Hydrogeological and geochemical evaluation of the eastern Minesing Wetland in support of the Hine’s Emerald Dragonfly (*Somatochlora hineana*)

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1.0 INTRODUCTION
The globally rare Hine’s Emerald dragonfly (*Somatochlora hineana*; HED) is a medium-sized dragonfly (about 60 millimetres long) characterized by bright green eyes, a metallic green thorax with two lateral yellow stripes, and a blackish-brown abdomen. It is a globally rare dragonfly, restricted to southern Ontario, Wisconsin, Michigan, Illinois and Missouri. To date, the 6,000 hectare Minesing Wetlands in Simcoe County is the only known location of the HED in Ontario. It was listed as endangered on January 13, 2012 by the Committee on the Status of Species at Risk in Ontario. The HED is restricted throughout its range to calcareous wetlands dominated by graminoid vegetation and fed primarily by groundwater seeps. Eggs from the HED are deposited in shallow channels or sheetflow in areas of herbaceous vegetation in marshes, meadow marshes, and fens.

The main threats to this species in Ontario are habitat loss due to changes in surface and subsurface hydrology (including water quality), competition from invasive species (e.g. Garlic Mustard, Purple Loosestrife, Glossy Buckthorn, and the non-native genotype of Common Reed) and vegetation succession from native species. Alteration to the groundwater quantity and quality has also been identified as a high threat to HED (Pulfer et al., 2013).

Funded through the MNR Species at Risk Stewardship Fund, the objective of this study is to address key knowledge gaps for the recovery of HED including determining groundwater levels and chemistry in the fen and recharge areas. The main components of this project consist of:

1. Establishment of two drilled monitoring wells in the recharge area upgradient of the fen.
2. Installation of nested shallow standpipes and deep piezometers in areas of known HED habitat through the infilling of the existing Bradford (1999) groundwater monitoring network.
3. Investigation of groundwater chemistry and groundwater levels in the fen and the recharge area.
4. Estimation of the recharge rates of the recharge area.
5. Update the ecological land classification mapping along the T6 and T3 transects.

1.1 MINESING HYDROLOGY
The Minesing Wetlands can be subdivided hydrologically into two regimes: the south-east fen and mixed boreal complex swamp, which are dominated by a groundwater influence and the remaining wetland components, which are dominated by surface water processes (Figure 1). The groundwater-dominated regime is herein further subdivided into 3 progressive ecohydrological zones.

*Discharge wetland system*: The south-east border of the Minesing Wetlands is bracketed by the ancestral shoreline of Glacial Lake Payette (a lower stage of Glacial Lake Algonquin), although the shorelines are largely buried. The base of these shoreline deposits correspond to the mixed conifer swamp complex. This unit is supported by relatively constant

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groundwater discharge from the regional A2 aquifer, the principal source of groundwater (Beckers and Frind, 2001; Bradford, 1999) to the mixed boreal complex swamp complex. Moving west towards the fen, this groundwater discharge coalesces into spring-fed tributaries and the vegetation changes from the open mixed/conifer swamp to low, hummocky terrain supporting deciduous and mixed forests that are at the fresh-moist/swamp forest transition.

**Flow through wetland system:** This unit transitions to a conifer swamp that develops tamarack-dominated components approaching the central shrub fen. It is characterized by very slow moving groundwater with the water table at or above the ground surface as a flow through hydrologic unit. Within the fen, three distinct vegetation communities are present:

1. Peat plain fen with string islands that form an extensive network of sedges and grasses mixed with coniferous and low shrub islands.
2. Peat plain-conifer complex dominated by cedar and tamarack that surrounds the fens and has colonized the string islands.
3. Remnant tamarack and cedar islands, dead standing trees and alder thickets that define the peat plain big marsh. Northward, there is a broad transition from the fen/boreal west-north-west toward the Nottawasaga River with the vegetation community marked by surface water features.

The transition between the discharge wetland feature and the flow through wetland system is considered diffuse and broad.

**Graminiod fen:** This unit corresponds to the HED category 1 habitat and is bracketed by coniferous string islands. Fens are minerotrophic, peat-accumulating ecosystems that have perennially saturated soils, and whose hydrologic regime, geochemistry, and potential ecological characteristics are produced by the landscape that supplies its groundwater (not precipitation) as well as long-term issues of site history (Cooper and Wolf, 2006). Typically, fens occupy a low point of relief in a basin and are usually characterized by very slow internal drainage through seepage. General characteristics of fens include:

- **Soil:** Non-acidic, sedge-derived peat; saturated or nearly saturated during most of the growing season;
- **Hydrology:** Constant, upwelling groundwater; waterlogged within at least a few inches of the surface with scattered small pools and rivulets; and
- **Vegetation:** Grasses, sedges, rushes, shrubs, various broad-leaved plants; many rare species.

The groundwater flow direction is generally north-west and is aligned with the ‘seepage fens’ on the eastern side of the wetland, which is perpendicular to the topography even though the gradient is extremely low (Bradford, 1999). The prominent lateral flow is the result of thick, relatively laterally continuous glaciolastrine silts and clays that underlie the wetland complex, acting as a regional impermeable unit and directing flow laterally instead of vertically. During dry periods, the net groundwater inflow is concentrated, whereas during storm events the net groundwater outflow is dilute meteoric water (Bradford, 1999).
1.2 HINE’S EMERALD DRAGONFLY (*Somatochlora hineana*)

The Hine’s Emerald (*Somatochlora hineana*) is restricted throughout its range to calcareous wetlands (marshes, sedge meadows and fens) dominated by graminoid vegetation in groundwater-fed wetlands such as fens. Adult males reside in seepage areas and fens and adjacent margins, whereas females are usually found in dry meadows, sometimes in adjacent forest openings, only coming into wetlands to lay eggs. HED deposit eggs in shallow channels or sheetflow in areas of herbaceous vegetation in marshes, meadow marshes and fens (Lee et al., 2006). The larvae remain in cool, shallow, slowly-moving waters of spring-fed marshes, alkaline fens, mineral-rich fens with shallow creeks, springs, small pools, marl deposits and calcareous marshy streams for three to five years before emerging as adults (Pulfer et al., 2013). In some locations, larvae use crayfish burrows, mainly of Digger Crayfish or of Devil Crawfish (also known as Meadow Crayfish), as refuge habitat in the summer and winter months. Crayfish burrows are thought to be a critical component of HED habitat where seasonal drought and freezing occurs and may be a factor limiting its distribution (Lee et al., 2006; Aley et al., 2007).

The habitat regulation for the HED protects areas being used for egg-laying or larval development (category 1 habitat; MNRF, 2014). Suitable wetland and aquatic areas are protected within 1600 metres of an egg-laying or larval development site, plus an additional
500 metre area around these wetland or aquatic features (category 2 habitat). Areas that do not allow water to filter into the soil, such as paved areas and buildings, are not included in the 500 metre area (Figure 2). Supporting rationale for these regulations consists of:

- **HED** rely on slow-moving, calcareous water with emergent vegetation for egg-laying and larval development. These conditions are associated with fens, marshes or areas where groundwater rises to the surface.
- Larvae depend on crayfish burrows for refuge from drought and for over-wintering. Crayfish burrows can be found along the edges of riparian zones.
- Adult HED travel to areas of natural vegetation for foraging, mating, and refuge. Because of the difficulty of flying through thickets and forests, HED typically stay near the edge of these types of habitats, which is approximately the first 100 metres.
- 1600 metres represents the average distance HED will travel to carry out life processes.

Alteration to the quantity and quality of groundwater moving into the wetlands used by the species is the greatest threat to its survival. Protecting the area within 500 metres of these wetlands will help to reduce these threats and is essential to maintaining breeding habitat for the HED.

### 2.0 Minesing Wetlands Groundwater Monitoring Network

Minesing Wetlands groundwater monitoring was completed through a series of shallow monitoring wells located along two transects, T3 and T6. Originally established in 1996 by Andrea Bradford as part of her PhD thesis research (Bradford, 1999), the transects commence at the Glacial Lake Payette shoreline at the eastern margin of the wetlands and terminate in the fen (Post, 2009). Seventeen of the original groundwater monitoring sites were located through field reconnaissance in 2009 (Post et al. 2010; Table 1). However, other piezometers and monitoring wells are originally located on these transects, but could not be relocated. Each groundwater station consists of a standpipe screened just below the surface of the peat and a piezometer screened just above the mineral soil (screen mid-point range = 1.5 to 2.3m). All of these monitoring wells are made of PVC and have screened intakes approximately 65cm long with an inside diameter of 3.2cm.
On October 29 and 31, 2013, nine additional monitoring sites were installed to infill the existing Bradford (1999) T3 and T6 transects, with infilling in areas of known co-occurrence of HED and digger crayfish (Figures 3 and 4). Two monitoring wells were installed at each additional site, excluding T6-12_13. The two wells consisted of 1) a shallow standpipe that was typically screened approximately from 10 cm to 80 cm below the ground surface and 2) the deeper piezometer, which was completed to the peat-marl clay sediment interface, generally located between 2.5 and 3 m below the ground surface with a 70 cm screen. This configuration is consistent with that installed by Bradford (1999). Due to the sediment present, site T6-12_13 consisted of only the sediment-overburden interface well. The monitoring wells were hand augured to the appropriate depth and manually installed. All wells consisted of 2.5” diameter PVC tubing with a slot 10.
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Figure 3: Distribution of the Minesing Wetlands monitoring wells and date of installation. The NVCA 2014 well is a recharge area monitoring well. Note that the Grenfel well is not shown in this figure.

Figure 4: Classification of the Minesing Wetlands monitoring wells according to the ecohydrological subdivision of the groundwater-dominated eastern Minesing Wetlands.
2.1 RECHARGE AREA MONITORING WELLS
Two groundwater monitoring wells located in the modelled recharge area were installed in accordance to O.Reg. 903 in 2014 as part of this project: one located on the Simcoe County Forest property off of Pinegrove Road (21m deep) installed in March, 2014 and one on Springwater municipal road allowance off of Grenfel Road (49m deep) installed in November, 2014. It is noted that the Grenfel Road monitoring well was advanced to 64m below grade; however a thick clay unit was encountered and the well was therefore screened in the water producing unit above this clay layer. The Ministry of the Environment water well records are located in Appendix 1. The purpose of these monitoring wells is to characterize the groundwater quality and levels in the recharge area located upgradient of the HED category 1 habitat.

The ground surface elevation of the Grenfel Road well, located on the top of the snow valley uplands, is approximately 275masl. Whereas the ground surface elevation on Pinegrove Road is 220masl and the fen is approximately 184masl. This corresponds to the 90m change in elevation. Further, the Grenfel Road well is screened at approximately 225masl, the Pinegrove well is screened at 199masl and the seepage front is roughly 190masl. Given the local overburden stratigraphy as inferred from the MOE water well records, the two monitoring wells are completed in the same stratigraphic/hydrostratigraphic unit as the seepage front and are characterized by downward vertical hydraulic gradients.

The Pinegrove well is located in the modelled<6month time of travel zone whereas the Grenfel well is situated on the boarder of the 10-25 year time of travel zones. This indicates water in the Pinegrove well area theoretically takes less than 6 months to discharge to the wetland system (e.g. T6-13 to T3-8 area), whereas the Grenfel well would take between 10 and 25 years.

A Solinst Level logger was installed in the Pinegrove Well on May 27, 2014 and on March 19, 2015 for the Grenfel well.

2.2 GROUNDWATER DATA
Information about groundwater in the Minesing Wetlands is comprised of the Bradford PhD field work completed in 1997 and 1998 (Bradford, 1999) and subsequent NVCA and Environment Canada work completed in 2009-2014. Water level data consists of both manual static measurements and automated level loggers. Table 2 outlines the number of manual static water levels that were measured per year from 2009 to 2014. In support of the work reported by Post et al. (2010), water levels at all stations were measured manually approximately once every two weeks for a total of seven measurements during the period of July 20 to October 16, 2009. The 1997-1998 water level data presented in Bradford (1999) was not compiled due to its presentation in graphical format.

HOBO water level loggers were deployed from July 20 to October 16, 2009 in three standpipes and two piezometers to record water levels and groundwater temperatures at 10 minute intervals. In 2014, 8 Solinst Level Loggers were deployed at 4 well nests from May 27 to November 11, 2014 and recorded groundwater level and temperature at a 60 minute interval (Table 3). For the selected sites, the loggers were deployed in both the shallow (“S”) and deep (“D”) wells. Three sites (T6-3A_13, T6-3B_13, and T6-4) correspond to the Graminoid Open Fen (FEOG1) and HED category 1 habitat. The other site, T6-5A_13, is situated in a Tamarack Organic Coniferous Swamp (SWCO2-2), upgradient of the graminoid fen. The raw water level data is baro-compensated and corrected based on 5 manual static readings taken during the logger deployment.
All groundwater data was collected during the ice-free period. Due to the focus of this project being on the HED category 1 habitat, the logger locations did not overlap from 2009 to 2014.

The groundwater quality dataset is comprised from 4 sampling events: July 20 and 21, 1998 (Bradford, 1999), October 14, 19, and 20, 2010 (Spoelstra and Post, 2012), November 11, 2013 (this study), and September 15, 2014 (this study). It is noted that the 2010, 2013, and 2014 sampling and analysis was completed by Environment Canada and the NVCA. The Bradford (2009) groundwater quality data is utilized in this report for comparative purposes.

Table 2: Summary of existing data points for groundwater levels and water quality, per well.

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<th>Number of Statics per year</th>
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<th>Sampled for Water Quality</th>
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Table 3: Well characteristics for sites where Solinst level loggers were deployed.

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<td>T6-7_P</td>
<td>7 1 1 2 2 2 5</td>
<td>✔ ✔ ✔ ✔ ✔ ✔ ✔</td>
<td></td>
</tr>
<tr>
<td>T6-7_S</td>
<td>7 1 1 2 2 2 5</td>
<td>✔ ✔ ✔ ✔ ✔ ✔ ✔</td>
<td></td>
</tr>
<tr>
<td>T6-9_P</td>
<td>7 1 1 2 2 2 5</td>
<td>✔ ✔ ✔ ✔ ✔ ✔ ✔</td>
<td></td>
</tr>
<tr>
<td>T6-9_S</td>
<td>4 1 1 2 2 2 5</td>
<td>✔ ✔ ✔ ✔ ✔ ✔ ✔</td>
<td></td>
</tr>
</tbody>
</table>

Recharge Area

<table>
<thead>
<tr>
<th>Name</th>
<th>Elevation (masl)</th>
<th>Stickup (m)</th>
<th>Top Screen (mbgs)</th>
<th>Bottom Screen (mbgs)</th>
<th>Depth (mbgs)</th>
<th>Level logger Depth (mbref*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6-3A_13_D</td>
<td>183.62</td>
<td>0.53</td>
<td>1.53</td>
<td>2.13</td>
<td>2.180</td>
<td>1.200</td>
</tr>
<tr>
<td>T6-3A_13_S</td>
<td>183.62</td>
<td>0.77</td>
<td>0.45</td>
<td>1.05</td>
<td>1.095</td>
<td>1.000</td>
</tr>
<tr>
<td>T6-3B_13_D</td>
<td>183.77</td>
<td>0.44</td>
<td>1.55</td>
<td>2.15</td>
<td>2.195</td>
<td>0.950</td>
</tr>
<tr>
<td>T6-3B_13_S</td>
<td>183.77</td>
<td>0.74</td>
<td>0.43</td>
<td>1.03</td>
<td>1.080</td>
<td>1.200</td>
</tr>
<tr>
<td>T6-4_D</td>
<td>183.96</td>
<td>0.69</td>
<td>1.64</td>
<td>2.28</td>
<td>2.331</td>
<td>1.120</td>
</tr>
<tr>
<td>T6-4_S</td>
<td>183.96</td>
<td>0.66</td>
<td>0.14</td>
<td>0.85</td>
<td>0.896</td>
<td>1.050</td>
</tr>
<tr>
<td>T6-5A_13_D</td>
<td>183.90</td>
<td>0.56</td>
<td>1.60</td>
<td>2.20</td>
<td>2.245</td>
<td>1.100</td>
</tr>
<tr>
<td>T6-5A_13_S</td>
<td>183.90</td>
<td>0.81</td>
<td>0.38</td>
<td>0.98</td>
<td>1.025</td>
<td>1.320</td>
</tr>
</tbody>
</table>

*mbref: metres below reference

3.0 GROUNDWATER LEVEL ANALYSIS

Analysis and interpretation of the groundwater levels is primarily based on data generated from eight level loggers deployed at four sites. Supplementary precipitation and temperature data from Environment Canada were also used to identify potential intra and inter-site groundwater-precipitation-temperature relationships and variability, with the focus on the HED category 1 habitat area.

With respect to groundwater levels, temperature, and precipitation, the analysis focussed largely on correlation measures in order to determine the relationships between the deep and shallow wells at one location and also between the four sites. Specifically, correlation coefficient (R) was used to determine the linear relationship between two variables. The value of R ranges from -1 to +1. A positive correlation exists when the value of x and y
increase simultaneously. A negative correlation exists when the x value increases while the y value decreases. There is no correlation or a weak linear correlation when R is equal or close to zero.

3.1 Groundwater Levels

The Minesing Wetlands study area is characterized as having the water table generally at ground surface, regardless of the ecohydrological regime (Table 4). The one exception is T6-11, where the water table is roughly 50cm below ground surface. It is noted that the HED category 1 habitat is marked by static water levels above ground surface (e.g. standing water present). The 2014 average manual static water measurements are similar for a given site, suggesting that groundwater flow is predominantly lateral, although 2014 was considered an above average precipitation year.

The continuous groundwater levels from the sites with automated level loggers exhibited broadly similar trends with respect to precipitation-based events and longer-term monthly trends (e.g. a distinct rise in groundwater levels following the June 17th precipitation event and fairly stable in the September-November period). The water level fluctuation range during the period of monitoring is 15-20cm for individual wells (Figure 5).

The average daily groundwater levels were calculated for the deep and shallow wells to determine the inter- and intra-correlation between and within sites for the 4 well locations (Figure 6; Table 5). The water levels within each site and also between the four sites have a strong positive correlation. The lowest correlation corresponds to a R value of 0.884 between T6-4_S and T6-3A_13_S. Location T6-3B_13 and T6-5A_13 have the strongest relationship. This suggests that the groundwater in the organic peat unit responds as a single hydrogeological unit.

The Pinegrove well, screen in a confined aquifer in the recharge area, displays a typical groundwater hydrograph for the water year. Although only recorded for part of the annual cycle, water levels are highest in May and gradually decreasing to October. As part of ongoing monitoring, the level logger will be deployed year round to obtain a complete annual hydrograph.

Table 4: 2014 average static water level measurements.

<table>
<thead>
<tr>
<th>Transect</th>
<th>Well</th>
<th>Average static water level (mbgs)</th>
<th>Wetland Hydrological System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transect</td>
<td>T3-1_S</td>
<td>0.063</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-1A_13_D</td>
<td>-0.010</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-1A_13_S</td>
<td>-0.045</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-2_D</td>
<td>0.166</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-2_S</td>
<td>-0.179</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-2A_13_D</td>
<td>0.093</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-2A_13_S</td>
<td>0.023</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-3_D</td>
<td>-0.020</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-3_S</td>
<td>-0.012</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-4_D</td>
<td>0.049</td>
<td>flow-through system</td>
</tr>
<tr>
<td>Transect</td>
<td>T3-4_S</td>
<td>0.039</td>
<td>flow-through system</td>
</tr>
</tbody>
</table>
Averaged groundwater elevations recorded on September 15, 2014 at each site were contoured to determine the groundwater flow direction (Figure 6). The September 15, 2014 data was selected for the plot as it corresponds to the water quality sampling date. The flow direction follows the regional topography, sloping to the west towards the Nottawasaga River from the Snow Valley Uplands. The discharge front wetland system exhibits a topographic gradient of 4m over roughly 400m whereas the flow through wetland system and the graminoid fen is regarded as flat. Along the T3 and T6 transects, the groundwater gradients were largely horizontal as indicated by Bradford (1999), with minimal downward gradient (Table 4).

<table>
<thead>
<tr>
<th>Transect</th>
<th>Well</th>
<th>Average static water level (mbgs)</th>
<th>Wetland Hydrological System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transect T3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T3-5_P</td>
<td>0.115</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-5_S</td>
<td>0.088</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-6_13_D</td>
<td>-0.003</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-6_13_S</td>
<td>-0.055</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-7_13_D (7AP)</td>
<td>0.080</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-7_13_S (7BS)</td>
<td>0.075</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-8_P</td>
<td>0.090</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T3-8_S</td>
<td>0.100</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T3-9_S</td>
<td>0.066</td>
<td>discharge system</td>
</tr>
<tr>
<td>Transect T6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T3-9_P</td>
<td>0.090</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T3-9_S</td>
<td>0.066</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T3-10_P</td>
<td>-0.086</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T3-10_S</td>
<td>0.043</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T6-11_P</td>
<td>0.495</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-11_S</td>
<td>0.533</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-12_13</td>
<td>0.128</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-13_P</td>
<td>0.005</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-13_S</td>
<td>0.010</td>
<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-2_P</td>
<td>0.038</td>
<td>flow-through system</td>
</tr>
<tr>
<td></td>
<td>T6-3A_13_D</td>
<td>-0.015</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-3A_13_S</td>
<td>-0.032</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-3B_13_D</td>
<td>-0.201</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-3B_13_S</td>
<td>-0.059</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-4_P</td>
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<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-4_S</td>
<td>0.042</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-5A_13_D</td>
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<td>Graminoid Fen</td>
</tr>
<tr>
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<td>T6-5A_13_S</td>
<td>0.024</td>
<td>Graminoid Fen</td>
</tr>
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<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-5B_13_S</td>
<td>-0.100</td>
<td>Graminoid Fen</td>
</tr>
<tr>
<td></td>
<td>T6-7_P</td>
<td>0.108</td>
<td>discharge system</td>
</tr>
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<td>T6-7_S</td>
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<td>T6-9_P</td>
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<td>discharge system</td>
</tr>
<tr>
<td></td>
<td>T6-9_S</td>
<td>0.088</td>
<td>discharge system</td>
</tr>
</tbody>
</table>

"
Figure 5: Groundwater level hydrographs for the period of May 27, 2014 to November 11, 2014.
Figure 5 cont’d: Groundwater level hydrographs for the period of May 27, 2014 to November 11, 2014.
Figure 5 cont’d: Groundwater level hydrographs for the period of May 27, 2014 to November 11, 2014.

Table 5: Averaged daily groundwater level correlation results (R-value) between the four well locations.

<table>
<thead>
<tr>
<th></th>
<th>T6-3A_13_D</th>
<th>T6-3A_13_S</th>
<th>T6-3B_13_D</th>
<th>T6-3B_13_S</th>
<th>T6-4_D</th>
<th>T6-5A_13_D</th>
<th>T6-5A_13_S</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6-3A_13_D</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-3A_13_S</td>
<td>0.976</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-3B_13_D</td>
<td>0.969</td>
<td>0.944</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-3B_13_S</td>
<td>0.964</td>
<td>0.919</td>
<td>0.975</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-4_D</td>
<td>0.949</td>
<td>0.930</td>
<td>0.958</td>
<td>0.942</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-4_S</td>
<td>0.928</td>
<td>0.884</td>
<td>0.927</td>
<td>0.949</td>
<td>0.98</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>T6-5A_13_D</td>
<td>0.956</td>
<td>0.891</td>
<td>0.952</td>
<td>0.971</td>
<td>0.92</td>
<td>0.93</td>
<td>8</td>
</tr>
<tr>
<td>T6-5A_13_S</td>
<td>0.965</td>
<td>0.965</td>
<td>0.971</td>
<td>0.936</td>
<td>0.95</td>
<td>0.91</td>
<td>1</td>
</tr>
</tbody>
</table>
Figure 6: Groundwater flow direction based on the averaged groundwater elevations per site as recorded on September 15, 2014. The contours are in metres above sea level.

3.2 GROUNDWATER LEVELS AND PRECIPITATION

Environment Canada daily total precipitation data was downloaded from the Barrie-Oro weather station. Although time lag was not analyzed in this study, the hydrograph in Figure 7 illustrates the groundwater levels increase 1 to 2 days after a rain event (e.g. June 17, 2014). The continuous logger data exhibited a moderate to strong correlation to precipitation events in the summer months when evapotranspiration is the highest and a weak correlation to precipitation events in the fall months when evapotranspiration effects are reduced. Further, both shallow and deep wells exhibit the same hydrograph profile response to precipitation events, suggesting that, similar to the temperature stratigraphic profile, the peat unit reacts as a single hydrostratigraphic unit.

3.3 GROUNDWATER TEMPERATURE

A correlation analysis was undertaken to determine the relationship between the temperature of the deep and shallow wells from the same location in order to define the thermal groundwater characteristics of the graminoid fen and the upgradient site (Figure 8). As shown on Table 6, all wells demonstrate a strong positive correlation. The temperature
between the deep and shallow wells changes simultaneously. Well T6-4 had the strongest relationship of 0.993 and also has the greatest depth difference of 1.44 m between the screen of deep and shallow well. This strongly suggests that the temperature profile of the organic peat unit acts homogenous with very little thermal stratigraphic variation.

Figure 7: Groundwater level and precipitation profile.
Figure 8: Groundwater temperature profiles for both shallow (red) and deep (blue) wells for the period of May 27, 2014 to November 11, 2014.
Figure 8 cont’d: Groundwater temperature profiles for both shallow (red) and deep (blue) wells for the period of May 27, 2014 to November 11, 2014.
Table 6: Correlation results for temperature between deep and shallow wells.

<table>
<thead>
<tr>
<th>Monitoring Well</th>
<th>Correlation Coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6-3A_13</td>
<td>0.957</td>
</tr>
<tr>
<td>T6-3B_13</td>
<td>0.951</td>
</tr>
<tr>
<td>T6-4</td>
<td>0.993</td>
</tr>
<tr>
<td>T6-5A_13</td>
<td>0.992</td>
</tr>
</tbody>
</table>

### 3.4 Groundwater Temperature and Air Temperature

Groundwater temperature was compared against the air temperature from the barologger. The daily average was taken from both variables to determine the correlation (Table 7). The air temperature recorded from May 27, 2014 to November 11, 2014 ranges from -0.95 ºC to 26.09 ºC. Not surprisingly, the Pinegrove well, which is approximately 24 m deep, has the weakest relationship between groundwater and air temperature. The Pinegrove well maintained the groundwater temperature between 8.7 ºC to 8.8 ºC at approximately 12 m below the ground surface and corresponds to typical deeper groundwater temperatures in the area. The rest of the wells have a moderate to high positive correlation between groundwater and air temperature. The level loggers in the graminoid fen area were deployed approximately 0.5 m below the ground surface; therefore the correlation is expected to be positive. The average groundwater temperature follows the same pattern as the air temperature (Figure 9). This positive, moderate to high correlation indicates that shallow wetland groundwater temperature is influenced by air temperature and follows the same seasonal trends, although the response of groundwater temperature to shorter-term fluctuations in air temperature is dampened. This is further supported by the typical groundwater temperature in the graminoid fen of approximately 15-17ºC), which is considerably higher than the Pinegrove well (8.7 ºC to 8.8 ºC).

Table 7: Correlation between daily groundwater temperature and air temperature.

<table>
<thead>
<tr>
<th>Monitoring Well</th>
<th>Correlation Coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T6-3A_13_Deep</td>
<td>0.628</td>
</tr>
<tr>
<td>T6-3A_13_Shallow</td>
<td>0.752</td>
</tr>
<tr>
<td>T6-3B_13_Deep</td>
<td>0.575</td>
</tr>
<tr>
<td>T6-3B_13_Shallow</td>
<td>0.737</td>
</tr>
<tr>
<td>T6-4_Deep</td>
<td>0.698</td>
</tr>
<tr>
<td>T6-4_Shallow</td>
<td>0.742</td>
</tr>
<tr>
<td>T6-5A_13_Deep</td>
<td>0.567</td>
</tr>
<tr>
<td>T6-5A_13_Shallow</td>
<td>0.617</td>
</tr>
<tr>
<td>A160056 (Pinegrove)</td>
<td>-0.561</td>
</tr>
</tbody>
</table>
Figure 9: Composite groundwater temperature profiles (red) vs the air temperature profile (blue) for the period of May 27, 2014 to November 11, 2014.
Figure 9 cont’d: Composite groundwater temperature profiles (red) vs the air temperature profile (blue) for the period of May 27, 2014 to November 11, 2014.
Figure 9 cont’d: Composite groundwater temperature profiles (red) vs the air temperature profile (blue) for the period of May 27, 2014 to November 11, 2014.
Figure 9 cont’d: Composite groundwater temperature profiles (red) vs the air temperature profile (blue) for the period of May 27, 2014 to November 11, 2014.
4.0 GEOCHEMISTRY ANALYSIS

The objectives of the geochemical analysis were to: 1) characterize the groundwater chemistry in the eastern portion of the wetlands in addition to the upgradient recharge area, 2) determine the geochemical signature of the HED category 1 habitat area, 3) provide indicators of anthropogenic impact (e.g. road salts and nutrients), and 4) complete a comparative analysis to previous hydrogeochemical work completed by Bradford (1999).

The Minesing Wetlands groundwater quality dataset is comprised from 4 sampling events: July 20 & 21, 1998 (Bradford, 1999), October 14, 19, and 20, 2010 (Spoelstra and Post, 2012), November 11, 2013 (this study), and September 15, 2014 (this study). It is noted that the 2010, 2013, and 2014 sampling and analysis was completed by Environment Canada and the NVCA. Table 8 outlines the parameters analyzed for each study.

The 2010, 2013, and 2014 sampling events were conducted during a period of minimal precipitation to minimize surface water runoff effects in the wetlands during groundwater sampling. Due to the fall sampling period and associated lowered evapotranspiration rates, the peat pore water may have been less concentrated than at other times of the year. Water levels in each well were first measured with a Solinst water level tape. Prior to the collection of samples for analysis, the wells were purged in excess of three well volumes using a manual Waterra foot valve pump. Each well was sampled for anions, cations, anionic herbicides, soluble reactive phosphorus (SRP) and ammonium (NH₄⁺), following filtration with a Waterra FHT–groundwater filter (0.45μm). Depending on the specific parameter, samples were store either refrigerated or frozen until analysis. Additional details on the specific methods used for the 2013 and 2014 sampling campaigns are given below.

4.1 ANALYTICAL METHODS

Chemical analyses were conducted at the lab facilities of the Groundwater Section of Environment Canada at the Canada Centre for Inland Waters, Burlington, Ontario.

Anions: Sub-samples for anions (fluoride, chloride, bromide, nitrite, nitrate, sulfate, phosphate) were filtered to 0.45μm and refrigerated until analysis. Analysis of anionic species was conducted using a Dionex 2500 ion chromatograph. Sample concentrations were calibrated against multi-ion standards that were analyzed with the samples. When necessary, samples were diluted with Milli-Q water to bring their concentration within the working range of the standards.

Cations: Sub-samples for cations (calcium, magnesium, sodium, potassium, iron) were filtered to 0.45μm and acidified with nitric acid prior to being refrigerated until analysis. Cation concentrations were determined by inductively coupled plasma-atomic emission spectroscopy using a HoribaJobinYvonUltima 2 ICP. Sample concentrations were calibrated against multi-ion standards that were analyzed with the samples. When necessary, samples were diluted with Milli-Q water to bring their concentration within the working range of the standards.

Ammonium: Sub-samples for ammonium analysis were filtered to 0.45μm and acidified with hydrochloric acid to a pH of approximately 5-6 and stored frozen until analysis. Ammonium concentrations were determined using a colorimetric method (Salicylate-Nitroprusside) by measuring absorbance at 640nm on a Beckman-Coulter DU720 UV/visible spectrophotometer. Sample values were calibrated against multiple ammonium standards that were analyzed with the samples. When necessary, samples were diluted with Milli-Q water to bring their concentration within the working range of the standards.
Anionic Herbicides: For the 2010 and 2013 campaigns, samples were re-filtered (0.45μm) and analyzed for select anionic herbicides (glyphosate, AMPA, 2,4-D, glufosinate, fosamine, MCPA and picloram) using suppressed ion chromatography (IC) coupled to atandem mass spectrometer (MS/MS). Separation was performed using a Dionex (Sunnyvale, CA, USA) 2500 IC system on a Dionex IONPAC® AS20 analytical column (2 x 250 mm). The IC was interfaced to an AB Sciex 5500 QTrap MS/MS (Concord, ON, Canada), and operated in the negative electrospray ionization (ESI) mode. Isotope labelled compounds were used as an internal standard's to account for matrix effects. Since the analysis of the 2010 samples, the IC-MS/MS method has upgraded on an ongoing basis to improve detection limits. These changes included pre-filtering to 0.22μm, separation using a Thermo Fisher (Waltham, MA, USA) Dionex ICS 5000 system, and ion suppression using a Dionex AERS 500 2mm instead of a Dionex ASRS 300 2mm. As a result, the detection limits and specific herbicides analyzed are slightly different for the various sampling campaigns.

Alkalinity: Alkalinity, expressed as the concentration of bicarbonate (HCO$_3^-$), was determined by titration using a Hach Alkalinity Test Kit (Model AL-DT).

Soluble Reactive Phosphorus: Sub-samples for SRP were field filtered to 0.45μm and refrigerated until analysis within 48 hours or less. SRP concentrations were determined using an orthophosphate colourometric technique, measuring the absorbance at 885nm using a 10cm path length cuvette on a Thermo Scientific Evolution 201 UV-visible Spectrophotometer. Sample values were calibrated against multiple SRP standards that were analyzed with the samples. When necessary, samples were diluted with Milli-Q water to bring their concentration within the working range of the standards.
**Table 8: Water quality parameters reported for each sampling campaign.**

<table>
<thead>
<tr>
<th>Jul-1998</th>
<th>Oct-2010, Nov-2013, Sep-2014*</th>
</tr>
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<tbody>
<tr>
<td>Bradford</td>
<td>NVCA and Environment Canada</td>
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<table>
<thead>
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<th></th>
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</thead>
<tbody>
<tr>
<td>Conductivity</td>
<td>pH</td>
<td>Ca</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ca</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F$^-$</td>
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</table>

*Notes: 2010 - SRP, Alk, Mn not analyzed; 2013 - Fosamine not analyzed; 2014 - AMPA and Glufosinate not analyzed.
### 4.2 Results

Table 9: Major cation chemistry for samples collected in Nov 2013. The minimum detection limit (mdl) for each parameter is given at the bottom of the table. "j" indicates that the value is greater than the mdl but less than the practical quantification limit.

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Date</th>
<th>Calcium (mg/L)</th>
<th>Magnesium (mg/L)</th>
<th>Potassium (mg/L)</th>
<th>Sodium (mg/L)</th>
<th>Ammonium (mg N/L)</th>
<th>Iron (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3-1-S</td>
<td>11-Nov-13</td>
<td>42.71</td>
<td>8.68</td>
<td>0.35</td>
<td>6.34</td>
<td>0.28</td>
<td>1.32</td>
</tr>
<tr>
<td>T3-1_13_D</td>
<td>11-Nov-13</td>
<td>68.14</td>
<td>10.87</td>
<td>0.52</td>
<td>8.38</td>
<td>1.45</td>
<td>0.44</td>
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<td>9.66</td>
<td>0.28</td>
<td>6.54</td>
<td>0.24</td>
<td>1.23</td>
</tr>
<tr>
<td>T3-2A_13_D</td>
<td>11-Nov-13</td>
<td>62.53</td>
<td>10.16</td>
<td>0.71</td>
<td>7.55</td>
<td>1.01</td>
<td>0.46</td>
</tr>
<tr>
<td>T3-2A_13_S</td>
<td>11-Nov-13</td>
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<td>6.39</td>
<td>0.36</td>
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</tr>
<tr>
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<td>9.40</td>
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<td>0.10j</td>
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<tr>
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<td>0.07j</td>
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<th>Parameter</th>
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</tr>
<tr>
<td>Potassium</td>
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</tr>
<tr>
<td>Sodium</td>
<td>0.08</td>
</tr>
<tr>
<td>Ammonium</td>
<td>0.10</td>
</tr>
<tr>
<td>Iron</td>
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</tr>
</tbody>
</table>
Table 10: Major cation chemistry for samples collected in Sep 2014. The minimum detection limit (mdl) for each parameter is given at the bottom of the table. "j" indicates that the value is greater than the mdl but less than the practical quantification limit.

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Date</th>
<th>Calcium (mg/L)</th>
<th>Magnesium (mg/L)</th>
<th>Potassium (mg/L)</th>
<th>Sodium (mg/L)</th>
<th>Ammonium (mg N/L)</th>
<th>Iron (mg/L)</th>
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</thead>
<tbody>
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<td>8.97</td>
<td>0.64</td>
<td>7.22</td>
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<td>1.04</td>
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<td>47.52</td>
<td>9.14</td>
<td>0.66</td>
<td>6.28</td>
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<td>7.91</td>
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<td>6.66</td>
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<td>0.90</td>
<td>6.06</td>
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<td>0.12</td>
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<td>T3-7_13_S</td>
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<td>10.24</td>
<td>1.07</td>
<td>6.39</td>
<td>0.12</td>
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<td>8.16</td>
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<td>4.17</td>
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<td>0.21</td>
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<td>9.11</td>
<td>0.72</td>
<td>4.79</td>
<td>0.26</td>
<td>0.02j</td>
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<td>15-Sep-14</td>
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<td>8.19</td>
<td>0.65</td>
<td>5.36</td>
<td>0.95</td>
<td>1.17</td>
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Table 11: Major anion chemistry and SRP for samples collected in Nov 2013. The minimum detection limit (mdl) for each parameter is given at the bottom of the table. "<" indicates that the value is greater than the mdl but less than the practical quantification limit.

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<th>Well ID</th>
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<th>Sulfate mg/L</th>
<th>Nitrate mg N/L</th>
<th>Fluoride mg/L</th>
<th>Bromide mg N/L</th>
<th>Nitrite mg N/L</th>
<th>SRP µg/L</th>
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<td>&lt;0.02</td>
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| mdl        | 0.01        | 0.05         | 0.016        | 0.004         | 0.02          | 0.003         | 2        |
Table 12: Major anion chemistry and SRP for samples collected in Sep 2014. The minimum detection limit (mdl) for each parameter is given at the bottom of the table. "j" indicates that the value is greater than the mdl but less than the practical quantification limit.

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<th>Nitrate mg N/L</th>
<th>Fluoride mg/L</th>
<th>Bromide mg/L</th>
<th>Nitrite mg N/L</th>
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<td>0.37</td>
<td>&lt;0.016</td>
<td>0.09</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>37</td>
</tr>
<tr>
<td>T3-4-S</td>
<td>15-Sep-14</td>
<td>3.16</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>28</td>
</tr>
<tr>
<td>T3-5-P</td>
<td>15-Sep-14</td>
<td>4.61</td>
<td>0.40</td>
<td>0.082</td>
<td>0.09</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>40</td>
</tr>
<tr>
<td>T3-5-S</td>
<td>15-Sep-14</td>
<td>3.22</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>21</td>
</tr>
<tr>
<td>T3-6_13_D</td>
<td>15-Sep-14</td>
<td>2.62</td>
<td>0.62</td>
<td>0.523</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>123</td>
</tr>
<tr>
<td>T3-6_13_S</td>
<td>15-Sep-14</td>
<td>2.97</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.09</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>70</td>
</tr>
<tr>
<td>T3-7_13_D</td>
<td>15-Sep-14</td>
<td>3.82</td>
<td>0.68</td>
<td>0.073</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>33</td>
</tr>
<tr>
<td>T3-7_13_S</td>
<td>15-Sep-14</td>
<td>3.95</td>
<td>0.42</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>41</td>
</tr>
<tr>
<td>T3-8-P</td>
<td>15-Sep-14</td>
<td>2.76</td>
<td>28.20</td>
<td>0.067</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>34</td>
</tr>
<tr>
<td>T3-8-S</td>
<td>15-Sep-14</td>
<td>2.40</td>
<td>0.43</td>
<td>&lt;0.016</td>
<td>0.09</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>50</td>
</tr>
<tr>
<td>T3-9-S</td>
<td>15-Sep-14</td>
<td>2.48</td>
<td>0.42</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>60</td>
</tr>
<tr>
<td>T6-1-P</td>
<td>15-Sep-14</td>
<td>2.55</td>
<td>0.39</td>
<td>0.066</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>19</td>
</tr>
<tr>
<td>T6-1-S</td>
<td>15-Sep-14</td>
<td>2.79</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>21</td>
</tr>
<tr>
<td>T6-2-P</td>
<td>15-Sep-14</td>
<td>3.32</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.09</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>48</td>
</tr>
<tr>
<td>T6-3A_13_D</td>
<td>15-Sep-14</td>
<td>2.65</td>
<td>&lt;0.05</td>
<td>&lt;0.016</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>18</td>
</tr>
<tr>
<td>T6-3A_13_S</td>
<td>15-Sep-14</td>
<td>2.79</td>
<td>0.35</td>
<td>&lt;0.016</td>
<td>0.06</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>18</td>
</tr>
<tr>
<td>T6-3B_13_D</td>
<td>15-Sep-14</td>
<td>2.78</td>
<td>0.35</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>22</td>
</tr>
<tr>
<td>T6-3B_13_S</td>
<td>15-Sep-14</td>
<td>2.53</td>
<td>0.37</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>22</td>
</tr>
<tr>
<td>T6-4-P</td>
<td>15-Sep-14</td>
<td>3.51</td>
<td>&lt;0.05</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>32</td>
</tr>
<tr>
<td>T6-4-S</td>
<td>15-Sep-14</td>
<td>2.94</td>
<td>0.38</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>22</td>
</tr>
<tr>
<td>T6-5A_13_D</td>
<td>15-Sep-14</td>
<td>3.12</td>
<td>0.35</td>
<td>&lt;0.016</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>25</td>
</tr>
<tr>
<td>T6-5A_13_S</td>
<td>15-Sep-14</td>
<td>3.21</td>
<td>&lt;0.05</td>
<td>&lt;0.016</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>26</td>
</tr>
<tr>
<td>T6-5B_13_D</td>
<td>15-Sep-14</td>
<td>4.98</td>
<td>0.35</td>
<td>0.135</td>
<td>0.10</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>49</td>
</tr>
<tr>
<td>T6-5B_13_S</td>
<td>15-Sep-14</td>
<td>2.90</td>
<td>0.45</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>20</td>
</tr>
<tr>
<td>T6-7-P</td>
<td>15-Sep-14</td>
<td>3.95</td>
<td>0.36</td>
<td>&lt;0.016</td>
<td>0.08</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>52</td>
</tr>
<tr>
<td>T6-7-S</td>
<td>15-Sep-14</td>
<td>3.93</td>
<td>0.64</td>
<td>&lt;0.016</td>
<td>0.07</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>87</td>
</tr>
<tr>
<td>T6-9-P</td>
<td>15-Sep-14</td>
<td>10.92</td>
<td>0.42</td>
<td>&lt;0.016</td>
<td>0.21</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>32</td>
</tr>
<tr>
<td>T6-9-S</td>
<td>15-Sep-14</td>
<td>3.34</td>
<td>9.21</td>
<td>&lt;0.016</td>
<td>0.11</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>26</td>
</tr>
<tr>
<td>T6-10_S</td>
<td>15-Sep-14</td>
<td>3.36</td>
<td>1.97</td>
<td>0.083</td>
<td>0.10</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>26</td>
</tr>
<tr>
<td>T6-12_13</td>
<td>15-Sep-14</td>
<td>4.46</td>
<td>0.64</td>
<td>&lt;0.016</td>
<td>0.13</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>49</td>
</tr>
<tr>
<td>T6-13-P</td>
<td>15-Sep-14</td>
<td>1.68</td>
<td>0.36</td>
<td>0.080</td>
<td>0.10</td>
<td>&lt;0.02</td>
<td>&lt;0.003</td>
<td>57</td>
</tr>
<tr>
<td>T6-13-S</td>
<td>15-Sep-14</td>
<td>2.21</td>
<td>4.83</td>
<td>0.620</td>
<td>0.13</td>
<td>9.844</td>
<td>0.054</td>
<td>34</td>
</tr>
</tbody>
</table>

mdl
0.01 0.05 0.016 0.004 0.02 0.003 2
Table 13: Anionic herbicide concentrations for samples collected in Nov 2013. The minimum detection limit (mdl) is given at the bottom of the table. “j” indicates that the value is greater than the mdl but less than the practical quantification limit.

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Date</th>
<th>Glyphosate</th>
<th>AMPA</th>
<th>2,4-D</th>
<th>Glufosinate</th>
<th>Fosamine</th>
<th>MCPA</th>
<th>Picloram</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3-6-S</td>
<td>11-Nov-13</td>
<td>14.6</td>
<td>2j</td>
<td>n.d.</td>
<td>15.9</td>
<td>n.d.</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>T6-9-S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-10_S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-13-P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-13-S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

mdl 2 2 3 3 2 25
Table 14: Anionic herbicide concentrations for samples collected in Sep 2014. The minimum detection limit (mdl) is given at the bottom of the table. "j" indicates that the value is greater than the mdl but less than the practical quantification limit.

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Date</th>
<th>Glyphosate</th>
<th>AMPA</th>
<th>2,4-D</th>
<th>Glufosinate</th>
<th>Fosamine</th>
<th>MCPA</th>
<th>Picloram</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3-1_13_D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T3-1_13_S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

mdl  2  3  2  2  25
4.3 DISCUSSION

The groundwater chemistry results from the four sampling events (1998, 2010, 2013, and 2014) are similar (Figures 10 and 11). The wetland groundwater exhibits relatively low total ion concentrations. The dominant cation present is calcium while bicarbonate is the dominant anion present (measured as alkalinity in 2013 and 2014).

Nutrient concentrations were low in groundwater from the eastern portion of the Minesing Wetlands (Tables 9-12). Nitrate was below the detection limit (<0.016 mg N/L) for all samples in 2013 except T3-4-P (0.142 mg/L) and T6-12-13 (89.572 mg/L). In 2014, nitrate was observed in 11 samples with a maximum concentration of 0.620 mg/L (T6-13-S). It is noted that Bradford (1999) did not find nitrate for any of the locations sampled in the current study. Wetlands are hot spots for denitrification and therefore the presence of nitrate in the shallow groundwater may be highly episodic. Drought periods that decrease water levels promote oxidation of wetland organic matter and the mineralization of organic nitrogen to NH$_4^+$ and its subsequent nitrification to nitrate. However, once water tables rise again to saturate the organic matter, anaerobic conditions rapidly develop and nitrate is consumed by denitrification. As such, the timing of sampling (e.g. summer vs. fall) could be a controlling factor of whether or not nitrate is detected in Minesing Wetlands groundwater. Greater plant uptake of nitrate in the summer or early fall (i.e. prior to senescence) could also contribute to seasonal differences in groundwater nitrate concentrations.

Wetlands tend to accumulate organic matter due to the production of detrital material from biota and relatively low rates of decomposition under flooded conditions (DeBusk and Reddy, 1998). Phosphorus (P) retention by wetlands may include surface adsorption on soil minerals (Zurayk et al., 1997), precipitation as a mineral (Reddy et al., 1987), microbial immobilization (Newbold et al., 1983), and plant uptake (Reddy et al., 1995). Soluble reactive phosphorus approximates the amount of orthophosphate that is directly available for use by plants. SRP is present in all samples (Tables 11 and 12) with a maximum value of 122.9 µg/L (T3-9-13_D).
Figure 10: Comparison of Minesing Wetland groundwater cation chemistry data from Bradford (1999; green, "a"), Spoelstra and Post (2012; blue, "b"), 2013 results (purple, "c"), and 2014 results (orange, "d") for the T3 and T6 transects. Box-and-whisker plots display the distribution of the data set including the minimum value, lower quartile (25th percentile), median, upper quartile (75th percentile), and the maximum value. Due to differences in the detection limits, only value >mdl are factored into these box plots.

Figure 11: Comparison of Minesing Wetland groundwater anion chemistry data from Bradford (1999; green, "a"), Spoelstra and Post (2012; blue, "b"), 2013 results (purple, "c"), and 2014 results (orange, "d") for the T3 and T6 transects. Box-and-whisker plots display the distribution of the data set including the minimum value, lower quartile (25th percentile), median, upper quartile (75th percentile), and the maximum value. Due to differences in the detection limits, only value >mdl are factored into these box plots.
Based on the ecohydrological characteristics, the groundwater component of the Minesing Wetlands is divided into the graminoid fen (also the HED category 1 habitat), the discharge system, and the flow-through system; in addition to the up gradient recharge area. Table 15 outlines the averaged major cations and anions for wells (both shallow and deep) located in these specified areas. Groundwater sodium and chloride concentrations were higher in the discharge wetland system relative to the upgradient recharge area, which may indicate a small anthropogenic influence. A similar effect could also be caused by natural variations in discharging groundwater chemistry or evapo-concentration of solutes in some areas. Further, the graminoid fen has the lowest Mg, and \( \text{SO}_4^{2-} \) values of the defined area excluding the recharge area \((n=1)\) and is characterized as a calcium dominated unit. However, all values are comparable with respect to each other except for \( \text{SO}_4^{2-} \). Based on the chemical parameters analyzed to date, there is not a unique geochemical signature that distinguishes the graminoid fen from the other units.

Table 15: Mean concentrations for select groundwater quality parameters in the four main wetland hydrological units: recharge area, graminoid fen, discharge wetland system and the flow through wetland system. The standard deviation of the mean is shown in brackets. Note the <mdl values were included in the calculation.

<table>
<thead>
<tr>
<th>Area</th>
<th>Wells</th>
<th>Averaged Parameters (mg/L)</th>
<th>Number of Samples</th>
<th>Average (mg/L)</th>
<th>Average (mg/L)</th>
<th>Average (mg/L)</th>
<th>Average (mg/L)</th>
<th>Average (mg/L)</th>
<th>Number of Samples</th>
<th>Average (mg/L)</th>
<th>Number of Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recharge area</td>
<td>Pinegrove well</td>
<td>Ca</td>
<td>1</td>
<td>82.86</td>
<td>11.66</td>
<td>2.73</td>
<td>2.74</td>
<td></td>
<td>1</td>
<td>12.59</td>
<td>1</td>
</tr>
<tr>
<td>Graminoid fen (HED category 1 habitat)</td>
<td>T6-3A_13, T6-3B_13, T6-4, T6-5A_13, T6-5B_13</td>
<td>Mg</td>
<td>24</td>
<td>61.88 (11.26)</td>
<td>9.61 (1.43)</td>
<td>5.23 (1.41)</td>
<td>3.33 (0.92)</td>
<td></td>
<td>0.45 (0.30)</td>
<td>3.18 (5.96)</td>
<td>23</td>
</tr>
<tr>
<td>Discharge wetland system</td>
<td>T6-7, T6-9, T6-10, T6-11, T6-12_13, T6-13, T3-8, T3-9</td>
<td>Na</td>
<td>35</td>
<td>60.53 (27.15)</td>
<td>12.37 (3.13)</td>
<td>9.49 (6.92)</td>
<td>4.25 (3.16)</td>
<td></td>
<td>3.18 (5.96)</td>
<td>1.09 (4.01)</td>
<td>48</td>
</tr>
<tr>
<td>Flow through wetland system</td>
<td>T6-1, T6-2, T3-1, T3-1A_13, T3-2, T3-2A_13, T3-3, T3-4, T3-5, T3-6_13, T3-7_13</td>
<td>Cl</td>
<td>62</td>
<td>56.63 (9.10)</td>
<td>9.82 (1.70)</td>
<td>6.71 (1.43)</td>
<td>3.16 (0.97)</td>
<td></td>
<td>1.09 (4.01)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although there was not a large range in concentrations for many of the parameters measured, some general spatial trends were observed. As groundwater discharging through wetland sediments gets closer to the surface, it is more likely to be mixed with wetland surface water and meteoric waters, as well as influenced by physical, biological and chemical processes occurring in the wetland sediments. Therefore, in order to identify areas where upland groundwater discharge has a higher impact on wetland groundwater chemistry, the deeper “P” and “D 2013” samples were used at each location to generate the spatial plots, similar to the approach used by Spoelstra and Post (2012; Figures 12-17). Due to the chemical composition of aquifer materials in the area surrounding the Minesing Wetlands, upland groundwater exhibits higher concentrations of calcium; however, it is
noted that this is based on one sample and is not statistically significant. Further, the spatial plots indicate that the average Ca concentrations are highest in the graminoid fen/HED habitat. This is consistent with HED restricted throughout its range to calcareous wetlands (marshes, sedge meadows and fens) dominated by graminoid vegetation in groundwater-fed wetlands such as fens.

One potential source of elevated Na and Cl in groundwater and surface runoff is the application of road salt for de-icing; however it may also be sourced naturally from deeper groundwater. Two sites in particular have higher Na concentrations compared to the rest of the samples: T6-9-P (24.58 mg/L (2013) and 23.70 mg/L (2014)) and T6-12_13 (10.88 mg/L (2013) and 12.31 mg/L (2014)) and chloride values (T6-9-P: 11.74 mg/L (2013) and 10.92 mg/L (2014) and T6-12_13: 5.80 mg/L (2013) and 4.46 mg/L (2014)). The fact that both Na and Cl are elevated in T6-9-P and T6-12_13 and the proximity of these two sites to Pinegrove Road provides a line of evidence for a possible small NaCl (e.g. road salt) influence on the groundwater collected at these locations. It should be noted that Na and Cl concentrations at are still quite low compared to other ground waters known to be contaminated by road salt (e.g. Meriano et al., 1999; Williams et al., 1999; Howard and Maier, 2007). Sodium and chloride levels in the HED category 1 habitat/graminoid fen (e.g. sites T6-3A_13, T6-3B_13, T6-5B_13, and T6-4) are considered as background wetland levels, except for T6-5B_13_D, which is slightly elevated but still well below the Provincial Water Quality Objectives for Na and Cl.

Figure 12: Averaged sodium concentrations in groundwater collected from the "P" series piezometers and "D 2013" wells at each sampling location.
Figure 13: Average chloride concentrations in groundwater collected from the "P" series piezometers and "D 2013" wells at each sampling location.

Figure 14: Average calcium concentrations in groundwater collected from the "P" series piezometers and "D 2013" wells at each sampling location.
Figure 15: Averaged magnesium concentrations in groundwater collected from the "P" series piezometers and "D 2013" wells at each sampling location.

Figure 16: 2013 glufosinate concentrations in groundwater collected from the "P" series piezometers and "D 2013" wells at each sampling location.
An additional indication of anthropogenic impacts to the groundwater chemistry is the presence of anionic herbicides. Of the seven herbicides screened for in the 2013/2014 groundwater samples, only glyphosate (Roundup), AMPA (breakdown product of glyphosate), and glufosinate were detected, and these concentrations were well below water quality guidelines (Tables 13 and 14). Based on the 2013 data, glufosinate and glyphosate were the most prominent herbicides detected. Both are popular, non-selective herbicides and can kill both broadleaf and grass weeds and do not have significant soil residual activity; therefore, they can only kill emerged weeds. The Canadian Water Quality Guideline for the Protection of Aquatic Life for glyphosate is 65,000ng/L (Trotter et al., 1990).

It should be noted that, due to improvements in analytical methods, the minimum detection limits for the 2013 and 2014 herbicide analyses were at least three times more sensitive than for the 2010 data set published by Spoelstra and Post (2012). Method changes also resulted in glufosinate and AMPA no longer being part of the analysis suite for the 2014 data set.

The distribution and concentrations of glufosinate and glyphosate are not uniformly distributed per well stations (shallow vs deep) or spatially (Figures 16 and 17). Ten sampling points from 2013 had only glufosinate present, while seven sampling points only had glyphosate present, and ten sampling points had both herbicides present. The highest glufosinate values observed were 945.4 ng/L (T3-2A_13_D) and 113.4 ng/L (T6-1-P), which corresponds to the White Cedar-Conifer Organic Coniferous Swamp and Sweet Gale Shrub Fen, respectively. Both sites are located distal to any direct anthropogenic influences and therefore the transport mechanism seems likely to be the atmospheric deposition of...
herbicide aerosols or soil particles. AMPA was found at site T3-1_13_S (6.9 ng/L). Pesticides were detected near the discharge front (e.g. T6-9-P) however their distribution was not uniform. From the 2014 results, the only herbicide detected was a single detection of glyphosate at site T3-6-P (7.1 ng/L). Note that, for all sampling years, the herbicides detected were present at very low levels compared to water quality guidelines. Potential sources of glyphosate (and AMPA) and glufosinate include agricultural, domestic and roadside application.

Based on the 2013 results, glufosinate and/or glyphosate is present in the graminoid fen e.g. sites T6-3A_13, T6-3B_13, T6-5B_13 except at site T6-4, which is situated in the middle of this narrow unit.

5.0 RECHARGE AREA DELINEATION AND RECHARGE RATES

Contributing recharge areas are geographical areas where precipitation and/or surface water enters the groundwater flow system, eventually be removed by discharge to surface water or pumping. Recharge areas are generally located in areas of elevated topography with permeable sand and gravel formations, often in areas of hummocky topography.

The NVCA retained Matrix Solutions to conduct a particle tracking exercise (both forward and reverse) to identify the contributing recharge areas to the discharge wetland ecohydrological zone, and by extension to the flow through system and graminoid fen. The report is located in Appendix 2. The calibrated groundwater model for the Barrie Tier Three Risk Assessment (AquaResources et al., 2013) was used to delineate recharge areas.

The hydrostratigraphic units underlying the study area are part of a regionally extensive and complex aquifer system. Four major sand and gravel aquifer units are identified in this system and are named, in order of depth, A1 to A4 (Golder Associates, 2004). The regional aquifer A2 is the principal source of groundwater to the eastern portion of the wetland complex (Beckers and Frind, 2001). Outcrops of A2 on the western margin of the Snow Valley Uplands result in the discharging springs and spring-fed creeks found in the discharge wetland system along the eastern edge of the wetland. Within the model, most of the discharge to the fen is from A2; aquifer A1 discharges to the headwaters of the streams.

The Snow Valley Uplands is the critical recharge area to the eastern part of the Minesing Wetlands (Beckers and Frind. 2001). Recharge originating from across the entire area of the Snow Valley Uplands was simulated to discharge from aquifer A2 to the eastern border of the wetland and corresponds to a 25-year time of travel capture zone. Based on the particle tracking results, the delineated recharge area within the 25 year travel-time zone covers approximately 18km², situated predominately in the upland area, and extends approximately 2-3 km southeast from the areas of interest across the upland area. Figure 18 has superimposed groundwater divides reflecting the deeper A2/A3 aquifer systems. It is noted that the relatively surficial A1 aquifer would likely be closer to the surface water flow divides.

The average recharge volumes are relatively high with an average of 307 mm/year; the delineated recharge area is comprised of variable vegetation, slope, and surface/subsurface soil conditions and thus the recharge rate within each recharge zone varies from 50mm to 350 mm/year (Figure 19). The recharge volume within the 25 yr zone accounts for approximately 67% and 89% of the discharge volume to the fen and Snow Valley area, respectively. The remainder is from beyond that travel time, or occurs within 30 days.
Land use in this area is dominated by row cropland (i.e. wheat, oats, barley, corn, soybean, etc) with deciduous or coniferous forests predominating on the flanks of the upland. Low density, rural residences in the area have private wells and septic systems (Figure 20). No agricultural irrigation systems or municipal water supplies are located in the delineated recharge area. A detailed description of the agricultural land management systems in the eastern Minesing Wetlands area is provided in Appendix 3. Several, short-headed watercourses prograde off the flanks of the uplands into the wetland and provide cold and cool water fisheries habitats.

Figure 18: Recharge/discharge areas for the groundwater dominated aspect of the Minesing Wetlands.
Figure 19: Recharge values for the recharge area, eastern Minesing Wetlands (Matrix Solutions, 2014).
Examination of the vegetation community type through Ecological Land Classification (ELC) was undertaken to determine the HED category 1 habitat characteristics and other possible HED habitat locations in the fen areas of the Minesing wetlands. Since vegetation communities in this area are strongly linked with hydrogeological regime, and both are determinant of HED habitat, potential identified relationships could provide further insight into preferred habitat for HED.

Vegetation community monitoring was undertaken on September 18 and 19, 2013 at each existing and new monitoring well station to qualitatively describe each community. See Appendix 4 for the detailed ELC summary. An approach consistent with the ELC (Lee et al., 1998), and wetland types consistent with those found in the Southern Ontario Wetland Evaluation System manual (MNR 2013) was used to describe vegetation communities at each existing monitoring well station on transects T3 and T6. The qualitative monitoring component consisted of a coarse inventory of vegetation. Mapped boundaries of the units were derived from previously existing mapping from previous ELC work done in Minesing Wetlands as a part of the Integrated Minesing Wetlands Monitoring Program (Post et al., 2010) and additional orthophotography interpretation. Boundaries were investigated on the
ground where transitions intersected with the two monitoring transects. Given time constraints, the area surveyed on the ground, and the time of year, the inventories should be considered a subset of vegetation present at each station with an emphasis on identifying the canopy cover composition (if present) and the most common/readily observable species in each layer. Wetland and fen/bog indicator species are noted where present.

The groundwater-dominated aspect of the Minesing Wetlands is subdivided into 3 ecohydrological units: discharge wetland system, flow-through wetland system, and graminoid fen. Based on the 2013 ELC mapping along the T3 and T6 transects, the groundwater discharge front is broadly characterized as an Organic Meadow Marsh-White Cedar-Conifer Organic Coniferous Swamp system with a slightly elevated/benched Fresh-Moist Sugar Maple Deciduous Forest that is marked by a depressed water table elevation (Figure 21). Progressing westward, this hydrologically transitions to a flow-through wetland system broadly characterized as an Organic Coniferous Swamp- Tamarack Organic Coniferous Swamp that progressively transitions to a Tamarack Treed Fen Type and ultimately to a Sweet Gale Shrub Fen. The presence of a Graminoid Open Fen within an Organic Coniferous Swamp is unique in transect 6 before transitioning downgradient/west to a Sweet Gale Shrub Fen Type. The Graminoid Open Fen corresponds to the HED category 1 habitat (Table 16).

Two coefficients are used to further characterize a vegetation community. Coefficients of conservatism (CC) represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from what is believed to be a pre-settlement condition and range from 0 to 10 (Swink and Wilhelm, 1994; Wilhelm and Masters, 1995). Whereas, coefficients of wetness estimate the probability for which a species occurs in wetlands, with positive values indicating a dry tendency and negative values indicating a wet tendency. Specific to HED category 1 habitat, the Graminoid Open Fen (2013)/Twig-rush Open Fen (2009) is characterized by an extremely high coefficient of conservatism value (7.7 in 2009 compared to 7.9 in 1999; Post et al., 2010). This narrow community was dominated by species with high CC values such as Twig-rush (Cladiummariscoides), green-keeled cotton-grass (Eriophorumviridi-carinatum), bog buckbean (Menyanthes trifoliata), beak-rush (Rhynchosporaalba) and horned bladderwort (Utriculariacornuta; Post et al., 2010). Also, this area is characterized by -4.6 (2009) and -4.9 (1999) coefficients of wetness, indicating that vegetation occurs almost always in wetlands under natural saturated conditions. In addition, this area has the lowest coefficients of wetness and highest coefficients of conservatism of the 12 sites observed in 2009 (Post et al., 2010). This suggests that the HED category 1 habitat is dominated by vegetation in a pervasively wet/saturated state, that associated vascular plant flora have a high fidelity to this specific high quality habitat, and that flora is intolerant of disturbance. Note that the “base of bluff” community that also provides larval habitat is different i.e. meadow/shallow marsh and that CC will be lower i.e. more like T6-13.

Potential additional HED sites based on the T3 and T6 transect ELC mapping are limited to Graminoid Organic Meadow Marsh (MAMO1; well site T6-13) based on the vegetation community assemblage (Figure 20). However, the uniqueness of the Graminiod Open Fen suggests the need for additional field-based mapping targeted in the string fen and the discharge front to identify comparable suitable vegetation assemblage and associated coefficients of wetness. Regionally, it is postulated/recommended that field-based reconnaissance for larval habitat be focused on areas that display Graminoid Organic Meadow Marsh to Graminoid Open Fen ELC vegetation community assemblages.
Figure 21: Ecological Lands Classification of the eastern Minesing Wetlands focused on the groundwater monitoring wells transects T3 and T6. A 500m buffer of confirmed HED locations is superimposed on the ELC mapping.
Table 16: Ecological Lands Classification, eastern Minesing Wetlands. See Figure 20 to for unit distribution.

<table>
<thead>
<tr>
<th>Transect</th>
<th>Well</th>
<th>2013 ELC Vegetation Community Type</th>
<th>2009 ELC Vegetation Community Type</th>
<th>Wetland Hydrological System</th>
<th>Sample Application of the Habitat Regulation</th>
<th>Community of Coefficient of Conservatism</th>
<th>Community Coefficient of Wetness</th>
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<td>transect T3</td>
<td>T3-1</td>
<td>Tamarack Treed Fen Type (FETC1-1)</td>
<td>Tamarack Treed Fen Type (FETC1-1)</td>
<td>flow-through system</td>
<td>Category 2 habitat</td>
<td>4.9</td>
<td>5.8</td>
</tr>
<tr>
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<td>T3-1A_13</td>
<td>Tamarack Treed Fen Type (FETC1-1)</td>
<td>White Cedar-Conifer Organic Coniferous Swamp Type (SWC02-2)</td>
<td>flow-through system</td>
<td>Category 2 habitat</td>
<td>5.2</td>
<td>6</td>
</tr>
<tr>
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<td>T3-2</td>
<td>Tamarack Organic Coniferous Swamp Type (SWC02-2)</td>
<td>Tamarack Organic Coniferous Swamp Type (SWC4-2)</td>
<td>flow-through system</td>
<td>Category 2 habitat</td>
<td>4.8</td>
<td>6</td>
</tr>
<tr>
<td>transect T3</td>
<td>T3-5</td>
<td>Organic Coniferous Swamp Type (SWC01-2?)</td>
<td>White Cedar-Conifer Organic Coniferous Swamp Type (SWC3-2)</td>
<td>flow-through system</td>
<td>Category 2 habitat</td>
<td>5.5</td>
<td>6</td>
</tr>
<tr>
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<td>Category 2 habitat</td>
<td>4.8</td>
<td>6</td>
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<td>Well</td>
<td>2013 ELC Vegetation Community Type</td>
<td>2009 ELC Vegetation Community Type</td>
<td>Wetland Hydrological System</td>
<td>Sample Application of the Habitat Regulation</td>
<td>NVCA 2009</td>
<td>Bradford 1999</td>
</tr>
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<td>T6-1</td>
<td>Sweet Gale Shrub Fen Type (FESD1-1)</td>
<td>Sweet Gale Shrub Fen Type (FES1-1)</td>
<td>flow-through system</td>
<td>Category 2 habitat</td>
<td>5.7</td>
<td>6</td>
<td>-4</td>
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<td>T6-10</td>
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<td>Fresh Moist Hemlock-Hardwood Mixed Forest (FOM6-2)</td>
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<td>Category 2 habitat</td>
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<td>T6-11</td>
<td>Fresh Moist Sugar Maple-Hardwood Deciduous Forest (FOD6-5)</td>
<td>Fresh Moist Sugar Maple-Hardwood Deciduous Forest (FOD6-5)</td>
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<td>Category 2 habitat</td>
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<td>4.9</td>
<td>-0.2</td>
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<td></td>
<td></td>
<td>Category 2 habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>Gramminiod Organic Meadow Marsh Ecosite (MAMO1)</td>
<td>White Cedar-Conifer Mineral Coniferous Swamp Type (SWC1-2)</td>
<td>discharge system</td>
<td>Category 2 habitat</td>
<td>3.5</td>
<td>4.8</td>
<td>-2.2</td>
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<td>White Cedar-Conifer Organic Coniferous Swamp Type (SWC01-2)</td>
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<td>Category 2 habitat</td>
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<td></td>
</tr>
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<td>Gramminiod Open Fen Ecosite (FEOG1)</td>
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<td>flow-through system</td>
<td>Category 1 habitat</td>
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<td></td>
<td></td>
</tr>
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<td>T6-3B_13</td>
<td>Gramminiod Open Fen Ecosite (FEOG1)</td>
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<td>Category 1 habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>T6-4</td>
<td>Gramminiod Open Fen Ecosite (FEOG1)</td>
<td>Twig Rush Open Fen (FEO1-1)</td>
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<td>Category 1 habitat</td>
<td>7.7</td>
<td>7.9</td>
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<td>T6-5A_13</td>
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<td>Category 2 habitat</td>
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<td></td>
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<td>T6-5B_13</td>
<td>Gramminiod Open Fen Ecosite (FEOG1)</td>
<td></td>
<td>flow-through system</td>
<td>Category 1 habitat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T6-7</td>
<td>White Cedar-Conifer Organic Coniferous Swamp Type (SWC01-2)</td>
<td>White Cedar-Conifer Organic Coniferous Swamp Type (SWC3-2)</td>
<td>discharge system</td>
<td>Category 2 habitat</td>
<td>5.9</td>
<td>6.2</td>
<td>-2.8</td>
</tr>
<tr>
<td>T6-9</td>
<td>Balsam Fir - Hardwood Organic Mixed Swamp type (SWMO4-1)</td>
<td>Poplar-Conifer Mineral Mixed Swamp (SWC3-2)</td>
<td>discharge system</td>
<td>Category 2 habitat</td>
<td>4.9</td>
<td>5</td>
<td>-1.1</td>
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</table>
7.0 COMPARISON TO OTHER HED SITES

The HED has been found in Wisconsin, Michigan, Illinois, and Missouri. Within Canada, it has been only located in the Minesing Wetlands.

Common habitat site characteristic is the presence of sheetflow and/or contained rivulets (Lee et al., 2006 and Aley et al., 2007). All sites of HED habitat in Michigan were at least water saturated: 6 sites were shallowly inundated up to 10 cm and also correspond to areas of highest Somatochlora sp. dragonfly larvae occurrence in pumped crayfish burrows (Lee et al., 2006). Furthermore, Aley et al. (2007) indicated that multi-structured vegetation strata (i.e. ground layer, low shrub, and tall shrub), and the juxtaposition of areas with standing water and drier mounds caused by microtopographic variation are most important for the HED.

Research by Bradbury et al. (2012) on the ground and surface water inflows at the Mink River Estuary, one of the larger HED sites in Wisconsin, found that the water is generally a calcium/magnesium bicarbonate type, and is relatively pristine with respect to common contaminants such as nitrate and chloride. Further, the groundwater and surface water were found to be isotopically similar, and groundwater discharging to the Mink River was determined to originate from local terrestrial precipitation (Bradbury et al., 2012).

The Minesing Wetlands HED site (category 1 habitat) is also characterized by standing water and the predominance of ground level vegetation. Given the extremely low gradient of the site, the contoured groundwater flow direction, and the consistent response to precipitation via the deployed level loggers that the groundwater is moving extremely slowly and westerly towards the Nottawasaga River. Similar to Bradbury et al. (2012), the Minesing Wetlands groundwater is geochemically characterized as calcium-bicarbonate/alkaline. The source of the groundwater is from the upgradient discharge wetland systems situated at the base of the bluffs.

8.0 CONCLUSIONS

Funded through the MNR Species at Risk Stewardship Fund, the objectives of this study were to address key knowledge gaps for the recovery of HED, including determining groundwater levels and chemistry in the fen and the recharge areas and completing water budget calculations of the fen. The main components of this project consisted of:

1. Establishment of two drilled monitoring wells situated modelled groundwater recharge area upgradient of the fen.
2. Installation of nested shallow standpipes and deep piezometers in area of known HED habitat through the infilling of the existing Bradford (1999) groundwater monitoring network.
3. Investigation of groundwater chemistry and groundwater levels in the fen and the recharge area.
4. Determine the recharge rates of the recharge area.
5. Update the ecological land classification mapping along the T6 and T3 transects.

Recharge area monitoring wells: Two groundwater monitoring wells located in the recharge area for the fen were installed in accordance to O.Reg. 903 in 2014: one located on the Simcoe County Forest property off of Pinegrove Road (21m deep) installed in March, 2014 and one on Springwater municipal road allowance off of Grenfel Road (49m deep) installed
in November, 2014. Given the local overburden stratigraphy based on the MOE Water Well Records, the two monitoring wells are completed in the same hydrostratigraphic as the seepage front and are characterized by downward vertical hydraulic gradients.

**Groundwater Monitoring Network infilling:** The Minesing Wetlands groundwater monitoring network originally consisted of 26 monitoring wells at 15 locations established by Bradford (1999). Nine additional well nests were installed as part of this project to infill the existing Bradford (1999) T3 and T6 transects in areas of known co-occurrences of HED and digger crayfish. The sites consist of 1) a shallow standpipe that was typically screened approximately from 10 cm to 80 cm below the ground surface and 2) the deeper piezometer, which was completed to the peat-marl clay sediment interface, generally located between 2.5 and 3 m below the ground surface with a 70 cm slot 10 screen.

**Groundwater levels:** The Minesing Wetlands is subdivided hydrologically into two regimes: the south-east fen and mixed boreal complex swamp, which are dominated by a groundwater regime, and the remaining wetlands components that are dominated by surface water processes. The groundwater-dominated regime is herein further subdivided into 3 progressive ecohydrological zones: discharge wetland system, flow through wetland zone, graminoid fen. An additional zone is the recharge area, which is located upgradient and east of the Minesing Wetlands.

The groundwater flow direction follows the regional topography, sloping to the west towards the Nottawasaga River from the Snow Valley Uplands. Specifically, the groundwater levels of the HED category 1 habitat area are characterized by:

1. Extremely low horizontal groundwater gradients.
2. Homogenous groundwater levels in the ubiquitous peat unit that is roughly 2.5m + thick and underlain locally by a thick mineral soil horizon of undetermined thickness.
3. Groundwater levels influenced by precipitation events with a typical 2-3 day lag in the groundwater hydrograph, both in shallow and deep wells.
4. Groundwater temperatures influenced the air temperature; however with little variation throughout the peat horizon.

Similar characteristics are displayed at the upgradient site (T6-5A-13) located in the Tamarack Organic Coniferous Swamp (SWCO2-2).

**Geochemical analysis:** The groundwater chemistry results from the four sampling events (1998, 2010, 2013, and 2014) are relatively similar; wetland groundwater exhibits relatively low ion concentrations. The dominant cation present is calcium while bicarbonate is the dominant anion.

The graminoid fen, corresponding to the HED category 1 habitat area, is characterized hydrochemically as a calcium dominated unit; however, there is no unique geochemical signature that differentiates the graminoid fen from the other units.

Anthropogenic influences in the wetland are noted by the low concentrations of certain anionic herbicides and the slightly elevated presence of Na and Cl in sites proximal to Pinegrove Road and located in the discharge wetland system (T6-9-P and T6-12_13). The highest glufosinate values measured were 945.4 ng/L (T3-2A_13_D) and 113.4 ng/L (T6-1-P), corresponding to the White Cedar-Conifer Organic Coniferous Swamp and Sweet Gale Shrub Fen, respectively, the sites farthest from the road. Note that herbicides present are at very low levels compared to water quality guidelines.

**Recharge area and recharge rates:** Based on particle tracking modelling, the delineated recharge area within the 25 year travel-time zone covers approximately 18km², is situated
predominately in the upland area, and extends approximately 2-3 km southeast from the areas of interest across the upland area. The recharge volumes are relatively high with an average of 307 mm/year; the delineated recharge area is comprised of variable vegetation, slope, and surface/subsurface soil conditions and thus the recharge rate within each recharge zone varies from 50mm to 350 mm/year. The recharge volume within the 25 yr zone accounts for approximately 67% and 89% of the discharge volume to the fen and Snow Valley area, respectively. The remainder is from beyond that travel time, or occurs within 30 days

*Vegetation analysis:* Based on the T3 and T6 transect ELC mapping, potential additional HED sites are limited to Graminoid Organic Meadow Marsh (MAMO1; well site T6-13) based on the vegetation community assemblage. However, the uniqueness of the Graminoid Open Fen suggests the need for additional field-based mapping targeted in the string fen and the discharge front to identify comparable suitable vegetation assemblage and associated coefficients of wetness. Regionally, it is postulated/recommended that field-based reconnaissance for larval habitat be focused on areas that display Graminoid Organic Meadow Marsh to Graminoid Open Fen ELC vegetation community assemblages.

### 8.1 Project Recommendations

1) Establish a regular monitoring program of water levels and groundwater chemistry for the Minesing Wetlands, including the two monitoring wells situated in the recharge area, for the purpose of detecting and quantifying long-term changes. The results from the 2014 loggers support the deployment of 1 logger per site. Eight sites are proposed for deployment of the existing project level loggers (see Table 17). Site T3-8 is also strongly recommended for long-term monitoring. The rationale for these sites is multi-fold:

   1. Continued HED category 1 habitat monitoring (T6-3B_13 and T6-5B_13)
   2. Transect end member monitoring (T6-13, T3-1 or T3-1A_13, and T6-1) for regional flow direction analysis
   3. Levels related to elevated geochemistry results (T6-1, T3-1A_13, T6-12_13 and T6-9)
   4. Infilling of the transects to ensure adequate coverage in multiple ELC units (T3-5 and T6-9)

   It is recommended that longer, if not annual, deployment of the loggers be undertaken to obtain complete water year hydrographs and the loggers be deployed in the deep wells.

   Also, it is recommended that 4 manual static measurements for all wells be undertaken per annum for a period of 6 years to develop a statistically defendable database of groundwater levels.

   Further, it is recommended that an annual fall water quality sampling program on all wells on the T3 and T6 transects be undertaken for 5 years for the purpose of detecting and quantifying long-terms changes.
Table: 17: Proposed monitoring wells for level logger deployment.

<table>
<thead>
<tr>
<th>Transect</th>
<th>Well</th>
<th>2013 ELC Vegetation Community Type</th>
<th>Wetland Hydrological System</th>
<th>Sample Application of the Habitat Regulation</th>
</tr>
</thead>
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<tr>
<td>Transect T3</td>
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<td>flow-through system</td>
<td>Category 2 habitat</td>
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<td>T3-5</td>
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<td>T3-9</td>
<td>White Cedar-Conifer Organic Coniferous Swamp (SWC01-2)</td>
<td>discharge system</td>
<td>Category 2 habitat</td>
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<td>Category 2 habitat</td>
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<td>T6-12_13</td>
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<td>Category 2 habitat</td>
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<td>flow-through system</td>
<td>Category 1 habitat</td>
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<tr>
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<td>T6-5B_13</td>
<td>Graminoid Open Fen Ecosite (FEOG1)</td>
<td>flow-through system</td>
<td>Category 1 habitat</td>
</tr>
</tbody>
</table>

2) Investigate the intra-annual variability of groundwater chemistry in the wetland and in the nearby upland groundwater. The temporal variability of groundwater chemistry in the Minesing Wetlands is currently unknown. Therefore it is not presently possible to say how differences in the timing of an annual wetland groundwater sampling initiative would affect the comparability of these data. It would be useful to conduct a more intensive sampling of the Minesing Wetlands groundwater at multiple times per year to adequately capture variations in groundwater chemistry as a function of seasonal variability in wetland hydrology and the biogeochemical processes that influence groundwater parameters. Not only would this be a first step towards a better understanding of the variability in the chemistry of Minesing Wetlands groundwater, but it would also provide a scientific basis for choosing the most meaningful time of year to conduct subsequent monitoring at a reduced temporal intensity (e.g. once annually).

3) Based on the ELC mapping of the category 1 habitat in the Minesing Wetlands, extrapolate the results to other comparable local areas to identify additional potential suitable habitat in the region.

4) If other HED larvae habitats are located, complete water quality analysis to further constrain the corresponding geochemical signature and undertake groundwater monitoring to determine the annual position of the water table over the course of the water year (October 1 to September 30).

5) Complete hydrological modelling scenario runs on potential hypothetical changes in the impervious covering the recharge area and the associated change in the groundwater.

6) Future proposed development in the modelled recharge area should utilize the report recharge values in the evaluation of pre and post development water balances to ensure that the water balances match.
9.0 ACKNOWLEDGEMENTS

The authors acknowledge the work of several individuals that contributed to this study. Field work was assisted by Ryan Mueller and Michael Saunders, Nottawasaga Valley Conservation Authority (NVCA). The 2013 Ecological Lands Classification mapping was completed by Lorraine Adderley (NVCA). This document benefitted greatly from the advice and review from Dave Featherstone (NVCA) and Tanya Pufler (Independent consultant). Funding for this study was provided by MNRF and Environment Canada.
10.0 REFERENCES


**APPENDIX 1: MOE WATER WELL RECORDS**

![Well Record Form]

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**Well Owner's Information**
- **First Name**: NOT AVAILABLE
- **Last Name**: NORTON
- **Organization**: NOT AVAILABLE
- **Mailing Address**: STREET NUMBER NAME
- **E-mail Address**: NOT AVAILABLE
- **Municipality**: NOT AVAILABLE
- **Province**: NOT AVAILABLE
- **Postal Code**: NOT AVAILABLE
- **Telephone No.**: NOT AVAILABLE

**Well Location**
- **Address of Well Location**: STREET NUMBER NAME
- **Township**: SPRING WATER
- **Lot**: 17
- **Concession**: B

**County/Region/Municipality**
- **City/Town/Village**: NOT AVAILABLE
- **Municipal Plan and Section Number**: NOT AVAILABLE

**Overburden and Bedrock Materials**

<table>
<thead>
<tr>
<th>General Colour</th>
<th>Most Common Material</th>
<th>Other Materials</th>
<th>General Description</th>
<th>Depth (m(ft))</th>
</tr>
</thead>
<tbody>
<tr>
<td>BLACK</td>
<td>ROCK</td>
<td></td>
<td>SOFT</td>
<td>0.5 (1.5)</td>
</tr>
<tr>
<td>BROWN</td>
<td>GRAY</td>
<td></td>
<td>HARD</td>
<td>1.5</td>
</tr>
<tr>
<td>BROWN</td>
<td>SAND</td>
<td></td>
<td>LOOSE</td>
<td>3.2</td>
</tr>
<tr>
<td>GREY SALT</td>
<td></td>
<td></td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>SAND</td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

**Annular Space**
- **Depth Set (m(ft))**: 3.0 (10.0)
- **Type of Seal Used**: Not Available
- **Volume Recorded (ml) (gallons)**: 1

**Results of Well Yield Testing**
- **Draw Down (m(ft))**: 2.0 (6.5)
- **Recovery (m(ft))**: 1.0 (3.0)
- **Pumping Schedule, gpm (lpm)**: 5
- **Pump intake set at (m(ft))**: 4
- **Pumping rate (gpm / lpm)**: 3

**Method of Construction**
- **Well Use**: Municipal Water Supply
- **Depth of Water**: 3.0 (10.0)

**Status of Well**
- **Well Dewatered**: Yes
- **Well Completed**: Yes

**Well Information**
- **Well Contractor**: NOT AVAILABLE
- **Well Technician**: NOT AVAILABLE
- **Province**: NOT AVAILABLE
- **Postal Code**: NOT AVAILABLE
- **Telephone No.**: NOT AVAILABLE

---

*Please provide a map of the Well Location.*
**Ontario Ministry of the Environment**

**Well Tag No.** (Print sticker and/or (Put Below))

**Tag #: A176452**

**Well Location**

- **Address of Well Location**: [Illegible]
- **Municipality**: Saugeen Shores
- **Province**: Ontario
- **Postal Code**: N0H 1S0

**Well Data and Monitoring Record**

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>0 ft. 30 in.</td>
</tr>
<tr>
<td>Type of Sediment Used</td>
<td>Clay and sand free</td>
</tr>
<tr>
<td>Volume Placed</td>
<td>1 cu. ft.</td>
</tr>
</tbody>
</table>

**Method of Construction**

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumps</td>
<td>2 1/2 HP</td>
</tr>
<tr>
<td>Horsepower</td>
<td>2</td>
</tr>
</tbody>
</table>

**Construction Record - casing**

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (in.)</td>
<td>4 in.</td>
</tr>
<tr>
<td>Thickness (in.)</td>
<td>0 in. 2 in. 1 in. 1 in.</td>
</tr>
<tr>
<td>Water Supply</td>
<td>100 ft. 100 ft. 100 ft. 100 ft.</td>
</tr>
</tbody>
</table>

**Well Details**

<table>
<thead>
<tr>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Level</td>
<td>0 ft. 30 in.</td>
</tr>
<tr>
<td>Water Level</td>
<td>10 ft. 10 in.</td>
</tr>
<tr>
<td>Water Level</td>
<td>10 ft. 10 in.</td>
</tr>
<tr>
<td>Water Level</td>
<td>10 ft. 10 in.</td>
</tr>
<tr>
<td>Water Level</td>
<td>10 ft. 10 in.</td>
</tr>
</tbody>
</table>

**Map of Well Location**

- **Well Location**: [Diagram]

---

**Ministry Use Only**

- **Approval**: [Stamp]
APPENDIX 2: DELINEATION OF CONTRIBUTING RECHARGE AREAS; EASTERN BOUNDARY OF THE MINESING WETLAND COMPLEX.

APPENDIX 3: FIELD-BASED AGRICULTURAL RESOURCE INVENTORY OF THE MINESING AREA, 2014

1.0 INTRODUCTION
The Snow Valley Uplands is the critical recharge area to the eastern part of the Minesing Wetlands (Beckers and Frind, 2001), further delineated through time of travel modelling by Matrix Solutions (2014). The land use in this area, in addition to the eastern aspect of the wetland (Figure 1), is dominated by row cropland, with deciduous or coniferous forests predominating on the flanks of the upland. Agriculture is the predominant land use in the recharge area but the crop distribution and characteristics were previously unknown.

The field based mapping at the local level provided an opportunity to determine the spatial distribution and occurrence of the crops at a specific point in time. This land use dataset can be used to determine crop distribution and total area grown, spatial distribution of irrigation systems for specific crop and slope, correlating the crops to the hydrologic characteristics of the soil, etc. to complement integrated water resource management.

Developed by OMAF, the Agricultural Resource Inventory (AgRI) is a database for farming practices and land management systems. The AgRI provides field specific information and evaluates the mix of crops on the landscape (OMAFRA, 2013). The objective of the AgRI is to document crop production, crop rotation patterns, tillage practices, and the distribution of crop-specific nutrient application, pest-management practice, and water management (OMAFRA, 2010).

The objective of this project is to complete 2014 AgRI mapping of the eastern Minesing area and integrate this dataset to develop a comprehensive understanding of crop distribution, crop rotation patterns, crop-specific irrigation distribution, etc.
Figure 1: Minesing AGRI mapping study area
2.0 METHODOLOGY
The farm-field survey was completed during July, 2014. The following methodology was used to complete this exercise:

1. Maps were generated using ArcGIS and imported to an iPad. The PDF Maps application, created by Avenza Systems Inc., was used during the in-field mapping process. The application is available for Apple iOS and Android systems. The application for Apple can be downloaded from iTunes: https://itunes.apple.com/ca/app/avenza-pdf-maps/id388424049?mt=8
2. Only visible fields were surveyed via a windshield survey for the following attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Description</td>
<td>Bailed, cultivated, harvested, patchy, ploughed, rolled, or weedy</td>
</tr>
<tr>
<td>Crop</td>
<td>Crop type: Alfalfa, Apples, Barley, Beets, Cabbage, Canola, Carrot, Corn, Edible Beans, Fallow, Hay, Nursery and Landscape, Oats, Onion, Parsnips, Pasture, Potato, Radish, Rye, Soybeans, Spring Wheat, Squash, Strawberries, Turf, Unknown* and Winter Wheat</td>
</tr>
<tr>
<td>Land Use</td>
<td>Field, farmstead or rough land</td>
</tr>
<tr>
<td>Irrigation System</td>
<td>Centre pivot, drip irrigation, stationary gun, traveling boom, or traveling gun</td>
</tr>
<tr>
<td>Livestock</td>
<td>Cattle, donkey, goat, etc.</td>
</tr>
<tr>
<td>Residue</td>
<td>Last season(s) crop residue</td>
</tr>
<tr>
<td>Row Direction</td>
<td>East, southeast, southwest, or south</td>
</tr>
<tr>
<td>Tillage</td>
<td>Tillage practices: conventional, conservation, or no-till</td>
</tr>
</tbody>
</table>

*Unknown: unknown was selected if the crop type was not identifiable or in some cases farm fields were ploughed or harvested and unable to identify the residue.

3. The data from the iPad was transferred to ArcGIS for quality assurance and control.
4. Some AgRI polygons were modified to fit the 2014 survey data. For instance, in 2012 a potato field had to be split into two different crop fields (soybeans and alfalfa).
5. Various maps and analyses were completed using the data.

3.0 RESULTS
3.1 Agriculture Land Use
A total of 3145 ha were surveyed, which include approximately 3053 ha of managed farm-fields, approximately 73 ha of rough land, and approximately 19 ha of farmstead (Figure 2, Table 1). Rough land is defined as a non-agricultural land that is overgrown with native plants and grasses. Non-mapped fields consist of approximately 1687 ha of farm-fields, 1370 ha of rough land, and 271 ha of farmstead land. The biggest land use, managed farm fields, correspond to 40% of the total land use, of which 65% were visible from the roadside. The second largest land use corresponds to woodland (35%)
Table 1: Mapped and non-mapped areas

<table>
<thead>
<tr>
<th>Land Uses</th>
<th>Mapped Areas (ha)</th>
<th>Non-Mapped Areas* (ha)</th>
<th>Total (ha)</th>
<th>% Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fields</td>
<td>3052.88</td>
<td>1686.87</td>
<td>4739.75</td>
<td>40.56</td>
</tr>
<tr>
<td>Farmstead</td>
<td>18.71</td>
<td>271.43</td>
<td>290.14</td>
<td>2.48</td>
</tr>
<tr>
<td>Rough land</td>
<td>73.27</td>
<td>1369.65</td>
<td>1442.92</td>
<td>12.35</td>
</tr>
<tr>
<td>Woodland</td>
<td></td>
<td>4059.91</td>
<td>4059.91</td>
<td>34.74</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>39.74</td>
<td>39.74</td>
<td>0.34</td>
</tr>
<tr>
<td>Urban</td>
<td></td>
<td>707.56</td>
<td>707.56</td>
<td>6.05</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>406.74</td>
<td>406.74</td>
<td>3.48</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3144.86</strong></td>
<td><strong>8541.91</strong></td>
<td><strong>11686.76</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

*Non-mapped areas are based on the 2012 Orthoimagery layer.
Figure 2: Mapped and non-mapped fields and rough land
3.2 Crop Distribution
Table 2 and Figure 3 display the variety of crops grown in the Minesing area. The main crops grown are soybeans, winter wheat and corn, covering approximately 2349 ha (75% of the total mapped farm-fields). Soybean, the predominant crop, covers 38% of the total mapped farm-fields. Secondly, winter wheat covers 22% of the total mapped farm-fields, and corn covering 14% of the mapped farm-fields.

Table 2: Crops grown in the Minesing study area

<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Number of Fields</th>
<th>Area Cover (ha)</th>
<th>Percentage (%)</th>
<th>Area per Field (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa - Forages</td>
<td>35</td>
<td>224.53</td>
<td>7.14</td>
<td>6.42</td>
</tr>
<tr>
<td>Asparagus</td>
<td>2</td>
<td>5.62</td>
<td>0.18</td>
<td>2.81</td>
</tr>
<tr>
<td>Barley</td>
<td>1</td>
<td>7.56</td>
<td>0.24</td>
<td>7.56</td>
</tr>
<tr>
<td>Berries - Unknown</td>
<td>2</td>
<td>12.82</td>
<td>0.41</td>
<td>6.41</td>
</tr>
<tr>
<td>Canola</td>
<td>5</td>
<td>58.33</td>
<td>1.85</td>
<td>11.67</td>
</tr>
<tr>
<td>Corn</td>
<td>38</td>
<td>440.57</td>
<td>14.01</td>
<td>11.59</td>
</tr>
<tr>
<td>Edible Beans</td>
<td>3</td>
<td>16.54</td>
<td>0.53</td>
<td>5.51</td>
</tr>
<tr>
<td>Fallow - Unknown</td>
<td>16</td>
<td>74.64</td>
<td>2.37</td>
<td>4.66</td>
</tr>
<tr>
<td>Hay - Forages</td>
<td>8</td>
<td>60.56</td>
<td>1.93</td>
<td>7.57</td>
</tr>
<tr>
<td>None</td>
<td>27</td>
<td>91.97</td>
<td>2.92</td>
<td>3.41</td>
</tr>
<tr>
<td>Nursery and Landscape</td>
<td>1</td>
<td>8.92</td>
<td>0.28</td>
<td>8.92</td>
</tr>
<tr>
<td>Oats</td>
<td>5</td>
<td>54.21</td>
<td>1.72</td>
<td>10.84</td>
</tr>
<tr>
<td>Pasture - Unknown</td>
<td>26</td>
<td>92.58</td>
<td>2.94</td>
<td>3.56</td>
</tr>
<tr>
<td>Rye</td>
<td>1</td>
<td>2.94</td>
<td>0.09</td>
<td>2.94</td>
</tr>
<tr>
<td>Soybeans</td>
<td>121</td>
<td>1203.43</td>
<td>38.27</td>
<td>9.95</td>
</tr>
<tr>
<td>Squash</td>
<td>3</td>
<td>3.28</td>
<td>0.10</td>
<td>1.09</td>
</tr>
<tr>
<td>Strawberries</td>
<td>2</td>
<td>6.54</td>
<td>0.21</td>
<td>3.27</td>
</tr>
<tr>
<td>Unknown</td>
<td>8</td>
<td>74.66</td>
<td>2.37</td>
<td>9.33</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>72</td>
<td>705.14</td>
<td>22.42</td>
<td>9.79</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>376</strong></td>
<td><strong>3144.86</strong></td>
<td><strong>100</strong></td>
<td><strong>127.31</strong></td>
</tr>
</tbody>
</table>
Figure 3: Crop distribution
3.3 Hydrologic soil groups and crop distribution
Soils are classified into one of four groups according to the rate of water infiltration when soils are bare, not frozen, and receive precipitation from long-duration storms. The four hydrologic soil groups are described in Table 3 (Natural Resources Conservation Service, 2007).

Table 3: Hydrologic Soil Group (HSG).

<table>
<thead>
<tr>
<th>Hydrologic Soil Group</th>
<th>Runoff Potential</th>
<th>Infiltration Rate (cm/hr.)</th>
<th>Soil Textures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group A</strong></td>
<td></td>
<td>&gt;0.76</td>
<td>Sand, loamy sand, or sandy loam</td>
</tr>
<tr>
<td></td>
<td>Soils have low runoff potential and high infiltration rates even when thoroughly wetted</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soils have moderately low runoff potential and moderate infiltration rates when thoroughly wetted</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group B</strong></td>
<td>0.38 – 0.76</td>
<td>Silt loam or loam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soils have moderately low runoff potential and moderate infiltration rates when thoroughly wetted</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group C</strong></td>
<td>0.13 – 0.38</td>
<td>Sandy clay loam</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soils have moderately high runoff potential and low infiltration rates when thoroughly wetted</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group D</strong></td>
<td>0 – 0.13</td>
<td>Clay loam, silty clay loam, sandy clay, silty clay or clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soils have high runoff potential and very low infiltration rates when thoroughly wetted</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the Minesing study area, 30% of the crops are grown in soils classified Group B and Group D. For soybean, the predominant crop in this area, 33% of the total field area corresponds to Group D and 29% to Group B. Winter wheat is predominantly grown in Group B and D, while corn is relatively evenly distributed in Groups A, B and C.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Area of Crops per Hydrologic soil groups (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A</td>
</tr>
<tr>
<td>Alfalfa - Forages</td>
<td>32.89</td>
</tr>
<tr>
<td>Asparagus</td>
<td>1.99</td>
</tr>
<tr>
<td>Barley</td>
<td></td>
</tr>
<tr>
<td>Berries - Unknown</td>
<td>5.07</td>
</tr>
<tr>
<td>Canola</td>
<td>8.98</td>
</tr>
<tr>
<td>Corn</td>
<td>111.29</td>
</tr>
<tr>
<td>Edible Beans</td>
<td>1.69</td>
</tr>
<tr>
<td>Fallow - Unknown</td>
<td>31.90</td>
</tr>
<tr>
<td>Hay</td>
<td></td>
</tr>
<tr>
<td>Nursery and Landscape</td>
<td>8.92</td>
</tr>
</tbody>
</table>
Oats  |  6.66  |  21.85  |  4.37  |  21.33  
Pasture - Unknown  |  2.72  |  25.19  |  29.24  |  33.58  
Rye  |  |  2.94  
Soybeans  |  201.47  |  345.18  |  243.14  |  388.75  
Squash  |  3.28  
Strawberries  |  0.66  |  5.88  
Unknown  |  6.53  |  26.54  |  20.22  |  21.37  
Winter Wheat  |  92.13  |  226.05  |  164.32  |  222.07  
**Total**  |  516.18  |  922.52  |  636.73  |  925.22  

It is noted that no irrigation systems were identified through this exercise in the mapped study area.
4.0 Summary
The major agricultural Minesing characteristics, based on the 2014 windshield AgRI mapping, consist of:

- Approximately 3053 ha of managed fields and approximately 73 ha of rough land were surveyed in July, 2014. Non-mapped fields consist of approximately 1687 ha of managed fields and 1370 ha of non-mapped rough land. Roughly 4740 ha (41%) of the total area of the study area corresponds to managed agricultural field.

- The main crops grown are soybean, winter wheat, and corn; covering approximately 75% of the total mapped farmfields. Soybean is the predominant crop, corresponding to 38% of the total mapped area.

- 62% of the crops are grown in soils hydrologically classified as Group D (30.8%) and Group B (30.7%), respectively.

4.1 Recommendations
The field based mapping provides an opportunity to determine the spatial distribution and occurrence of the crops at a specific point in time. This foundational, agriculture-focused, land use dataset allows for integrated analysis related to crop distribution and total area grown, spatial distribution of irrigation systems for specific crop and slope, correlating the crops to the hydrologic characteristics of the soil, etc. Application of the GIS-based field data dataset can be collectively utilized for a variety of program areas, e.g. the determination of broad nutrient application rates, crop-specific targeted stewardship/BMP outreach, potential for soil erosion, etc. The following recommendations are herein offered for consideration:

- Collect a 5 year AgRI mapping data to be able to understand the Minesing area crop distribution and crop rotation.
- Possible expansion of the AgRI mapping to capture farmstead and tillage characteristics to gain the holistic snapshot of agricultural practices at the subwatershed scale.
- Continued use of the IPAD for mapping and exploration of opportunities to map fields that are not visible, e.g. drones and other applicable precision agriculture opportunities.
- Complete an economic analysis of crop valuation for the study area and the individual crop, percentage of crop grown in the subwatershed vs. the county level and the associated overall value.
5.0 References

Matrix Solutions Inc. 2014. Delineation of Contributing Recharge Areas; Eastern Boundary of the Minesing Wetland Complex.


APPENDIX 4: VEGETATION COMMUNITY ANALYSIS DATA BY STATION

Minesing Fen – ELC Vegetation Assessment
Vegetation community assessment was undertaken at each existing and new monitoring well station to qualitatively describe each community. The purpose of this was to examine the hydrological regime in conjunction with the vegetation community type to see if there are other possible habitat locations for HED in the fen areas of the Minesing Wetlands. Since vegetation communities in this area are strongly linked with hydrogeological regime, and both are determinant of HED habitat, more information on the distribution of each could give us further insight into preferred habitat for HED.

Vegetation community monitoring was undertaken on September 18 and 19, 2013. An approach consistent with the Ecological Land Classification (Lee et al., 1998), and wetland types consistent with those found in the Southern Ontario Wetland Evaluation System manual (MNR 2013), was used to describe vegetation communities at each existing and future NVCA well monitoring station. The qualitative monitoring component consisted of a coarse inventory of vegetation. Mapped boundaries of the units were derived from previously existing mapping from previous ELC work done in the Minesing Wetlands as a part of the Integrated Minesing Wetlands Monitoring Program (Post et al., 2009) and additional orthophotography interpretation. Boundaries were investigated on the ground where transitions intersected with the two monitoring transect. Given time constraints, the area surveyed on the ground, and the time of year, the inventories should be considered a subset of vegetation present at each station with an emphasis on identifying the canopy cover composition (if present) and the most common/readily observable species in each layer. Wetland and fen/bog indicator species are noted where present.

Transect 6

Station T6-13
This is the well closest to Pinegrove Rd. It is one of Bradford’s original wells. The well sits in the middle of a relatively open marshy area. Tree cover at the time of investigation was less than 25%. The predominant vegetation community was dominated by emergent hydrophytic macrophytes, notably cattail and sedges. Trees present were immature and successional in nature. Canopy species included trembling aspen, balsam fir and cedar. The water table was at 1-3 cm (shallow and deep wells were measured) below ground level at the time of surveys. Organic substrates were noted on the surface and have been examined in past evaluations. Vernal pooling was noticed on approximately 30% of the surface. As such this area best fit the description of Graminoid Organic Meadow Marsh Ecosite (MAM01). This is a departure from the 2009 ELC work done at the location, which found the community to be a Cedar-Conifer (SWC1-2) ecosite and noted a greater presence of conifers and a lesser influence of emergent hydrophytic plants. This could possibly be due to clearing efforts on the part of nearby landowners. Hunting blinds, perches, and ATV trails were visible in the area. It is not difficult to imagine that the area has been cleared somewhat in the last 4 years to allow for open areas to attract deer.
Bradford Station: T6-13  
NVCA Station: 093  
Elevation: 191m  
Organics: (not sampled)  
2013 ELC Vegetation Type: MAMO1 – Graminoid Organic Meadow Marsh Ecosite

<table>
<thead>
<tr>
<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
<th>&gt;10 m</th>
<th>2-10 m</th>
<th>0.5-2 m</th>
<th>0.5-0 m</th>
<th>0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPUTRE</td>
<td><em>Populus tremuloides</em></td>
<td>Trembling Aspen</td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ABIEBAL</td>
<td><em>Abies balsamea</em></td>
<td>Balsam Fir</td>
<td>S</td>
<td>R</td>
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<td>R</td>
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<td>M,S</td>
<td>T</td>
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<td>M, S</td>
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Wetland Indicator: Y = Yes, N = No  
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog  
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
**Station T6-11**

This next well on the T6 transect is one of Bradford’s original wells. This well sits in an area of upland deciduous forest best classified as **Dry – Fresh Upland Deciduous Forest Ecosite (FODM4)**. Water levels in the deep well sat at 64 cm below ground surface, and in the shallow well no water was detected. Although mature trees existed in this location, there was also evidence of successional species. This suggests that there may have been disturbance in the area in the past. In fact, there was a nearby area where trees had been felled. Sugar maple was relatively uncommon in this area constituting <10% of the canopy cover. The canopy consisted largely of Red Maple, White Ash and Trembling Aspen, with some Black Cherry and Eastern Hemlock present. The understory contained smaller specimens of White Ash and Eastern Hemlock as well as Balsam Fir. The ground layer was dominated by Meadow Horsetail with some white ash saplings and sedges. This vegetation assessment is largely consistent with the vegetation assessment done in 2009.

<table>
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<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
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<th>0.5-2 m</th>
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<td>D</td>
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<tr>
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<td>S</td>
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<tr>
<td>VITIRIP</td>
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<td>Wild Grape</td>
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<tr>
<td>ACTAPACH</td>
<td>Actaea pachypoda</td>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T6-10

This next well on the T6 transect is one of Bradford’s original wells. This well sits in a wet swamp swale fed by groundwater seeps (as evidenced by localized presence of watercress). This unit is best described as **Baslam Fir – Hardwood Organic Mixed Swamp Type (SWMO4-1)**. Organics were deeper than 40 cm. The canopy cover was largely Balsam Fir and Balsam Poplar with trace amounts of Yellow Birch. The ground layer was sparse but did contain small saplings of Green Ash as well as some Spinulose Wood Fern and Wild Sarsasparilla. It would be expected that earlier in the year, there would be greater cover of the ground layer including more fern species, which were unidentifiable by this date. This vegetation assessment is somewhat different than the vegetation assessment done in 2009. Although many of the species are the same, there was more evidence of a drier unit in 2009. It appears that the area is wetter now and that the species contingent has changed somewhat, especially in the lower layers. There were certainly very wet areas in this unit including a running stream, several deep mud puddles, and vernal pooling. Water levels in the shallow well indicated water at 2 cm below the ground surface.

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<th>NVCA Station: 067</th>
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<td>Organics: thick organic layer &gt; 40 cm.</td>
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<th>Common Name</th>
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<th>Wetland Type</th>
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<td>A</td>
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<tr>
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<td>Balsam Poplar</td>
<td>S</td>
<td>O</td>
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<tr>
<td>BETUALL</td>
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<td>Yellow Birch</td>
<td>S</td>
<td>T</td>
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<tr>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
**Station T6-9**

This next well on the T6 transect is one of Bradford’s original wells. This well sits in the same wet swamp swale unit as station T6-10. There were some important differences within the unit between the first station and the second. These changes are noted in bold on the data sheet. This location had a greater presence of Yellow Birch in the canopy and understory than the last location; it also had a couple of specimens of American Elm. At the ground layer, this spot was more diverse in species (especially in fern species) and had greater cover than the last spot, likely because of its location further from the seep areas noted near the last well. The ground was not as wet (water table was at 5-6 cm), although there was still some vernal pooling and obviously saturated organic soils. Ground layer species included Wild Sarsaparilla, Bunchberry on knolls, Royal Fern, and Crested shield ferns. Some fern remnants were not identifiable. None of these differences in vegetation composition were influential enough to change the ELC vegetation type designation.

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*Wetland Indicator: Y = Yes, N = No*  
*Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog*  
*Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace*
Station T6-7

This next well on the T6 transect is one of Bradford’s original wells. This well sits in a wet stunted coniferous swamp with fen indicator species at the ground level. This unit is best described as **White Cedar-Conifer Organic Coniferous Swamp Type (SWCO1-2)**. There was a less than 10% cover of trees over 10 m, mostly Tamarack. The dense canopy was somewhat stunted (2-10 m in height), consisting of Eastern White Cedar and Balsam Fir. In the ground layer there was a large presence of tall sedge species and ferns, while in the lower ground layer (<0.5 m) Dwarf Raspberry, Bunchberry, and Creeping-Snowberry occupied the moss hummocks and drier knolls that rose above standing water puddles. There were several Fen indicator species present in this vegetation unit: Tamarack, Creeping-Snowberry, Small Cranberry, and Sweet gale. This vegetation assessment is consistent with that done in 2009 although the 2009 assessment includes more species (codes have changed since the old SWC3-2 is the current SWC1-2).

<table>
<thead>
<tr>
<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
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<td>Purple Avens</td>
<td>Y</td>
<td>M, S</td>
<td>T</td>
<td></td>
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</tr>
<tr>
<td>CALTPAL</td>
<td>Caltha palustris</td>
<td>Marsh Marigold</td>
<td>Y</td>
<td>M, S</td>
<td>T</td>
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</tr>
<tr>
<td>MOSS_SP</td>
<td>n/a</td>
<td>Moss sp.</td>
<td>D</td>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
**Station T6-5A_13**

This next well on the T6 transect is not one of Bradford’s original wells. Its location was selected to infill the network along the T6 transect and to indicate a change of ELC units. This well sits in a wet coniferous swamp with fen indicator species. This unit is best described as **Tamarack Organic Coniferous Swamp Type (SWCO2-2)**. It was not previously evaluated as part of the 2009 exercise, but the unit boundaries had been very roughly delineated through orthophotography as Coniferous Swamp (SWC). The canopy cover was largely Tamarack, Eastern White Cedar, and Black Spruce. The shrub layer consisted of Velvet-leaf blueberry and Sweet gale, and the ground layer was abundant with bunchberry, sedges. There were several Fen indicator species present in this vegetation unit: Tamarack, Black Spruce, Sweet gale, Leatherleaf, False Mayflower, and Small Cranberry.

<table>
<thead>
<tr>
<th>Bradford Station: T6-5A_13</th>
<th>NVCA Station: Well Pot. 9</th>
<th>Elevation: 186 m.</th>
<th>Organics: thick organic layer</th>
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<p>| 2013 ELC Vegetation Type: SWCO2-2 - Tamarack Organic Coniferous Swamp Type |
|-------------------------------|------------------|-----------------|-----------------|----------------|-----------------|-----------------|----------------|</p>
<table>
<thead>
<tr>
<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
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<th>0.5-2 m</th>
<th>0.5-0 m</th>
<th>0 m</th>
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<td>S, F</td>
<td>A</td>
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<tr>
<td>THUJOCC</td>
<td>Thuja occidentalis</td>
<td>Eastern White Cedar</td>
<td></td>
<td>S, F</td>
<td>O</td>
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<td>PICEMAR</td>
<td>Picea mariana</td>
<td>Black Spruce</td>
<td>Y</td>
<td>S, F, B</td>
<td>R</td>
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<td>S, F, B</td>
<td>O</td>
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<td>Sweet Gale</td>
<td>Y</td>
<td>M, S, F</td>
<td>R</td>
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<td>CHAMCAL</td>
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<td>Leatherleaf</td>
<td>Y</td>
<td>M, S, F, B</td>
<td>T</td>
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<td>Sedge</td>
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<td>MAIATRI</td>
<td>Maia trifolium</td>
<td>False Mayflower</td>
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<td>S, F, B</td>
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<tr>
<td>MAIACAN</td>
<td>Maia Canadensis</td>
<td>Canada Mayflower</td>
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<tr>
<td>VACCOXY</td>
<td>Vaccinium oxycoccos</td>
<td>Small Cranberry</td>
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<td>S, F, B</td>
<td>R</td>
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<tr>
<td>GEUMRIV</td>
<td>Geum rivale</td>
<td>Purple Avens</td>
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<td>M, S</td>
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<td>Moss sp.</td>
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Wetland Indicator: Y = Yes, N = No

Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog

Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Stations T6-5B_13, T6-4, T6-3B_13, T6-3A_13
This grouping of wells all occur within the same ELC unit. T6-4 is one of Bradford’s original wells. The others were selected to infill the network of monitoring wells along the T6 transect, especially in this unit, which is noted for several occurrences of HED. Two locations within this unit were surveyed for vegetation. This unit is a graminoid fen unit. This unit is best described as Graminoid Open Fen Ecosite (FEOG1). Station T6-4 was evaluated as part of the 2009 exercise, and was found to be Twig-Rush Open Fen Type (FEO1-1/FEOG1-1); this is consistent with what was identified in 2013. There was relatively no canopy cover with only the odd Black spruce over 10 m. There were some short trees found at the unit edges and throughout the unit clumped as little “islands”. These consisted of Black Spruce, Eastern White Cedar, and Tamarack. The shrub layer consisted of tall sedges, Common reed (native), and sweet gale. The ground layer contained several different species of rushes, grass-of-parnassus, pitcher plant, bog buckbean, and bog rosemary.

There were several Fen indicator species present in this vegetation unit: Black Spruce, Tamarack, American Reedgrass, Grass of Parnassus, Bog buckbean, Pitcher Plant, Bog Rosemary, Sweet Gale, and Marsh St. John’s Wort. Note that P. australis subsp. americanus. This was identified by shiny, reddish to purplish lower stem internodes, the colony was found with rather scattered stems, and in past years the NVCA has sent several specimens from the fen to Trent University Herbarium and have been identified as subspecies americanus.

<table>
<thead>
<tr>
<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
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<tr>
<td>PICEMAR</td>
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<td>Black Spruce</td>
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<td>T R</td>
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<td>THUJOCC</td>
<td>Thujaoccidentalis</td>
<td>Eastern White Cedar</td>
<td>S, F</td>
<td>R</td>
</tr>
<tr>
<td>LARILAR</td>
<td>Larixlaricina</td>
<td>Tamarack</td>
<td>Y S, F</td>
<td>T</td>
</tr>
<tr>
<td>PHRAAUS</td>
<td>Phragmitesaustralis subsp. americanus</td>
<td>American Reedgrass</td>
<td>Y M, S, F</td>
<td>T R</td>
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<td>CARE_SP</td>
<td>Carex sp.</td>
<td>Sedge sp.</td>
<td></td>
<td>A</td>
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<tr>
<td>RUSH_SP</td>
<td>Rush sp.</td>
<td></td>
<td></td>
<td>A</td>
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<tr>
<td>PARNGLA</td>
<td>Pannasiaglaucum</td>
<td>Grass of Parnassus</td>
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<td>Menyanthes trifoliata</td>
<td>Bog buckbean</td>
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<td>R</td>
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<td>Sarraceniapulverea</td>
<td>Pitcher Plant</td>
<td>Y F, B</td>
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<td>ANDRPOW</td>
<td>Andromeda polifolia</td>
<td>Bog Rosemary</td>
<td>Y F</td>
<td>R</td>
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<tr>
<td>MYRIGAL</td>
<td>Myrica gale</td>
<td>Sweet Gale</td>
<td>Y M, S, F</td>
<td>T</td>
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</table>

Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Bradford Station: T6-3A_13  
NVCA Station: Well Pot 11  
Elevation: 184 m.  
Organics: thick peat organic layer (approximately 280 cm)  
2013 ELC Vegetation Type: FEOG1 – Graminoid Open Fen Ecosite

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<tr>
<th>Plant Species Code</th>
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<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
<th>Abundance</th>
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<td>THUJOCC</td>
<td>Thuja occidentalis</td>
<td>Eastern White Cedar</td>
<td>S, F</td>
<td>O</td>
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<tr>
<td>PHRAAUS</td>
<td>Phragmites australis subsp. americanus</td>
<td>American Reedgrass</td>
<td>Y</td>
<td>M, S, F</td>
<td>O</td>
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<tr>
<td>LARILAR</td>
<td>Larix laricina</td>
<td>Tamarack</td>
<td>Y</td>
<td>S, F</td>
<td>R</td>
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<tr>
<td>PICEMAR</td>
<td>Picea mariana</td>
<td>Black Spruce</td>
<td>Y</td>
<td>S, F, B</td>
<td>T</td>
</tr>
<tr>
<td>MYRIGAL</td>
<td>Myrica gale</td>
<td>Sweet Gale</td>
<td>Y</td>
<td>M, S, F</td>
<td>A</td>
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<tr>
<td>ANDRPOL</td>
<td>Andromeda polifolia</td>
<td>Bog Rosemary</td>
<td>Y</td>
<td>F</td>
<td>R</td>
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<td>RUSH_SP</td>
<td>Rush sp.</td>
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<td>SOLI_SP</td>
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<td>Goldenrod sp.</td>
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<td>F</td>
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<tr>
<td>TRIAFRA</td>
<td>Triadenum fraseri</td>
<td>Marsh St. John's Wort</td>
<td>Y</td>
<td>M, F</td>
<td>T</td>
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</table>

Wetland Indicator: Y = Yes, N = No  
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog  
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
**Station T6-2**

T6-2 is one of Bradford’s original wells. This unit is a graminoid fen unit. This unit is best described as **White Cedar – Conifer Organic Coniferous Swamp Type (SWCO1-2)**. Station T6-2 was not evaluated as part of the 2009 exercise. There was dense tree cover present, although the trees here were largely less than 10m. Cedar and Tamarack make up the tree cover. The shrub layer is dense with Royal Fern and and Reedgrass and the occasional Speckled Alder. The ground layer consisted of Dwarf Raspberry, Grass of Parnassus, Star Flower and Canada Mayflower with Moss covering the entire ground surface, which was not ponded.

There were several fen indicator species present in this vegetation unit: Tamarack, Royal Fern, Speckled Alder, Grass of Parnassus, and Leatherleaf.

<table>
<thead>
<tr>
<th>Bradford Station: T6-2</th>
<th>NVCA Station: 83</th>
<th>Elevation: 185 m.</th>
<th>Organics: thick organic layer &gt;40 cm</th>
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<td>THUOCC</td>
<td>Thujaoccidentalis</td>
<td>Eastern White Cedar</td>
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<td>OSMUREG</td>
<td>Osmundaregalis</td>
<td>Royal Fern</td>
<td>Y</td>
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<td>Cinnalatifolia</td>
<td>Slender Wood Reedgrass</td>
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<td>Rubuspubescens</td>
<td>Dwarf Raspberry</td>
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<td>TRIBOR</td>
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<td>MOSS_SP</td>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T6-1
T6-1 is one of Bradford’s original wells. This unit is a shrub fen unit. This unit is best described as Sweet Gale Shrub Fen Type (FESD1-1). Station T6-1 was evaluated as part of the 2009 exercise; this evaluation is largely consistent with that one, which labelled the unit the same (Sweet Gale Shrub Fen – FES1-1). There were very few trees present. There were some stunted Tamarack and Cedar trees in isolated islands and sporadically throughout the unit, along with American Reedgrass. Shrubs included Speckled Alder, Sweet gale, and Leatherleaf. Tall herbaceous plants also took a major role in the vegetation composition of this unit, including sedge and rush species, marsh fern, goldenrods, Grass of Parnassus, royal fern and asters. There was an abundance of moss at the ground layer.
There were several fen indicator species present in this vegetation unit: American Reedgrass, Tamarack, Speckled Alder, Marsh Fern, Sweet Gale, Grass of Parnassus, Royal Fern, and Leatherleaf.

### Bradford Station: T6-1
**NVCA Station:** 128  
**Elevation:** 183 m.  
**Organics:** thick organic layer >40 cm
2013 ELC Vegetation Type: FESD1-1 – Sweet Gale Shrub Fen Type

<table>
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<tr>
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<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
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<td>THUJOCC</td>
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<td>Eastern White Cedar</td>
<td>S, F</td>
<td>T</td>
<td>R</td>
</tr>
<tr>
<td>PHRAAUS</td>
<td>Phragmitesaustralis</td>
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<td>M, S, F</td>
<td>O</td>
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<td>Larixlaricina</td>
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<td>R</td>
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<tr>
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<td>Y</td>
<td>F</td>
<td>O</td>
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<td>OSMUREG</td>
<td>Osmundaregalis</td>
<td>Royal Fern</td>
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<td>S, F</td>
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<td>SOLI_SP</td>
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<td>MOSS_SP</td>
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<td>Moss sp.</td>
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Wetland Indicator: Y = Yes, N = No  
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog  
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
**Transect 3**

**Station T3-9**

Well T3-9 is of Bradford’s original wells. This well sits in a wet coniferous swamp with fen indicator species at the ground level. This unit is best described as **White Cedar-Conifer Organic Coniferous Swamp Type (SWCO1-2)**. There was a dense canopy of trees consisting of Eastern White Cedar, Balsam Fir, Black Spruce, and Black Ash. There was also a lot of deadfall, though standing snags were rare. Smaller specimens of Balsam Fir and Black Ash were also present. The Shrub layer was relatively sparse including Wild Sarsaparilla, Royal Fern, Crested Shield Fern, and Elecampane. The ground layer was dominated by sphagnum mosses. Dwarf Raspberry, Bunchberry, and Creeping-Snowberry occupied the moss hummocks and drier knolls that rose above small standing water puddles. A small inclusion of the ground layer was dominated by sedges. There were several Fen indicator species present in this vegetation unit: Eastern White Cedar, Black Spruce, Royal Fern, and Creeping Snow-Berry. This vegetation assessment is largely consistent with that done in 2009 although the 2009 assessment includes more species (codes have changed since the old SWC3-2 is the current SWC1-2).

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<table>
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<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
<th>Wetland Type</th>
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<th>0.5-2 m</th>
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<tbody>
<tr>
<td>THUJOCC</td>
<td>Thuja occidentalis</td>
<td>Eastern White Cedar</td>
<td>S, F</td>
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**Wetland Indicator:** Y = Yes, N = No  
**Wetland Type:** S = Swamp, M = Marsh, F = Fen, B = Bog  
**Abundance:** A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-8

Well T3-8 is of Bradford’s original wells. However, it was not evaluated as part of the 2009 ELC exercise. This unit is best described as **White Cedar-Conifer Organic Coniferous Swamp Type (SWCO1-2)**. Although similar to the last unit, there are some key differences in the vegetation composition. Most notably, in this unit there are almost equal proportions of Eastern White Cedar and Tamarack with Black Spruce playing a minor role, whereas the last unit had much less Tamarack and a significant amount of Black Spruce. There was a dense canopy of trees consisting of Eastern White Cedar, Tamarack, Balsam Fir, and Black Spruce. There was also a lot of deadfall, though standing snags were rare. Smaller specimens of Eastern White Cedar, Balsam Fir, and Black Ash were also present. The Shrub layer was relatively sparse including only some sedges. The ground layer was dominated by sphagnum mosses. Sedges, Bunchberry, and Creeping-Snowberry occupied the moss hummocks and drier knolls that rose above small standing water puddles. This vegetation assessment is largely consistent with that done in by Bradford who labelled this area as tamarack-cedar-black spruce swamp.

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<th>Plant Species Code</th>
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<th>Wetland Indicator</th>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-7_13:
Well T3-7_13 is not of Bradford’s original wells. This location was selected to infill the network of existing monitoring wells whilst targeting a new vegetation community. This unit is best described as **Tamarack Organic Coniferous Swamp Type (SWCO2-2)**. There was a canopy of trees consisting of largely Tamarack. The understory consisted of Black Spruce and Eastern White Cedar. There was also a lot of deadfall, though standing snags were rare. The shrub layer was relatively dense with sedges, Goldenrod, Red Osier Dogwood, Royal Fern, and Tall Meadow Rue. The ground layer contained false mayflower, Dwarf Raspberry, and ferns in a matrix of thick sphagnum mosses.
Bradford Station: T3-7_13  
NVCA Station: New Well 7  
Elevation: 
Organics: thick organic layer  
2013 ELC Vegetation Type: SWCO2-2 Tamarack Organic Coniferous Swamp Type

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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-6_13

T3-6_13 is not one of Bradford’s Original Wells. This unit is a coniferous swamp unit. This unit is best described as **White Cedar Organic Coniferous Swamp Type (SWCO1-1)**. Trace Black Spruce over 10 m. were found in the canopy. Stunted White Cedar and Speckled Alder were common in this unit. The ground layer contained Goldenrods, Lake-bank sedge, ferns, other sedges, and asters. As well as Bunchberry, Goldthread, and Dwarf Raspberry all on a thick carpet of Sphagnum mosses. Organics extended well past 250 cm and were fibric and mesic in nature.

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<th>Plant Species Code</th>
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<th>Common Name</th>
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Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-5

T3-5 is one of Bradford’s Original Wells. This unit is a coniferous swamp unit. This unit is best described as **White Cedar – Conifer Organic Coniferous Swamp Type (SWCO1-2)**. This unit was assessed as a part of the 2009 report and that assessment is consistent with this one, identifying the unit as Cedar-Conifer Organic Coniferous Swamp (SWC3-2). The previous assessment found many more species of understory plants; this could be because of the timing of the survey. It would be expected that earlier in the season, more ground plants would be found. White Cedar, Black Spruce, and Tamarack were common in the canopy layer, with smaller Cedar specimens found in the understory. The shrub layer was rather sparse with only some occasional Royal Ferns. The ground layer was also sparse with Bunchberry, Dwarf Raspberry and Wild Sarsaparilla existing on the drier areas of moss hummocks. The ground was dominated by a layer of mosses.

<table>
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<th>Plant Species Code</th>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Wetland Indicator</th>
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Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog

Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-4
T3-4 is one of Bradford’s Original Wells. This unit is a coniferous swamp unit. This unit is best described as **Tamarack Organic Coniferous Swamp Type (SWCO2-2)**. This unit was assessed as a part of the 2009 report and that assessment is consistent with this one, identifying the unit as Tamarack Organic Coniferous Swamp (SWC4-2). The previous assessment found many more species of understory plants this could be because of the timing of the survey. It would be expected that earlier in the season, more ground plants would be found. Tamarack trees were dominant in the canopy layer, with Black Spruce and Balsam Fir only found in the understory. The shrub layer was rather dense with some speckled alder (especially in isolated areas), Royal Fern, Joe-Pye Weed, Ferns, Goldenrods, Cattails, and Tall Meadow-Rue common. The ground layer was abundant with sedges, Poison Ivy, and Dwarf Raspberry on a carpet of thick sphagnum mosses. The water table was 9-10 cm below ground level.

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<th>Plant Species Code</th>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-3

T3-3 is one of Bradford’s Original Wells. This unit is a coniferous swamp unit. This unit is best described as **Tamarack Organic Coniferous Swamp Type (SWCO2-2)**, although it is distinct from the last unit. This unit was assessed as a part of the 2009 report and that assessment is consistent with this one, identifying the unit as Tamarack Organic Coniferous Swamp (SWC4-2). The previous assessment found many more species of understory plants; this could be because of the timing of the survey. It would be expected that earlier in the season, more ground plants would be found. Tamarack trees were abundant with traces of Black Spruce in the canopy layers of this unit. The shrub layer was rather dense with some speckled alder (especially in isolated areas), Royal Fern, Rice Cutgrass, Ferns, and other graminoids. The ground layer was dominated by a thick carpet of moss. The water table was high at this location. Statics were taken at 1 and 5 cm below ground level.

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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-2

T3-2 is one of Bradford’s Original Wells. This unit is a coniferous swamp unit. This unit is best described as **White Cedar Organic Coniferous Swamp Type (SWCO1-1)**. This unit was assessed as a part of the 2009 report and that assessment is consistent with this one, identifying the unit as White Cedar-Conifer Organic Coniferous Swamp (SWC3-2). The previous assessment found many more species of understory plants; this could be because of the timing of the survey. It would be expected that earlier in the season, more ground plants would be found. Eastern White Cedar trees were abundant with traces of Tamarack in the canopy layers of this unit. The shrub layer was rather sparse with only some Royal Fern. The ground layer contained Dwarf Raspberry, Slender Wood Reedgrass, bedstraw, and Beggar’s Ticks on the hummocks of moss which dominated the ground layer. The water table was high at this location. Statics were taken at 0 and 3 cm below ground level.

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<td>T</td>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Station T3-2A_13

T3-2A_13 is a new well that was installed to provide infill the existing network of monitoring wells. This unit is a coniferous swamp unit. This unit is best described as **Tamarack Organic Coniferous Swamp Type (SWCO2-2)**. Stunted Tamarack were abundant in the unit. The shrub layer contained Winterberry and Speckled Alder in small amounts. The lower layers contained plenty of Royal Fern and Rice Cutgrass, along with lesser amounts of Sweet Gale, Goldenrods, Marsh Fern, Joe-Pye Weed, and Asters. The ground layer was dominated with Sphagnum mosses but also contained sedges, bedstraw, Marsh Marigold, and Dwarf Raspberry. There were several fen indicator species present in this vegetation unit: Tamarack, Speckled Alder, Winterberry, Royal Fern, Marsh Fern, and Sweet Gale. At this location we found that peat extended to 240 cm below ground. The organic layers progressed from fibric to mesic (Von Post 6) and back to fibric (Von Post 2). At 240 cm. Clay was found this clay contained organic particles and shells.

<table>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace
Stations T3-1, T3-1A_13

T3-1 is one of Bradford’s original wells. T3-1A_13 is a new well that was installed to provide additional data in the area of known HED occurrence events. This unit is a treed fen unit, as it has >10% tree cover, but still less than 25% tree cover (i.e. Swamp). This unit is best described as **Tamarack Treed Fen Type (FETC1-1)**. Station T3-1 was not evaluated as part of the 2009 exercise. There were few trees present. Only trace numbers of Tamarack were over 10 m. There were stunted Tamarack in isolated islands and sporadically throughout the unit, along with small amounts of Eastern White Cedar and Freeman’s Maple. American Reedgrass and Cattail occurred within the unit, though not in large numbers. Rice-cut grass and other sedges and rushes were the most abundant plant in the lower layers. Royal Fern, Sweet gale, Marsh St. John’s Wort, and Grass of Parnassus were present in the lower layers. Bog Laurel and Bog Rosemary, along with Bog Buckbean, and Pitcher Plant covered the ground layer. There were several fen indicator species present in this vegetation unit: Tamarack, American reedgrass, Royal Fern, Marsh Fern, Sweet Gale, Marsh St. John’s Wort, Grass of Parnassus, Bog Laurel, Bog Buckbean, Bog Rosemary, and Pitcher Plant.

Well T3-1A_13 was in the same unit as the evaluated location of station T3-1. At this location we found that peat extended to 240 cm below ground. The organic layers progressed from fibric (Von Post 4, and 2) to mesic (Von Post 5). At 240 cm. Clay was found and only 10 cm more of soil could be recovered. This clay contained organic particles and shells.
Bradford Station: T3-1
NVCA Station: 079
Elevation: 240 cm. of organics
2013 ELC Vegetation Type: FETC1-1 – Tamarack Treed Fen Type

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<td>Larix laricina</td>
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<td>Typha latifolia</td>
<td>Broadleaf Cattail</td>
<td>Y</td>
<td>M, S</td>
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<td>LEERORY</td>
<td>Leersia azyoides</td>
<td>Rice Cutgrass</td>
<td>Y</td>
<td>M, S</td>
<td>A</td>
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<tr>
<td>CARE SP</td>
<td>Carex sp.</td>
<td>Sedge sp.</td>
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<tr>
<td>OSMURE G</td>
<td>Osmundaregalis</td>
<td>Royal Fern</td>
<td>Y</td>
<td>S, F</td>
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<td>MYRIGAL</td>
<td>Myrica gale</td>
<td>Sweet Gale</td>
<td>Y</td>
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<td>TRIAFRA</td>
<td>Triadenum fraseri</td>
<td>Marsh St. John’s Wort</td>
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<td>PARNGLA</td>
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<td>Grass of Parnassus</td>
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<td>Eutrochium maculatum</td>
<td>Joe Pye Weed</td>
<td>Y</td>
<td>M, S</td>
<td>R</td>
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<td>THALPUB</td>
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<td>Tall Meadow-rue</td>
<td>M, S</td>
<td>R</td>
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<td>SOLI SP</td>
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<td>Goldenrod sp.</td>
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<td>ANDRPOI</td>
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<td>MELYTRI</td>
<td>Menyanthes trifoliate</td>
<td>Bog buckbean</td>
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<td>Pitcher Plant</td>
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<td>R</td>
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<td>Thelypteris palustris</td>
<td>Marsh Fern</td>
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<td>R</td>
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Wetland Indicator: Y = Yes, N = No
Wetland Type: S = Swamp, M = Marsh, F = Fen, B = Bog
Abundance: A = Abundant, D = Dominant, O = Occasional, R = Rare, T = Trace