The 90th percentiles, or low flows, shows that Oswego Creek at Canboro, Ball's Falls and Smithville have had past occurrences of no flow. For a watershed of 293 km^2, such as Ball's Falls, or a watershed of 81 km^2, such as Oswego Creek, to have zero flow provides more evidence there is very little surface/groundwater interactions for catchments located within the Haldimand Clay Plain, a runoff driven system.

3.3.2 Twelve Mile Creek

The overall flow regime observed for Twelve Mile Creek is not typical of Southern Ontario. While peak flows were observed during the March spring freshet and did decline through April and May, flows were relatively constant through June, July and August. The extremely constant rate of flow throughout the year is most often seen in watersheds with some form of reservoir regulation, or significant groundwater discharge. Due to the lack of any reservoirs or significant control structures on Twelve Mile Creek, the steady flow is most likely caused by a very significant groundwater discharge.

The 10th percentile flows are on average approximately four times the median flow for the month of March. This suggests the spring flow regime was flashy, as the peak flows were not sustained for a large period of time.

Summer low flows are relatively constant indicating significant groundwater discharge within the gauged catchment.

3.3.3 Four Mile Creek

The flow regime observed is not entirely typical of Southern Ontario. Due to spring freshet, annual peak flows are observed during the month of March. Flows decline through the months of April, May and June, but did not exhibit summer low flows. This is likely due to the flow of irrigation water that was directed into the system from July until September. More natural/ambient conditions are interpreted to occur after mid-September when lower evaporation and more regional rainfall allow streamflow to recover.

The 10th percentile flows are on average approximately four times the median flow for the month of March. This suggests the flow regime is extremely flashy, as peak flows are not sustained for large periods of time. Soon after a precipitation event, flows quickly return to baseflow conditions. This is indicative of a well-drained watershed dominated by tight surficial materials.

3.4 Baseflow Characterization

A baseflow separation exercise was also carried out. Baseflow is the release of water from storage contained within the upstream drainage area that drains to a particular gauge. This water released from storage could originate in aquifers, and hence is termed groundwater discharge, but also could originate from wetlands or reservoirs.

In general, baseflow follows the same seasonal trends as streamflow for Twenty Mile Creek, the Welland River, Oswego Creek, and Four Mile Creek. While Twelve Mile Creek shows almost identical streamflow and baseflow, mean monthly estimates for low flow periods (summer months) indicating a reliable source of baseflow from the Fonthill Kame-Delta Complex; however this may be affected by the lack of long term data.

3.5 Additional Streamflow Comments

3.5.1 Niagara-on-the-Lake Watershed Planning Area

In Niagara-on-the-Lake (NOTL) an extensive network of municipal drains and field tile drains provide for conveyance of runoff from the flat topography in the middle portions of the subwatersheds, and as a result flow is flashy overall. In some respects NOTL is more typical of an urban than a rural watershed (Aquafor Beech, 2008).

The Town of NOTL has its own local drainage legislation allowing the municipality to regulate irrigation within its jurisdiction. Irrigation water to supply agriculture is currently taken from several Great Lakes sources, i.e. Ontario Power Generation (OPG) Sir Adam Beck Generating Station reservoir, the Chippawa Power Canal, the Welland Canal, and the Niagara River. Generally the irrigation system is in operation from May 15 – September 15; however the season may be extended a couple weeks on either side of these target dates to meet local needs.

3.5.2 Lake Erie North Shore Watershed Planning Area

In Lake Erie North Shore the outflow from Eagle Marsh Drain and Wignell Drain can be reduced during elevated lake levels as control structures prevent backflow from Lake Erie. Outflows are pumped to Lake Erie when the control structures are in place.

3.5.3 Central Welland River Watershed Planning Area

Three notable man-made modifications to the Welland River are the (i) Old Welland Canal, (ii) New Welland Canal and (iii) Ontario Power Generation operations at the Niagara River. Two inverted siphons were built to convey the flow of Welland River water beneath the Old and New Welland Ship Canals. These structures flow full under pressure and create backwater pools during floods in a manner similar to dams (NPCA, 1999).

Originally, the Welland River drained directly into the Niagara River at Niagara Falls. However, its flow is now diverted entirely into the Queenston-Chippawa Power Canal. Since 1953, the lower portion of the Welland River flows in reverse, drawing Niagara River water to the Power Canal. This regulated diversion of water in the lower Welland River creates a pattern of regular diurnal fluctuations in water levels that extend approximately 60 km upstream of the diversion (Philips Engineering Ltd., 2004).

Also under normal conditions, the Old Welland Canal provides additional flow to the Welland River at, and immediately downstream of the old siphon. Flow enters the Welland River from the Old Welland Canal through two pathways. First are a series of ports in the roof of the old siphon which allow 14.2 m^3/s of Lake Erie water to dilute the

Welland River water. Second is a bypass flow at the Welland Water Treatment Plant which allows 4.5 m^3/s of flow (Stantec, 2008).

3.6 Hydrogeology

3.6.1 Aquifer Units

Bedrock aquifers are typically those shallower units containing limestones and dolostones such as the Guelph-Lockport, Bois Blanc and Onondaga Formations. The Salina Formation also has a good water yielding capacity but the water quality is usually not suitable for drinking due to the presence of naturally occurring elevated concentrations of salts, minerals and sulphate along with the presence of hydrogen sulphide gas. The Queenston Formation may also provide marginal supplies for domestic demands but may have naturally occurring poor water quality. Other bedrock formations, i.e. Cataract and Clinton, are not generally considered significant sources of groundwater and may have natural poor water quality.

Overburden aquifers are generally of two (2) main types: (i) unconfined near-surface coarse-grained deposits, e.g. Fonthill Kame-Delta Complex and (ii) confined contact zone aquifers at the bedrock surface consisting of granular overburden and fractured bedrock overlain by clay. Singer et al (2003) listed some of these confined “contact zone” aquifers (e.g. Wainfleet, Port Colborne, St. Catharines and Niagara-on-the-Lake aquifers). Waterloo Hydrogeologic Incorporated (WHI) in a study published in 2005, mapped “Sand and Gravel” thickness above bedrock which indicated that these “contact zone” aquifers may be quite extensive as an available source of groundwater in our area.

3.6.2 Water Table Aquifers

Water table aquifers include flow in both the overburden and bedrock. WHI (2005) indicated these aquifers would include the Onondaga Escarpment, the upper portion of the Fonthill Kame-Delta Complex, part of the Niagara Escarpment (i.e. Lockport Formation), and at times, the contact zone aquifer at depth. Groundwater flow may be to and from the water table to deeper aquifers and back again.

3.6.3 Deeper Aquifers

Our deeper aquifers include flow in both overburden and bedrock. WHI (2005) indicated that these deeper aquifers, greater than 15 metres below ground surface, could include portions of the contact zone aquifer, the Fonthill Kame-Delta Complex, the Lockport Formation, and other bedrock formations.

3.6.4 Surface Water and Groundwater Interactions

The soils of the Haldimand Clay Plain limit the interactions between surface water and groundwater in much of our area. Interaction does occur at the Niagara Escarpment (particularly in karst locations), along the Escarpment face as diffuse seeps, and as discharge to numerous creeks and streams originating at the foot of the Escarpment (both seasonal and perennial). Significant groundwater discharge, on a local scale, occurs where various watercourses cut into the more permeable overburden and fractured bedrock. Examples of groundwater discharge to surface water include Twelve Mile and Four Mile Creeks.

Another more ephemeral source of groundwater discharge may be lateral groundwater flow and discharge to low lying depressions through fractured surficial clay.

3.7 Wetlands

Wetlands consist of land that is seasonally or permanently covered by shallow water or have a water table close to or at its surface, resulting in hydric soils which support vegetation dominated by hydrophyllic or water tolerant plants. They are often thought of as a transition zone between terrestrial and aquatic ecosystems, and as such are the most biologically diverse of all ecosystems.

Wetlands provide very important ecological functions such as supporting biodiversity by providing food, water and shelter for a variety of wildlife during all or part of their life cycles, for specialized or rare plant and animal species that depend on wetlands exclusively as their habitat, and by providing cover for species moving to and from aquatic and terrestrial ecosystems.

Wetlands also provide very important hydrological functions such as natural filtration of nutrients, contaminants and sediments thereby improving water quality, cycling nutrients up the food chain, and retention of water to decrease peak flows. Water retention reduces flooding, increases groundwater infiltration, increases watercourse baseflows, and minimizes erosion.

There are five main types of wetlands; marsh, fen, bog, swamp, and open water. The NPCA watershed contains all types of wetlands. By area, Niagara is covered by more swamp wetlands than any other type. A swamp is a wetland which has temporary or permanent inundation of large areas of land by shallow water. Swamps generally consist of scattered dry hummocks containing terrestrial vegetation, surrounded by aquatic vegetation, and are therefore characterized by rich biodiversity.

In Niagara, our swamps are mostly made up of a particular type of swamp referred to as a slough forest. Slough forests are forested areas with undulating land that contain both seasonally ponded areas, referred to as sloughs or vernal pools; and ridges of higher land. These interspersed high and low points result in forests containing both water-tolerant tree species such as Red Maple *(Acer rubrum)*, Green Ash *(Fraxinus pennsylvanica)*, and Silver Maple *(Acer saccharinum)* in the wetter areas of hydric soils; and can contain rare vegetation types such as Pin Oak *(Quercus palustris)* swamp and Buttonbush *(Caphalanthus occidentalis)* shrub swamp. These communities may also contain drier species such as Sugar Maple *(Acer saccharum ssp. saccharum)*, White Oak *(Quercus alba)*, Shagbark Hickory *(Carya ovata),* and American Beech *(Fagus grandifolia)* in the drier ridges that run through the wetland.

Even small isolated seasonal pools which contain standing water for only a short period in the spring and summer can provide vital habitat for rare and specialized species such as frogs and salamanders which rely on fish-free sources of water to survive, and are often found in no other habitats.

Slough forests are located in abundance over large areas of the southern portion of the watershed due to the flat topography containing undulating wetland forests. This adds significantly to the flood storage capacity of the watershed. The tree cover and leaf litter intercept rain and slow and lower the amount of water reaching the ground, and natural groundcover helps to take up water, and slow its movement across the landscape. The sloughs hold back water during peak flow periods such as the spring freshet, and contribute to local groundwater and watercourse baseflows as water slowly soaks into the ground over a period of weeks or months.

Historically, the study area would have been almost completely forested. The Haldimand Clay Plain would have been dominated by lowland forests and slough wetlands. By studying old aerial photography it is easy to see the dark slough patterning across the southern landscape, even in some areas which had recently been converted to agriculture.

The largest wetlands in the study area are Wainfleet Bog and Humberstone Marsh.

The largest continuous forest in the study area is the Caistor-Canborough Slough Forest located in the Haldimand portion of the watershed. Other significant slough forests within the study area are: Willoughby Marsh, Attercliffe Station Slough Forest, and North Cayuga Slough Forest.

The main threats to wetlands historically in Niagara have been drainage for agriculture and human settlement. Wetlands were often viewed as being of low economic value as they required drainage and clearing to be agriculturally productive, and held little value except for hunting and some recreational uses. Now that the importance of wetlands for flood control, water quality protection, groundwater infiltration and habitat are better understood, development is regulated by municipalities, the regional governments and the NPCA, to ensure their benefits remain on the landscape over the long term.

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