Ephemeral Wetland Restoration of an Agricultural Floodplain in Walsingham Township, Ontario

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ABSTRACT
An integral challenge in the 21st century is the responsible management and protection of wetlands in southern Ontario, as urbanization, agriculture and pollution have significantly affected wetland distribution, connectivity, and biological diversity. In this report, the ecological function and genesis of vernal pools within the Carolinian landscape are explored, due to a lack of significant data and research regarding vernal pools, and their significance as diverse flora and fauna habitat in Ontario. Preliminary research into the ecological importance, structure and design of vernal pools was applied in developing and implementing plans to restore a degraded agricultural floodplain into a fully functional vernal pool. During October 2008, construction of the vernal pool was carried out on a volunteer landowner’s property in Walsingham township, Norfolk County, Ontario, as a private land stewardship initiative to combat fragmentation and subsequent loss of crucial Carolinian forest, prairie and wetland habitat. A detailed monitoring protocol was also developed using Environment Canada’s “Ecological Monitoring Assessment Network” parameters to monitor species indicative of overall ecosystem health and succession within the restored vernal pool ecosystem. Recommendations are made to continue monitoring for several years to effectively track the genesis of vernal pool habitat, and ultimately develop a clearer foundation for the future restoration and protection of vernal pool habitat throughout southern Ontario.

1.0 INTRODUCTION

Increased urbanization throughout southern Ontario has resulted in fragmentation of wetlands and natural areas, and subsequent anuran habitat decline (Findlay et al, 2001). Despite Ontario’s legislative efforts to curb wetland drainage, incremental wetland loss continues (Walters & Shrubsole, 2005). In particular, ephemeral wetlands are afflicted by urban and agricultural pressures on local and regional hydrologic regimes (Colburn, 2004). By disturbing natural hydrology, ephemeral wetlands that support biologically diverse communities are often replaced by terrestrial flora and fauna (Medley et al, 1995).

“Vernal pools and isolated forested wetlands are among the most threatened of freshwater wetlands globally” (Baldwin et al, 2006). Vernal pools are an important type of ephemeral wetland that are part of the Carolinian zone – one of southern Ontario’s most vulnerable ecozones (Haber, 1998). They typically form within or near wooded areas and forests, alvars, and sand dunes (Colburn, 2004). They are isolated, with no continuously flowing water year round, and remain small and relatively shallow compared to permanently flooded ponds and wetlands (Brooks, 2004; Colburn, 2004). Vernal Pools are seasonally inundated for a minimum of two months, and normally retain their highest water levels through the spring (Colburn, 2004). They often dry annually by the end of the summer, or every few years (Zedler, 2003; Colburn, 2004). During late summer, vernal pools often expose the majority of the pool bottom, which supports both aquatic and terrestrial communities through the spring and summer (Colburn, 2004).
2.0 RATIONALE

2.1 Vernal Pools

Vernal pools are characterized by the dynamic changes they endure over short periods, as well as the wide range of species they host (Zedler, 2003; Colburn, 2004). They are distinguished from permanent ponds and wetlands due to the wet-dry cycle that is central to their ecological function (Zedler, 2003; Brooks, 2004). This cycle prevents the establishment of predatory fish species, and provides safe breeding and rearing habitat for amphibians, invertebrates, and insects (Biebighauser, 2006). Obligate vernal pool species, including Fairy Shrimp (*Eubranchipus bundyi*), Wood Frog (*Rana sylvatica*), Spotted Salamander (*Ambystoma maculatum*), and Blue-spotted Salamander (*Ambystoma laterale*), remain threatened by fragmentation and destruction of ephemeral wetland habitat in southern Ontario (Ontario Vernal Pools Association (OVPA), 2008; Zedler, 2003).

Vernal pools are an important aquatic-terrestrial ecotone that transfer and store energy and material, and support biologically diverse communities (Zedler, 2003; Colburn, 2004). However, Ontario wetland conservation initiatives often overlook vernal pools as ‘significant wildlife habitat’ (Baldwin 2005; OVPA, 2008). This is largely due to the small size of vernal pools, and lack of information and research regarding the significance and identification of vernal pools throughout Ontario (Baldwin, 2005; OVPA, 2008).

Vernal pools represent an achievable goal in the restoration of Ontario’s drained wetland system, since they can be implemented on public lands, and through private land stewardship (as carried out in this restoration project). Increased research is needed into the ecologic and hydrologic functions of vernal pools – within the southern Ontario landscape – to successfully showcase their significance as wildlife habitat in Ontario.

2.1.1 Hydrology

Vernal pools are regularly fluctuating ecosystems that reflect localized hydrologic conditions, providing a diverse range of changing seasonal habitats. Vernal pools remain inundated for a minimum of two to three months to a maximum of five to ten years (Colburn, 2004; Zedler, 2003). Unlike other lentic ecosystems that are acutely isolated and ephemeral (i.e. rainwater pools), vernal pools have an extended hydroperiod that provide habitat for a range of flora and fauna throughout the seasons (Brooks, 2004; Zedler, 2003). Vernal pools are interconnected with local wetlands, ephemeral streams, creeks, and rivers, and support the migration of myriad aquatic, riparian and terrestrial species (Colburn, 2004; Zedler, 2003). Furthermore, some amphibians with extended larval periods, such as the Fowler’s Toad (*Bufo fowleri*), depend on constant, isolated small bodies of water into early summer (Colburn, 2004; Boone et al, 2006).

The primary water sources of vernal pools are precipitation, surface runoff, floodwater and groundwater (Zedler, 2003; Boone et al, 2006). Retention is reliant on the surface area of the pool, snow and rainfall input, and ecosystem structure, including soil type and vegetation (Boone et al, 2006; Colburn, 2004). Vernal pools within an upland environment are more dependent upon precipitation as a water input, whereas lowland pools support similar communities to nearby wetlands and fluvial systems (Baldwin, 2005; Colburn, 2004).
The greatest water input among most vernal pools is surface runoff, and is distributed via rainstorm and snowmelt, with maximum water volumes achieved during spring, and occasionally fall (Brooks, 2004; Colburn, 2004). Ephemeral streams also temporarily contribute to wooded vernal pool hydrology during the spring (Zedler, 2003; Colburn, 2004).

Groundwater inflow is another source of inundation that can affect pool hydrology most when depressions meet underlying reservoirs (Colburn, 2004). In such cases, some wetland plants can survive without the presence of standing water into late summer (Colburn, 2004). Groundwater input should be considered only in cases where local aquifers are common and shallow, since precipitation accounts for the primary inputs in most cases (Colburn, 2004).

Floodplains are an important part of a fluvial landscape that counteract water overflow associated with spring precipitation and melt (Paillex et al, 2009). Vernal pools are a compensatory landscape feature for flooding as well, and can form in floodplains and nearby fluvial systems, depending on location, topography and hydrology (Baldwin, 2005; Colburn, 2004; Boone et al, 2006). During spring and fall overflow, floodplains can be the primary inundation source for some vernal pools (the constructed pool is located within a floodplain), as well as connecting hydrologic regimes and promoting pool biodiversity (Colburn, 2004; Diefenderfer & Montgomery, 2009). Vernal pools located within floodplains often receive and hold water for extended periods, which can provide isolated aquatic habitat for species reliant on aquatic habitat into the summer (Colburn, 2004). Vernal pools have variable hydrology, and act as an indicator of local and regional hydrologic variation (Colburn, 2004). Annual inundation levels can fluctuate profoundly, and vernal pool hydrology is indicative of local and regional climate (Colburn, 2004). Hydrologic variance shapes the structure and ecology of vernal pools, and governs the natural adaptation and succession of aquatic and terrestrial flora and fauna (Colburn, 2004).

2.1.2 Flora

Vernal pools host myriad aquatic, riparian, and terrestrial vegetation types, which are primary sources of energy and materials that support established species. Plant distribution is most affected by flood duration and depth, as well as nutrient availability and sunlight (Biebighauser, 2006; Colburn, 2004). Vernal pool vegetation communities are typical of those found in local swamps, marshlands and other permanent wetlands (Zedler, 2003; Colburn, 2004). Categorically, there are two branches of plant community types that establish within a vernal pool environment (Colburn, 2004). Vernal pools can host vegetative ‘islands’ of novel wetland vegetation in an upland environment. Alternatively, they can act as low level depressions and support plant communities that reflect surrounding wetland ecology (Baldwin, 2005; Colburn, 2004).

As local hydrology changes, plant distribution is considerably affected within vernal pools. Pools that flood in the spring and dry during the summer encourage markedly different vegetation establishment during different times (Baldwin, 2005; Colburn, 2004). During spring fill, short-cycle and long-cycle pools are often covered with leaves floating on the water surface, with little vegetation within the basin (Colburn, 2004). Wetland sedges and grasses that establish in the spring decline as they are replaced by more terrestrial species (grasses, ferns and herbaceous annual plants).
Plant community establishment also depends on local seed bank, surrounding vegetation, and previously established perennials (Colburn, 2004). Plant community structure also differs annually, since plants are limited in their capacity to endure root flooding or drought, and local hydrology can vary drastically from year to year (Zedler, 2003; Colburn, 2004).

Established vegetation communities govern a considerable portion of vernal pool ecology since plant detritus is the primary contributor of materials and energy (Colburn, 2004). Vernal pools are an important feature of the Carolinian forest zone (Carolinian Canada, 2008; OVPA, 2008). A wide range of herbaceous vegetation inhabits vernal pools, with shrubs, grasses and ferns located within riparian zones, and sedges, rushes, and aquatic vegetation inundated within the pool (Colburn, 2004).

2.1.3 Fauna

Vernal pools support several invertebrate, amphibian, waterfowl, songbird, shorebird, and mammal species. Since vernal pools have no established populations of fish, a large majority of animals within such an environment thrive on the absence of fish predation (Colburn, 2004). The life history of resident vernal pool animals must also be adapted to periodic spring/fall flooding, as well as intermittent or annual summer droughts (Baldwin, 2005; Colburn, 2004).

The presence of aquatic, terrestrial and riparian vegetation plays a foundational role in the transfer of energy and materials throughout vernal pools, supporting fauna and retaining water (Colburn, 2004). Shading provided by vegetation cover preserves the hydroperiod of vernal pools by regulating temperature, and maintaining organic material input (M. Epaphras et al. 2006; Korhonen et al. 2006; Zedler, 2003; Colburn, 2004). Grasses, sedges, shrubs and woody plants provide cover for amphibians from terrestrial and aquatic predators (Colburn, 2004). Dead woody material within pools also provides habitat and safety from predators for amphibians, as well as surface area for amphibian metamorphosis (Diefenderfer, 2009).

Vernal pools provide vital ecological conditions for the survival of amphibian species (Baldwin et al, 2006). The lack of predatory fish species in vernal pools is essential for some amphibian species’ reproduction, and also provides safe temporary wetland habitat for adults (Colburn, 2004). Vernal pools host non-obligate amphibians as well, that dwell in different types of water bodies, including permanent wetlands (Brooks, 2004; Colburn, 2004).

Connectivity between surrounding forests and other temporary and permanent wetlands plays a large role in forming the amphibian community structure of vernal pools (Zedler, 2003; Colburn, 2004). Amphibian species developing in vernal pools migrate upland to neighbouring fluvial, wetland and terrestrial ecosystems where they interact and preserve regional amphibian diversity (Baldwin et al. 2006; Lichko & Calhoun, 2003). For example, Wood Frog (Rana sylvatica) populations must have other ephemeral pools within 1,000 m to perpetuate healthy gene exchange (Colburn, 2004).

The protection and restoration of vernal pools is largely centered on the vital ecological services and breeding habitat they provide to amphibians (Colburn, 2004; Baldwin et al. 2006). Obligate vernal pool amphibians require spatially and ecologically complex habitat for survival (Baldwin et al. 2006; Baldwin, 2005). Timing of metamorphosis and pool departure varies according to the hydrologic conditions of
Amphibians are the most abundant obligate vernal pool species. The presence of Wood Frogs (*Rana sylvatica*) within forested areas are indicative of nearby woodland vernal pools, since they depend on the habitat they provide during early spring precipitation and melt (Colburn, 2004; Baldwin et al, 2006). The survival of Spotted (*Ambystoma maculatum*), and Blue spotted Salamanders (*Ambystoma laterale*) is also contingent on vernal pools, since they require fishless habitat with considerable vegetative cover and woody debris to lay eggs during late March (Baldwin, 2005; Colburn, 2004; OVPA, 2008). The Jefferson Salamander is the most threatened obligate vernal pool amphibian species, with sparse populations located throughout Southern Ontario that are especially vulnerable to forest fragmentation, urbanization and wetland loss (Baldwin, 2005; OVPA, 2008).

Invertebrates are common in a vernal pool environment as well, and exist primarily as permanent resident communities, since inhabitant invertebrates lack significant dispersal capability (Williams, 1997; Colburn, 2004). *Anostracan crustacean*, commonly referred to as Fairy Shrimp, is the primary obligate invertebrate species that heavily depends on vernal pool habitat in Canada (OVPA, 2008; Williams, 1997). Fairy Shrimp prefer cold spring and fall water because they are adapted to coldwater wetland systems, and their eggs can last several years of drought within a pool’s substrate (Williams, 1997; Colburn, 2004).

### 2.2 Carolinian Canada: Genesis and Evolution

Southwestern Ontario has not always experienced the moderate climate and biodiversity of today. After glacial retreat, the initial vegetation was representative of today’s arctic landscape, first supporting mosses, lichens, ferns, grasses, sedges, rushes, wildflowers and shortly after insects, birds and large mammals (Waldron, 2003). The pioneer tree species were Tamarack (*Larix laricina*), White Spruce (*Picea glauca*) and Black Spruce (*Picea mariana*), creating a forest-tundra landscape with stands of trees scattered among initial shrubbery such as Red Osier Dogwood (*Cornus sericea*) and Willow (*Salix spp.*) (Waldron, 2003). With the next wave of migrants arrived Balsam Fir (*Abies balsamea*), Birch (*Betula spp.*), Ironwood (*Ostria virginiana*), Black Ash (*Fraxinus nigra*), Poplar (*Saliceae spp.*), White Cedar (*Thuja occidentalis*) and Blue-Beech (*Carpinus caroliniana*) along with large herbivores such as mastodons, mammoths, bison, moose, caribou and beavers (Waldron, 2003).

Another transition occurred around 10,000 B.P. which saw Jack Pine (*Pinus banksiana*), Red Pine (*Pinus resinosa*), White Pine (*Pinus strobus*), Hemlock (*Tsuga canadensis*), Elm (*Ulmus spp.*), Maple (*Acer spp.*) and Oak (*Quercus spp.*) establish in southern Ontario (Waldron, 2003). More species such as Butternut (*Caryocar nuciferum*), Beech (*Fagus spp.*), Ash (*Fraxinus spp.*) and Hickory (*Carya spp.*) migrated their way north. By 3,500 B.P., southern Ontario had moist, fertile soils supporting deciduous forest species, such as Sycamore (*Ficus spp.*), Basswood (*Tilia americana*),

In 1915, Canadian researchers first used ‘Carolinian’ to represent the region’s woodlands as a mix of oaks, maples, chestnuts, walnuts, elms, hickories, ashes, and more sparsely distributed species like black gum, paw-paw and cucumber tree (Waldron, 2003). This description is representative of most natural southern Ontario woodlands today.

### 2.2.1 Carolinian Forest Characteristics: Vernal Pools

Vernal pools are an important feature of the Carolinian zone that form in lowland depressions and hold excess spring melt water and precipitation (Johnson, 2009; Canadian Wildlife Service, 2005; OVPA, 2008). The presence of vernal pools is characteristic of a healthy and mature lowland Carolinian forest (Carolinian Canada, 2008; OVPA, 2008). Pools are usually formed from stochastic disturbances that drop dead or weak trees. Over time, pits and mounds form and hold water for extended periods (Canadian Wildlife Service, 2005). A Carolinian forest vernal pool supports Carolinian tree species that favour damp soil and have shallow roots, such as the Red Maple (*Acer rubrum*), Black Gum (*Nyssa sylvatica*), American Sycamore (*Platanus occidentalis*), and Black Willow (*Salix nigra*) (Colburn, 2004).

Vernal pools support an extensive range of wetland flora and fauna that distinguishes the biologically diverse Carolinian zone (Canadian Wildlife Service, 2005; Baldwin et al, 2006). Obligate vernal pool amphibians, such as the Wood Frog (*Rana sylvatica*), are dependent on the fishless aquatic habitat of vernal pools, and reach a critical population threshold when vernal pool habitat is reduced (Baldwin et al, 2006; Zedler, 2003). Amphibians, waterfowl, and mammals pass through vernal pools for food, rest and sustenance as well (Canadian Wildlife Service, 2005). Ephemeral groundcovers are the first plants to appear in the Carolinian forest, and thrive surrounding vernal pools (Johnson, 2009; Colburn, 2004). Ultimately, vernal pools represent a productive, energy rich ecotone of heightened biodiversity between the Carolinian forest ecosystem and ephemeral wetland systems (Johnson, 2009; OVPA, 2008).

### 3.0 SITE DESCRIPTION

#### 3.1 General Site Description

The restoration property is owned by private landowners, Brian Craig and Paula Jongerden. The property is 20 hectares in area, with roughly 12 hectares currently dedicated to restoration. It is located approximately 9.3 km SSW of Delhi, Ontario in North Walsingham township, in Norfolk County. Norfolk County is a city-status single-tier municipal government, touted as the forest capital of Canada (Craig, 2009). The property is on Lot 24, Concession 11, and to the south of the 12th Concession Road, where these is access to the property. Please refer to Appendix I for several maps showing the location of the property and project site.
3.2 Geology and Soils of Norfolk County

The geological history of Norfolk County was greatly influenced by the [roughly] 1,000 m thick glacier that once covered southern Ontario about 16,000 years ago (Waldron, 2003). The extent of the ice coverage was as far south as current day Ohio, Pennsylvania and New York States (Waldron, 2003). As global temperatures began to rise, ice melted and deposited a mixture of sand, silt, gravel and clay; these materials were accumulated over time in the glacier with past movement (Waldron, 2003). The melting glacier eventually formed lakes, where deposits of sand, silt, gravel and clay were made, also known as glaciolacustrine deposits. These glacial Lakes Whittlesey and Warren also formed a delta, with deposits of sands and silts (Chapman & Putnam, 1984). The delta was created as the glacier withdrew and deposited deltaic sands and silts that were carried from a large discharge of meltwater from the Grand River; this has formed what is now known as the Norfolk Sand Plain (see below).

The Norfolk Sand Plain extends from the north shore of Lake Erie northward to Brantford on the Grand River (Chapman & Putnam, 1984). The sand plain encompasses most of Norfolk County, the eastern end of Elgin County, southern Brant County and a small area of Oxford County, totalling 3,134 square kilometres (Chapman & Putnam, 1984).

Please refer to Figure 1 in Appendix I for a map showing the quaternary geology of the area. The restoration site is approximately outlined in red. As shown on the map, the restoration site has three different characteristics, represented by the numbers 9a, 11 and 13 and are defined as follows (Barnett & Girard, 1982):
9a: Glaciolacustrine shallow water and deltaic deposits slightly modified by wind, with fine to medium sand
11: Older alluvium in terrace remnants: fine to medium sand with occasional pebbles
13: Modern alluvium: clay, silt, sand, muck

Alluvium refers to materials deposited by water. At the restoration site, the majority of the area is classified as alluvium material due to the adjacent Big Creek that often floods; the remaining area is sandy.

Please refer to Figure 2 in Appendix I for a map showing the soils of the property and the surrounding area. Norfolk County was the first county in Ontario to complete a soil survey in 1928 for the purposes of selecting appropriate locations for tobacco cultivation (Chapman & Putnam, 1984). Areas of Plainfield sand (Ps) occupy the majority of land in Norfolk County, accounting for roughly thirty percent of the total area (Experimental Farms Branch, 1928). The coarseness of Plainfield sand allows water to drain freely, creating a thin surface soil horizon low in organic matter (Chapman & Putnam, 1984). Once the soils have been cultivated, the sand is highly susceptible to wind erosion due to the lack of soil organic matter that keeps the soil aggregated. Regular cropping in areas of coarse sand eventually exhausted the humus in the soil, farm output decreased, wind erosion further increased and as a result many farms were abandoned in the past (Chapman & Putnam, 1984).

On the restoration property, the soil type is classified as Fs, or well-drained coarse sand. Note that this soil type is not the same as Plainfield sand, but has similar characteristics, such as good drainage and coarseness. It occupies roughly ten percent of the total land area in Norfolk County (Experimental Farms Branch, 1928). Since it is well-drained and coarse, wind erosion is common with this soil type.
In other areas in Norfolk County, finer sands have allowed the development of Grey Brown Luvisols (Chapman & Putnam, 1984). Nowadays, areas with finer sands are preferred over areas with coarse sand due to the relatively higher fertility and moisture content (Chapman & Putnam, 1984).

### 3.3 Ecological Significance

#### 3.3.1 Site Hydrology: Big Creek Watershed

The project site is located adjacent to Big Creek on the floodplain of the property, where the agricultural field meets the forested riparian zone. Due to its proximity to Big Creek (<50 m) the site is directly influenced by its hydrologic regime throughout the year. After snowmelt in the spring, water levels often breach the banks and result in a partial or full inundation of the floodplain (location of project site). During the summer when water levels are lowest, the project site may experience unseasonably dry conditions. In either case, the seasonal and annual hydrological regime of Big Creek directly affects the study site and governs the conditions available for vegetation establishment and wildlife habitat from year to year. In the larger context, the Big Creek watershed is provincially significant, especially the coastal wetland of the Big Creek Marsh complex. The watershed covers an area of 723 km$^2$ and the Big Creek floodplain has been designated as an Area of Natural and Scientific Interest (ANSI) supporting wet meadows, marshes, shrub thickets and oxbow ponds (Shortt et al. 2004; Ontario Ministry of Natural Resources, 2008). The Big Creek Marsh complex, owned by the Canadian Wildlife Service, is located at its entrance to Lake Erie in Long Point’s inner bay and covers approximately 1,200 hectares (Bishop et al. 1996; Bunting et al. 1997). The marsh has been designated as a National Wildlife Area and is part of a UNESCO World Biosphere Reserve that provides globally significant habitat to a variety of bird, amphibian, invertebrate, and fish species (Ontario Ministry of Natural Resources, 2004). Restoring abandoned agricultural fields and wetland areas to mitigate historical losses in the region will act to enhance the ecological integrity of the Big Creek watershed.

#### 3.3.2 Vegetation: Seedbank

The project site is located on a floodplain area, adjacent to Big Creek. Therefore, the high water table and low lying elevation of the study site create favourable conditions for many wetland plant species. A preliminary vegetation inventory was completed and a comprehensive list of trees, shrubs, grasses, wildflowers, herbs, sedges, rushes and ferns was established. The list was established for the purpose of researching desirable and undesirable wetland species that were to be included in the wetland. The variety of wetland plant species already inhabiting the area will positively influence the vernal pool by providing a diverse seedbank to re-establish the area following excavation. The following (Table 1) is a comprehensive list of the identifiable vegetation at the project site:

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>Plantation Locale</th>
<th>Additional Info</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Populus deltoides</em></td>
<td>Eastern Cottonwood</td>
<td>Edge/Periphery</td>
<td></td>
</tr>
<tr>
<td>Species</td>
<td>Common Name</td>
<td>Habitat</td>
<td>Notes</td>
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</tr>
<tr>
<td><em>Acer rubrum</em></td>
<td>Red Maple</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Alnus glutinosa</em></td>
<td>European Alder</td>
<td>N/A</td>
<td>Invasive tree</td>
</tr>
<tr>
<td><em>Fraxinus pennsylvanica</em></td>
<td>Green Ash Tree</td>
<td>N/A</td>
<td>Pest/many seeds</td>
</tr>
<tr>
<td><em>Platanus occidentalis</em></td>
<td>American Sycamore</td>
<td>Riparian/Edge</td>
<td>Carolinian species</td>
</tr>
<tr>
<td><em>Nyssa sylvatica</em></td>
<td>Black Gum</td>
<td>Inundated/Riparian</td>
<td>Carolinian species</td>
</tr>
<tr>
<td><em>Liriodendron tulipifera</em></td>
<td>Tulip-Tree</td>
<td>Edge/Periphery</td>
<td>Carolinian species</td>
</tr>
<tr>
<td><em>Fraxinus nigra</em></td>
<td>Black Ash</td>
<td>Inundated/Riparian</td>
<td>Carolinian species</td>
</tr>
<tr>
<td><em>Acer saccharinum</em></td>
<td>Silver Maple</td>
<td>Inundated/Riparian/Edge</td>
<td></td>
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<tr>
<td><strong>Shrubs</strong></td>
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<td><em>Salix petiolaris</em></td>
<td>Slender Willow</td>
<td>Riparian/Edge</td>
<td></td>
</tr>
<tr>
<td><em>Salix bebbiana</em></td>
<td>Bebb’s Willow</td>
<td>Riparian</td>
<td></td>
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<td><em>Salix interior</em></td>
<td>Sandbar willow</td>
<td>Edge</td>
<td></td>
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<td><em>Cornus stolonifera</em></td>
<td>Red-Osier Dogwood</td>
<td>Riparian/Edge</td>
<td>Winter food</td>
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<td><strong>Herbs</strong></td>
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<td><em>Lythrum salicaria</em></td>
<td>Purple loosestrife</td>
<td>N/A</td>
<td>Aggressive, Invasive</td>
</tr>
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<td><em>Lysimachia ciliata</em></td>
<td>Fringed loosestrife</td>
<td>Edge</td>
<td></td>
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<td><em>Anenome Canadensis</em></td>
<td>Canada anemone</td>
<td>Riparian/Edge</td>
<td></td>
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<td><em>Apocynum medium</em></td>
<td>Intermediate dogbane</td>
<td>Riparian/Edge</td>
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<td><em>Eupatorium maculatum</em></td>
<td>Spotted Joe-Pye Weed</td>
<td>Riparian</td>
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<td><em>E. perfoliatum</em></td>
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<td>Inundated/Riparian</td>
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<td><em>A. syriaca</em></td>
<td>Common Milkweed</td>
<td>Periphery</td>
<td>Slightly wet-dry soil</td>
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<td>Swamp Milkweed</td>
<td>Riparian/Edge</td>
<td>Monarch larvae food</td>
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<td><em>Verbena hastate</em></td>
<td>Swamp Verbena</td>
<td>Riparian/Edge</td>
<td>Potential pest-clonal</td>
</tr>
<tr>
<td><em>Solidago Canadensis</em></td>
<td>Canada Golden Rod</td>
<td>Edge</td>
<td></td>
</tr>
<tr>
<td><em>Anemone quinquefolia</em></td>
<td>Wood Anemone</td>
<td>Edge</td>
<td>Requires shade</td>
</tr>
<tr>
<td><em>Petasites rigidus</em></td>
<td>Coltsfoot</td>
<td>Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Impatiens capensis</em></td>
<td>Yellow Jewelweed</td>
<td>Riparian</td>
<td>Supports hummingbirds</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Agrostis scabra</em></td>
<td>Tickle Grass</td>
<td>Edge</td>
<td>Soil dry out periodically</td>
</tr>
<tr>
<td><em>Leersia oryzoides</em></td>
<td>Cutgrass</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Phalaris arundinacea</em></td>
<td>Reed Canary Grass</td>
<td>Edge</td>
<td>Aggressive when disturbed</td>
</tr>
<tr>
<td><em>Phragmites australis</em></td>
<td>Common Reed</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><strong>Sedges</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cyperus schweinitzii</em></td>
<td>Umbrella Sedge</td>
<td>Riparian/Edge</td>
<td></td>
</tr>
<tr>
<td><em>Carex bebbii</em></td>
<td>Bebb’s Sedge</td>
<td>Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Carex stipata</em></td>
<td>Awl Fruited Sedge</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Carex diandra</em></td>
<td>Lesser Panicled Sedge</td>
<td>Riparian</td>
<td></td>
</tr>
<tr>
<td><strong>Rushes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Juncus tenuis</em></td>
<td>Path Rush</td>
<td>Riparian/Edge</td>
<td></td>
</tr>
<tr>
<td><em>S. atrovirens</em></td>
<td>Black Bulrush</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Juncus canadensis</em></td>
<td>Canada Rush</td>
<td>Riparian</td>
<td></td>
</tr>
<tr>
<td><em>Scirpus validus</em></td>
<td>Softstem Bulrush</td>
<td>Riparian</td>
<td></td>
</tr>
<tr>
<td><strong>Ferns</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Equisetum fluviatile</em></td>
<td>Water Horsetail</td>
<td>Inundated/Riparian</td>
<td></td>
</tr>
<tr>
<td><em>E. arvense</em></td>
<td>Field Horsetail</td>
<td>Riparian/Edge</td>
<td></td>
</tr>
</tbody>
</table>
3.3.3 Contribution to Big Picture
The project site is located in the heart of the Carolinian forest; an ecozone extending from the southeastern United States to its northernmost range in southern Ontario. The small portion of the range within southern Ontario is commonly referred to as Carolinian Canada. Carolinian Canada represents only 1% of the country's area, but hosts more species of flora and fauna than any other ecosystem in Canada, including 2,200 herbaceous plants and 70 types of trees (Carolinian Canada, 2008). Carolinian Canada harbours one third of all the rare, threatened and endangered species in the country; including 351 of Ontario’s 542 rare plants, trees such as the paw-paw, tulip and kentucky coffee tree, rare birds including the Prothonotary Warbler (*Protonotaria citrea*) and Acadian Flycatcher (*Empidonax virescens*) and a variety of reptiles and amphibians such as the Blue Racer snake (*Coluber constrictor foxii*) and Blanchard’s Cricket Frog (*Acris crepitans blanchardi*) (Carolinian Canada, 2008; Murphy & Meloche, 2006).

Historically, agricultural and urban developments have caused habitat fragmentation and continue to threaten the ecological integrity of the Carolinian forest in southern Ontario. Declines in forest cover have been more pronounced in areas with fertile soils for agriculture, most notably in Essex County, where approximately 3% of historical forest cover remains today (Carolinian Canada, 2008). However, large scale tree planting and woodland restoration initiatives are progressing, and areas like Norfolk County now support up to 30% forest cover (Tony Difazio, Personal Communication, 2008). Norfolk County has also been historically dominated by agriculture, however, recent efforts from non-government conservation-based organizations and individual landowners have helped reverse this trend. Carolinian Canada, a non-profit conservation based organization, recently established the Big Picture Program; an initiative working to connect core areas of Carolinian habitat, and create a more contiguous forest network (Carolinian Canada, 2008). As they mature through time, it is hoped that the ephemeral wetland and surrounding Carolinian forest will positively contribute to regional landscape ecology. As the forest matures, it will help mitigate historical habitat fragmentation in Norfolk County by adding to the network of forest corridors planned through the Big Picture Project by Carolinian Canada. The vernal pool will enhance the ecological functionality of the surrounding environment, being a characteristic feature of the Carolinian forest ecosystem and providing habitat for rare and endangered native Carolinian species.

4.0 SHORT TERM OBJECTIVE

4.1 Wildlife Habitat Creation
The primary objective in constructing the vernal pool was the creation of new habitat for various migratory and static species. Vernal pools are a specialized breeding habitat that offer protection to species adapted to living in a fish free environment (Colburn, 2004). They also provide small-scale wetland habitat to migratory waterfowl that are challenged by increasingly fragmented wetland systems (Semlitsh, 2003; Lichko & Calhoun 2003). Species that are adapted to the ephemeral conditions within vernal pools are negatively affected by human influence and climate change (Brooks, 2004). Moreover, vernal pools are not well protected in Canada, given that their size often
excludes them as significant wildlife habitat; largely due to a lack of information on vernal pools and municipal resource constraints (OVPA, 2008).

The constructed vernal pool will act as an aquatic-terrestrial ecotone, directly connecting Carolinian forest, riparian floodplain, and adjacent Big Creek. Ecotones are a congregation of communities that rely on one or several habitats, and are regions of heightened biodiversity (Kolasa1 and Weber, 1995; Zalewski et al, 2001). Similarly, the constructed vernal pool will provide habitat and sustenance for a biologically diverse variety of plant and animal species. The pool will provide habitat for diverse wildlife, most importantly amphibians, waterfowl and endangered and at risk species. The landowner identified several species using a nearby red maple swamp on the property, including Spring Peepers (Pseudacris crucifer), Wood frogs (Rana sylvatica), Gray Tree frogs (Hyla versicolor), Pickerel frogs (Rana palustris) Green frogs (Rana clamitans), American toads (Bufo americanus), Western Chorus frogs (Pseudacris triseriata), Wood ducks (Aix sponsa) and other waterfowl. As the pond matures to a swamp, it will provide a sanctuary for the aforementioned species, as well as the endangered Prothonotary Warbler (Protonotaria citrea) and species currently under review by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), such as the Western Chorus Frog (Pseudacris triseriata) and Jefferson Salamander (Ambystoma jeffersonianum). Although amphibians and waterfowl are the most typical species associated with vernal pools, it is hypothesized that a diverse group of wildlife will be attracted. A monitoring program will begin in spring 2009, to measure important wetland indicators.

5.0 LONG TERM OBJECTIVES

5.1 Sediment Trap
Centuries of agricultural development are attributed to the loss of ephemeral and permanent wetlands throughout the Big Creek watershed (Durley, de Loe and Kreutzwiser, 2003). Increased agricultural activity has resulted in significant erosion, harming the health and productivity of the land as well as the dynamics (i.e. suspended solids, substrate) of nearby wetlands and waterways (Rengstorff, 2001).

Over time, the constructed vernal pool will trap sediments from meltwater and precipitation runoff, and will receive its largest sediment input via Big Creek overflow during spring, and occasionally fall. The accumulation of sediment and summer drying will allow the constructed pool to become contained, forming integral habitat for ephemeral wetland species (Florsheim and Mount 2002). Therefore, the vernal pool will act as a sediment trap by restricting sediment inputs into Big Creek, as one of the main objectives.

5.2 Groundwater Recharge
Walsingham township is dependent on groundwater as one of the primary water sources serving the rural population. The groundwater is used for irrigation and domestic uses (Dryden-Cripton, 2005). Rural water use in the area has had a significant impact in the area, since consumption is highest during dry summer months, when groundwater plays the largest role in regulating water levels throughout the Big Creek watershed (Dryden-Cripton, 2005). Furthermore, groundwater regulates temperature and maintains the Big Creek coldwater ecosystem that harbours the trout and salmon species that
require consistently cold temperatures (Dryden-Cripton, 2005; Ontario Ministry of Natural Resources, 2008).

Vernal pools recharge groundwater as they are inundated for significant periods (Biebighauser, 2006). The surface area of the constructed vernal pool is approximately 1,700 m$^2$, and will provide groundwater recharge to adjacent Big Creek. By providing a consistent groundwater input, it is hypothesized that this ecological service will assist in the maintenance of the Big Creek coldwater ecosystem.

5.3 Restoration of Agricultural Land
A large hill adjacent to the constructed vernal pool, as well as the surrounding property, has a history of agricultural use. Sediments, pesticides and fertilizers have run off into adjacent Big Creek due to significant tillage, mono-cropping, bare soil, and use of conventional agricultural techniques. The result has been a decline in the fertility of local soil, alteration of the landscape, and increased sediment input into Big Creek. The implementation of the vernal pool, combined with reforestation and native vegetation introduction throughout the property, will allow the gradual restoration of land affected by extensive agricultural use.

6.0 RESTORATION METHODOLOGY

6.1 Replication of Hydroperiod
One of the most important characteristics of vernal pool ecosystems is the hydroperiod (seasonal inundation and drying of the wetland) (Brooks, 2004). Vernal pools are temporarily flooded which promotes amphibian breeding in the spring and summer, however they usually dry up by late summer providing juveniles safety from fish and other predators (Semlitsh, 2003; Lichko & Calhoun 2003). Therefore, when creating an artificial wetland is it essential to design for an appropriate depth that will create an appropriate hydro-period. If the wetland is too deep it might still be flooded in late summer and predatory fish could establish; on the other hand if the wetland is too shallow it might dry up too early and prevent amphibian breeding altogether. As mentioned earlier, one of the main objectives for this vernal pool restoration project is to create wildlife habitat, especially for amphibian breeding. A variety of literature on wetland creation/restoration recommended the use of standard reference wetlands to replicate specific desired functions (Brooks et al. 2008). To achieve the goal of creating an optimal hydroperiod this reference wetland principle was used with a hardwood swamp on the property. The reference wetland exhibited many characteristics that were desired for the created vernal pool including the hydro-period. Furthermore, surveying equipment was used to measure the difference in elevation between the water level in Big Creek and the bottom of the reference wetland. The survey equipment was then used to measure the difference in elevation between the water level in Big Creek and the ground level of the project site. Lastly, the difference between the two measurements (0.9m) was concluded to be the appropriate depth for the vernal pool. Therefore, in order to replicate the hydro-period of the reference wetland, the vernal pool was excavated to approximately 0.9 m, or 3 feet.
6.2 Natural Shape
Although the project essentially involves creating an artificial ecosystem, an important objective was to implement methods that would replicate a naturally functioning wetland. Many artificially created ponds and wetlands are designed to take a circular, uniform shape which is not representative of how that system would naturally exist in the environment. Designing the vernal pool to take an irregular shape with random perimeter contours will allow for a natural appearance and will be more representative of a naturally occurring vernal pool as it matures over time (Brian Craig, Personal Communication, 2008). In order to achieve this, the excavator was instructed to create irregular waves and contours around the perimeter of the wetland. This method not only results in a more natural ecosystem, but also increases the area of littoral zone which provides extra habitat for plants, amphibians, waterfowl and other species.

6.3 Slope
As mentioned above, one of the main functions of vernal pools is to provide a safe breeding area for amphibians throughout spring and most of the summer (Lichko & Calhoun 2003). Creating a proper hydroperiod and incorporating desirable vegetation were methods implemented to attract and provide habitat for amphibians and other species. Another technique/method was included in the design to enhance the conditions for survival of newly born amphibians. When born in the spring and summer, juveniles emerge from their aquatic birthplace into the surrounding terrestrial environment. A variety of external factors, including slope, can affect the ability of newborn amphibians to successfully emerge and survive. Based on recommendations from restoration ecologist Allan Arthur and Paul Gagnon, a gradual 1:4 slope was established for the wetland to facilitate a smooth, stress free exit. It is believed that a gradual slope will decrease potential stress on juvenile amphibians and increase their chances of surviving and inhabiting the wetland area and surrounding Carolinian forest.

6.4 Construction: Description of Parameters
The pond has been designed to take an irregular, non-uniform shape based on landscape characteristics and desired functions. The surface area of the proposed pond is approximately 1,700 m$^2$. The depth is approximately 0.9 m, with several depressions of 1.3 m, and a 1:4 slope along the littoral zone. Based on the surface area, depth and slope, the total volume of fill to be excavated is roughly 1,400 m$^3$. The spoils were placed adjacent to the project site on the east and southwest sides and the disturbed areas planted with native prairie grasses, shrubs and trees.

6.5 Vegetation
Within the boundaries of the vernal pool (approximately 1,700 m$^2$), many native wetland species were established. Those species deemed beneficial to the constructed pool ecosystem were removed and transplanted into the constructed pool, while invasive and noxious vegetation were buried under the spoils. A “self-design” approach was adopted in re-establishing resident plant communities due to adaptations of existing vegetation to the local environment (Mitsch et al, 1998).

During construction (October 2008), the research team removed species catalogued as beneficial carefully by hand to ensure their survival. Seeds of native
Boneset (*Eupatorium perfoliatum*) and wetland grasses were also collected for later distribution within the pool’s riparian zone. Collected species were temporarily placed in water or soil for replacement the following day. Saved species were planted within the vernal pond according to each species’ habitat requirements. Prior to planting, vegetation species were catalogued into four habitat categories according their preferences:

1. **Inundated**: plant species that require an aquatic, submerged habitat for survival.
2. **Riparian**: plant species that require intermittent flooding and saturated, sandy soil.
3. **Edge**: plant species that require wet sandy soil, with little submersion.
4. **Periphery**: plant species that require moist to dry, sandy soil without submersion.

Following the completion of the vernal pond construction, saved species were transplanted to their habitat regions within the vernal pool. Seeds of native wetland grasses and *E. perfoliatum* were distributed throughout the pool’s riparian zone to help combat erosion and promote habitat.

### 7.0 PROSPECTIVE MONITORING

#### 7.1 Protocol Introduction

The following section outlines the rationale and plans for implementing the monitoring protocol. Monitoring will focus on eight key wetland indicators; amphibians, butterflies, vespsids, vesicular-arbuscular mycorrhizal (VAM) fungi, aquatic invertebrates (benthos), dragonflies, birds and vegetation (Craig, 2009 & Murphy (a), 2009). The objective of the protocol is to measure the ecological integrity of the wetland and also contribute to local, regional, provincial and national biodiversity databases.

At the restoration site, three transects will be setup as a simple method for monitoring some of the environmental indicators included in this protocol, specifically butterflies, vespsids and dragonflies. A variety of alternative monitoring methods are used for the remaining indicators. Transects will be setup in the spring/summer of 2009 with wooden stakes and fluorescent markers. Each transect will run the entire length of the wetland, with a width of two meters. Transects along 1) a riparian zone, 2) a littoral zone and 3) an area in the ‘regeneration’ or spoils zone will be the focus for monitoring to ensure that different types of habitats are represented in the observations. Please note that all monitoring sheets are found in Appendix II.

#### 7.2 Amphibian Monitoring

Amphibians are important environmental indicators. When combining the effects of habitat fragmentation, increasing ultraviolet radiation and agrochemical and human pollutant discharge into surface waters, these factors (among others) are effectively reducing amphibian populations worldwide.

Since other prevalent amphibians such as salamanders search for mates by smell, males of most frog and toad species attract mates by sound (Unknown (c), 2002), each with a distinct “song.” An amphibian expert or a well-trained ear can determine which species are present, and approximately how many. A methodology was adopted from Environment Canada’s Ecological Monitoring and Assessment Network (EMAN), named FrogWatch, and is further described below.
The following information on frogs is from the FrogWatch website, a valuable resource for monitoring frogs across Canada. (Unknown (c), 2002)

In late March, male frogs will begin to call for mates. The first species to be heard are Spring Peepers (*Pseudacris crucifer*) and Wood (*Rana sylvatica*) and Chorus (*Pseudacris triseriata*) frogs. Larger species such as the Bullfrog (*Rana catesbeiana*) could start calling in June or July. Ideally, monitoring should occur once or twice a week from March to July; however a single monitoring event is still useful. The individual(s) monitoring should listen for at least three minutes, at dusk, or after a rainfall.

Individual(s) performing the monitoring will fill out the **FrogWatch Observation Form**, which can be found in Appendix II. Monitoring for frogs should occur annually, and results compared. To identify species, it is recommended taking an amphibian identification guide for Southern Ontario when monitoring in the field. For further reference, Appendix III gives a list of the 13 different frog species in Ontario, each with a link to hear the individual songs.

### 7.3 Butterfly Monitoring

Butterflies are great ecological indicators partly due to the different environmental requirements throughout metamorphosis, i.e. from larva to pupa, and into an adult butterfly (Batra, 2006). Butterflies are particularly sensitive to disturbances in microclimatic regimes and land-use changes, and are useful indicators of overall habitat quality (Batra, 2006).

Due to rapid changes in land-use, industrial proliferation, agricultural intensification and an exponentially increasing human population, natural habitats are suffering - particularly wetlands (Moron et al, 2008). As a result, the natural landscape is becoming more fragmented with rampant habitat and species loss.

Since butterflies are sensitive to land-use changes and intensified agriculture, they are important ecosystem indicators of habitat connectivity or fragmentation (Murphy (a), 2009) in addition to overall habitat quality. Therefore, habitat connectivity or fragmentation will also be measured by the presence of butterflies.

Monitoring for habitat connectivity or fragmentation is most meaningful five to ten years after restoration begins (Murphy (a), 2009). This will allow for the establishment of native vegetation and niche habitats which promote connectedness across the landscape. This component of the monitoring protocol will be useful for measuring long-term ecosystem success.

The approach for monitoring butterflies is described in further detail below, adapted from Batra (2006) and McIlveen (1999).

For butterfly monitoring, the transect method involves an individual walking along the transects and identifying butterflies in flight or resting. Butterflies outside the two meter transect will be excluded. Butterflies that cannot be identified are recorded as unidentified or caught using a butterfly net for further identification and released afterwards.

Monitoring should occur in the early summer, i.e. May, June, July, when there is the greatest abundance and diversity of species. Butterflies should be identified to the species, and the number observed, even for the most common species. If feasible, the plant host species and where the butterfly was observed should be recorded. Also, it is important to make the same observations pertaining to butterfly larvae or caterpillars.
These observations can be made along the same butterfly transects with close attention to the vegetation to which the larvae adhere.

Individual(s) performing the monitoring will fill out the **Butterfly Observation Form**, which can be found in Appendix II. Monitoring for butterflies and larvae should occur annually and results compared. To identify species, it is recommended taking a butterfly identification guide for Southern Ontario when monitoring in the field.

### 7.4 Vespid Monitoring

Also known as wasps, the vespidae family has roughly 300 different species in North America; examples include yellowjackets, paper wasps, hornets and pollen wasps (Johnson & Triplehorn, 2004). Wasps are important for the pollination of some plant species and predate and parasitize various insect species, effectively keeping insect populations stable (Johnson & Triplehorn, 2004). Therefore, vespid is good ecosystem indicators (Murphy (a), 2009).

Vespid monitoring should occur late in the season, around the end of August and into September (Murphy (a), 2009). It is during this time when male drones are produced and are outside the nest looking for mates (Johnson & Triplehorn, 2004). Monitoring will occur along the same two meter wide transects used for butterfly and other monitoring activities. Individual(s) performing the monitoring will walk along the transects and catch all vespid species in flight or at rest for identification and released afterwards. The use of an insect net is required for capturing. Wasps that cannot be caught are recorded as unidentified but still counted. Also, wasps outside the transect area are excluded.

Individual(s) performing the monitoring will fill out the **Vespid Observation Form**, which can be found in Appendix II. Monitoring for vespids should occur annually and results compared. To identify species, it is recommended taking a vespid identification guide for Southern Ontario when monitoring in the field. A free online guide titled Identification Atlas of the Vespidae (*Hymenoptera, Aculeata*) of the Northeastern Nearctic Region by the Biological Survey of Canada is available from the following link: [http://www.biology.ualberta.ca/bsc/ejournal/ejournal.html](http://www.biology.ualberta.ca/bsc/ejournal/ejournal.html).

### 7.5 Fungi Monitoring

Soil fungi are integral for sustaining ecosystems. As primary decomposers, soil fungi are non-photosynthetic and will use dead or living organic matter for energy (Oelbermann, 2008). Soil fungi have the greatest biomass of all soil organisms and are the first visual clues that organic matter decomposition is occurring (Oelbermann, 2008). Fungi decompose cellulose, lignin and other complex compounds and will return decomposed organic materials back into the soil, effectively increasing the soil organic matter content (Oelbermann, 2008). Soil organic matter helps with soil aggregation, and reduces erosion.

Mycorrhizae are types of soil fungi that form mutualistic relationships with plant roots (Oelbermann, 2008). Also, mycorrhizal relationships improve plant nutrient uptake in infertile soils (Pagano & Scotti, 2008). Mycorrhizae hyphae (fungi roots) can extend up to 100 times or greater the root length of a plant, allowing further access to water and nutrients (Oelbermann, 2008). It is noteworthy to mention that a common mistake in restoration is failure to restore soil VAM fungi (Murphy (b), 2005).
Two types of mycorrhizal fungi, Ectomycorrhizae (ECM) and Vesicular-Arbuscular Mycorrhizae (VAM) are important indicators of soil quality and ecosystem health (Murphy (a), 2009). Mycorrhizal fungi greatly increases soil aggregation, acting as a soil cement. ECM fungi improves root penetration and increases nutrient uptake 10 to 100 times that if no ECM fungi available; the fungi transports mineral nutrients to plant roots that would otherwise be inaccessible (Murphy (b), 2005). VAM fungi increases phosphorus uptake in plants (Murphy (b), 2005) which is a limiting nutrient in many ecosystems. As a result of increased phosphorus uptake, the vegetation will have increased disease and pest resistance and increased growth (Murphy (b), 2005).

To monitor mycorrhizal fungi, a relatively simple procedure will be explained below for growing VAM fungi based on the Trap Culture Method of Murphy (b), 2005. Growing ECM fungi is difficult, requiring specific environmental conditions and will likely be unsuccessful unless growing in an industrial or commercial setup (Murphy (b), 2005). Therefore, VAM fungi will be monitored using the Trap Culture Method and will be used as the indicator for fungi monitoring.

VAM Trap Culture Method:

The VAM Trap Culture Method for fungi monitoring will be focused in the regeneration, or spoils area of the restoration site. The steps are described in detail below.

1. Dig up the root ball and the surrounding rhizosphere for any plant species, removing all above-ground vegetative growth.
2. Using a garden spade, axe or similar apparatus, break up the soil and root ball.
3. Remove all roots that are present and separate from soil.
4. Break the roots into smaller fragments.
5. Mix root fragments with sterile potting soil.
6. With large zip-loc bags, mix sterile potting soil and root fragments (Step 5) with sterile coarse sand (1:1.5 ratio).
7. Fill 15 cm diameter gardening pots with mixture from Step 6.
8. Germinate seeds or transplant a stem(s) or a shoot(s) from a species of interest.
9. Gardening pots can be placed under artificial lighting or put outside.
10. Photoperiod should be 14:10, i.e. 14 hours sunlight, 10 hours darkness.
11. If using artificial lighting, consider the specific lumen output and the requirements of the plants and adjust accordingly.
12. Water plants once per week (roughly 400 mL per pot) and no fertilizers added (Stinson et al., 2006).
13. Leave plants in pots alone for 4 months.
14. After 4 months, allow soil and plants in pots to dry out and remove light source.
15. Allow pots to dry out for 2 weeks.
16. Remove all above-ground vegetative growth and put soil (and root ball) from each pot into individual zip-loc bags and leave alone for 30 days.
17. After 30 days, remove the soil and root ball from the bags and cut (vertical) into 3 equal sections.
18. Place each of the sections into a separate household blender containing distilled water.
19. Run blender at highest speed for 7 seconds to break up plant roots and release fungus spores. The coarse sand should adhere to the bottom of the blender.
20. Sieve material from blender through 500 um and 45 um tandems.
21. VAM Fungi spores end up in the 45 um sieve, with loosely aggregated soil/organic muck on the 500 um sieve.
22. Depending on the quantity of material in the sieves, use a 50 – 250 mL flask with rubber stopper for transporting. Add both sieved materials to the flask.
23. Pour material from flasks to an area(s) of interest in the field.

Monitoring for VAM fungi should occur annually and results compared. For comparison, the volume of material in the 45 um sieve (i.e. VAM fungi spores) will be used as the indicator. Individual(s) performing the monitoring will fill out the Fungi Observation Form, which can be found in Appendix II.

7.6 Aquatic Invertebrate Monitoring
Aquatic invertebrate monitoring will focus on the benthic communities of the wetland. To monitor benthos in the wetland, the Ontario Benthos Biomonitoring Network (OBBN) Protocol Manual, written by Jones et al. (2004), will be used. Monitoring for benthos will be completed during the fall season (Murphy (a), 2009).

Aquatic benthos measures ecosystem health as indicators of freshwater quality. Benthos respond well to environmental disturbances and are useful for determining the following changes in water quality: nutrient loading and eutrophication; dissolved oxygen concentration; presence of contaminants (i.e. dissolved metals) and toxins (herbicides such as Atrazine); acidification; salinization; sedimentation. These changes in water quality will influence species abundance, diversity and community composition. (Adamus and Brandt, 1998)

Individual(s) performing the monitoring will fill out the OBBN Field Sheet - WETLANDS, which can be found in Appendix II. It is also found in Appendix 6 of the OBBN Protocol Manual. Monitoring for benthos should occur annually and results compared. To identify benthos, Appendix 1 of the OBBN Protocol Manual provides a guide.

7.7 Dragonfly Monitoring
Dragonflies are an integral part of wetland ecosystems as top predators of invertebrates while providing prey for vertebrate species such as frogs and birds (Rice and Foote, 2002). Researchers often use dragonflies as ecosystem indicators because they are easier to identify relative to other insects and small invertebrates and are dependent on ecosystem components below, notably benthos (Parks Canada, 2008). Dragonflies will often respond to changes in the food web providing an excellent indication of wetland health (Rice and Foote, 2002; Parks Canada, 2008).

Monitoring dragonfly populations in the wetland will be completed via collecting and counting exuviae (exoskeletons) after ecdysis. Ecdysis is a biological process in which dragonflies and other invertebrates shed the external protective skeleton during growth (Foster and Soluk, 2003). Using exuvia to monitor dragonflies has recently proven to be more effective than traditional methods such as adult/larvae collection and mark-recapture; larvae do not necessarily mature to adults, and recapturing is often
difficult (Foster and Soluk, 2003). Monitoring will begin in late spring and continue throughout the summer to coincide with dragonfly ecdysis. Monitoring will occur along the same 2 m wide transects used for butterflies and vespids. The process will involve walking along each 2 m wide transect and collecting identifiable dragonfly exoskeletons from vegetation surfaces, surface water and the riparian zone. Monitoring activity will focus on exoskeleton counts and recording the locations of highest density. Counting exuvia is indicative of the wetland supporting successful breeding and metamorphosis (Foster and Soluk, 2003). Recording the locations of highest exuvia density will provide insight into favorable microhabitat requirements for dragonfly breeding in wetlands (Foster and Soluk, 2003).

Individual(s) performing the monitoring will fill out the Dragonfly Observation Form, which can be found in Appendix II. Monitoring for dragonflies (exoskeleton counts) should occur annually and results compared. To identify species, Bugs of Ontario, written by Acorn and Sheldon (2003), provides good reference material.

7.8 Bird Monitoring
The focus for bird monitoring will be establishing a species list, abundance monitoring and demographic monitoring for waterfowl, songbirds, shorebirds and rare/endangered bird species within the wetland. The field methods used will be directly from the EMAN standardized Monitoring Bird Populations in Small Geographic Areas protocol by Dunn et al. 2006. The species list will be completed using the visual/aural survey technique of an area search and focus on identifying species. Abundance monitoring will be completed also using the visual/aural survey technique, focusing on population counts and species composition. Demographic monitoring will be completed using techniques for reproductive success including nest counts, mist netting and breeding activity.

Monitoring for birds in the wetland will include waterfowl, songbirds, shorebirds and rare/endangered species. Monitoring will be completed throughout all four seasons due to the lack of migratory species at certain times of the year (Dunn et al. 2006). Waterfowl and shorebirds typically feed on plants and invertebrates and healthy populations can be attributed to the condition of vegetation and invertebrate (bentho) communities in the wetland (Wetland Regional Monitoring Program, 2002). Songbirds typically nest in upland areas but also prefer the variety of vegetation throughout the aquatic-terrestrial ecotone (Nova Scotia Museum of Natural History; Reinert and Mello, 1995). Therefore, monitoring songbirds will be indicative of wetland conditions and the health and functionality of the surrounding upland environment and ecosystem as a whole. Similar to dragonflies, waterfowl, shorebirds and songbirds will respond to ecosystem perturbations making them an excellent bio-indicator for wetland health.

Individual(s) performing the monitoring will fill out the Bird Observation Form, which can be found in Appendix II. Monitoring for birds should occur annually and results compared. To identify species, it is recommended taking an identification guide for Ontario birds when monitoring in the field.

7.9 Vegetation Monitoring
Vegetation monitoring will be completed using the standardized EMAN Terrestrial Vegetation Biodiversity Monitoring Protocol written by Pichette and Gillespie.
Instead of using established transects, permanently marked quadrats of varying sizes will be implemented as per the methods used in the above protocol (Pichette and Gillespie, 2001). Vegetation monitoring will be completed in July (Murphy (a), 2009). The Canopy-Tree Stratum Biodiversity Protocol methods are not applicable to this project, because a wetland ecosystem is being monitored, not a mature forest community. However, both the Shrub and Small-Tree and Ground Vegetation Stratum Biodiversity Monitoring Protocols will be followed to monitor wetland vegetation. Previous vegetation inventories identified a variety of shrubs, small-trees and ground cover species, making the Shrub and Small-Tree and Ground Cover Protocols applicable.

Individual(s) performing the monitoring will fill out the Vegetation Observation Form, which can be found in Appendix II. Monitoring for vegetation should occur annually and results compared. To identify species, it is recommended taking the identification guide for wetland plants titled Wetland Plants of Ontario, written by Newmaster, Harris and Kershaw (1997) when monitoring in the field.

8.0 TIMELINE AND FUNDING

The restoration project began in the winter of 2008 when a site visit was made to the property to meet the landowner and brainstorm possible restoration and rehabilitation that would be feasible for an undergraduate study. First, extensive research on ephemeral wetlands, specifically vernal pools, was completed and a preliminary proposal to excavate and construct the wetland was prepared.

In the summer of 2008, two site visits were made to speak with local experts in regards to hydrology, vegetation and wetland design. A vegetation survey was done to identify desirable and undesirable species (i.e. invasive or non-native species). Also, surveying helped to determine an appropriate depth to excavate the new wetland, based on the depth of a ‘reference’ wetland on the opposite end of the property. After preliminary research, speaking with experts, and field work was complete, two proposals were sent to the Long Point Region Conservation Authority (LPRCA) to 1) excavate, and 2) establish vegetation.

Funding was granted and excavation and transplanting began on October 14th, 2008. By October 16th, the entire wetland had been excavated and desirable vegetation transplanted, followed by riparian zone seeding.

9.0 LESSONS LEARNED

The most significant learning opportunity for this restoration project is determining whether or not the newly established wetland is working; will the wetland be effective at achieving the long-term goal to ultimately create a functional, productive vernal pool ecosystem? This uncertainty is a major issue that is problematic for many restoration ecologists. Through researched methodologies, one intuitively knows that restoration is occurring, but with very little quantitative data to support this assumption (Craig, 2009). Therefore, the Monitoring Protocol for the wetland will be invaluable in the long term, perhaps five to ten years post-restoration. It will serve as a measure of ecosystem health and functionality by monitoring key environmental indicators.
Another area for further learning is additional knowledge of local Carolinian flora. The vegetation was expectedly different in its appearance during October when excavation and transplanting occurred compared to the summer when identification was completed. As a result, some species listed as ‘desirable’ were removed and buried in the excavation spoils such as Blue Vervain (Verbena hastate) which was mistaken for Purple Loosestrife (Lythrum salicaria). On the other hand, since most plants had gone to seed, collection was easy for placement in the riparian area after excavation.

At times, excavation was very quick in some areas and recovery of some native species for transplanting was difficult. For instance, only two Swamp Milkweed (Asclepias incarnate) individuals were recovered, which are highly desirable due to its ability to attract butterflies. Although unavoidable, it is assumed that some desirable species and individuals were also buried in the spoils. For future projects, perhaps visiting the site and recovering the most vital vegetation prior to excavation could be useful. Overall, through trial and error, the project was a great learning experience.

10.0 CONCLUSION

Due to the nature of this project, representative results cannot be reached until initial monitoring is completed in spring 2009. Successional changes will begin to take effect in spring 2009, as vegetation, amphibians and other species adapt to the wetland environment. Preliminary monitoring results will be obtained by fall 2009 for amphibians, vegetation and any other indicators present at this time. However, several years of monitoring is warranted to establish comprehensive results regarding the ecosystem structure and function of the wetland. Monitoring all suggested indicators over several years will provide representative results to determine whether the restored wetland effectively fulfilled the primary objectives.

11.0 ACKNOWLEDGEMENTS

Considerable support was provided by Dr. Stephen D. Murphy and Brian Craig, who co-advised the research, design and construction of the project. Additional gratitude is extended to Paul Gagnon from Long Point Region Conservation Authority, Jonathan Morgan from the University of Waterloo Map & Design Library and Paula Jongerden for her generosity and hospitality.
12.0 APPENDIX I - MAPS

Figure 1: Quaternary geology of the Tillsonburg Area.
Source: Barnett, P.J., and Girard, C.K., 1982
Figure 2: Soils of Norfolk County, Ontario.
Source: The Experimental Farms Branch, 1928
Figure 3: Wetland project site location.
13.0 APPENDIX II – MONITORING PROTOCOL

**FrogWatch Observation Form**

Abundance Codes:
1. No frogs or toads seen or heard
2. Frog(s) or toad(s) seen but not heard
3. Individuals can be counted, calls not overlapping
4. Some individuals can be counted, other calls overlapping
5. Full chorus, calls continuous and overlapping

<table>
<thead>
<tr>
<th>Date:</th>
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<tbody>
<tr>
<td>Name of Observer:</td>
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<tr>
<td>Location Name:</td>
<td></td>
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<tr>
<td>Air Temperature:</td>
<td></td>
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<tr>
<td>Water Temperature:</td>
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<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance Code</th>
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</table>

**Additional Information:**


Butterfly Observation Form

<table>
<thead>
<tr>
<th>Species</th>
<th>Butterflies</th>
<th>Larvae/Caterpillars</th>
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Additional Information (behaviour, sex, plant host species):
**Vespid Observation Form**

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<th>Date:</th>
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<tbody>
<tr>
<td>Name of Observer:</td>
</tr>
<tr>
<td>Transect Name/Location:</td>
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<tr>
<td>Air Temperature:</td>
</tr>
<tr>
<td>Water Temperature:</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Count</th>
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</table>

**Additional Information:**
# Fungi Observation Form

**Date:**

**Name of Observer:**

**Location:**

**Air Temperature:**

**Water Temperature:**

<table>
<thead>
<tr>
<th>Name of Plant Grown</th>
<th>Volume of Spores (45 μm sieve)</th>
<th>Volume of organics/muck (500 μm sieve)</th>
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</thead>
<tbody>
<tr>
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**Additional Information (grown indoors/outdoors):**
Ontario Benthos Biomonitoring Network Field Sheet - WETLANDS

Date: 
Time: 
Agency: 
Investigators: 

Wetland Name: 
Site #: 
Location: centroid of 3 replicates; Lat/Long or UTM 
Elevation (m asl): 
Datum & zone: 

Water Quality 
Water Temperature (°C): 
DO (mg/l): 
Conductivity (uS/cm): 
Alkalinity (mg/l as CaCO₃): 

pH: 

Site Description and Map 
Draw a map of the site (with landmarks) and indicate areas sampled. Attach photograph (optional)
Show north arrow.

Benthos Collection 
Method (circle one): 
* Traveling Kick & Sweep 
* Jab & Sweep 
* Coring 
* Artificial Substrate 
* Other (specify): 

Gear Type (circle one): 
* D-net 
* Corer 
* Rock Baskets 
* Other 
Mesh Size: 500 micron (or specify)

Replicates | Sampling distance covered (m) | Time (min.) | Max. Depth (m) | # Pooled per replicate | Location (UTM or Lat./Long; note datum, zone) |
--- | --- | --- | --- | --- | --- |
Sample 1 |  |  |  |  |  |
Sample 2 |  |  |  |  |  |
Sample 3 |  |  |  |  |  |
### Substrate

**Enter dominant substrate class and second dominant class for each sub-sample**

<table>
<thead>
<tr>
<th>Dominant</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
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</thead>
<tbody>
<tr>
<td>2nd</td>
<td></td>
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</table>

### Substrate Notes

### Organic Matter-Areal Coverage

| Use: 1: Abundant, 2: Present, 3: Absent and circle dominant type |
|-------------------------------|-------------------|
| Woody Debris                  | Detritus          |

### Riparian Vegetative Community

*Use: 1 (None), 2 (cultivated), 3 (meadow), 4 (scrubland), 5 (forest, mainly coniferous), 6 (forest, mainly deciduous)*

<table>
<thead>
<tr>
<th>Zone (dist. From water's edge)</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
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<tbody>
<tr>
<td>1.5-10 m</td>
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<tr>
<td>10-30 m</td>
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<tr>
<td>30-100 m</td>
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</table>

### Aquatic Macrophytes and Algae

*Use: 1: abundant, 2: Present, 3: Absent. Circle dominant type*

<table>
<thead>
<tr>
<th>Macrophytes</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
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<tbody>
<tr>
<td>Emergent</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Rooted Floating</td>
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<td>Submerged</td>
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<tr>
<td>Free Floating</td>
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### Aquatic Algae

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<thead>
<tr>
<th>Algae</th>
<th>Sample 1</th>
<th>Sample 2</th>
<th>Sample 3</th>
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<tbody>
<tr>
<td>Floating Algae</td>
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<tr>
<td>Filaments</td>
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<tr>
<td>Attached Algae</td>
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<tr>
<td>Slimes or Crusts</td>
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### Wetland Description

- Marsh
- Fen
- Other
- Swamp
- bog
- Riverine, floodplain
- Coastal (lakeshore)
- Riverine, headwater
- Inland
- Seasonal
- Unknown
- Permanent

### Wetland Morphometry (optional, will be calculated by OB3N Coordinator using OFAT)

- Surface area (m²): 
- Perimeter (m):

### Notes (esp. related to land-use, habitat, obvious stressors)

### Candidate reference Site - Minimally Impacted? (circle one)

- Yes
- No

### General Comments

Wetland Sheet-Pg. 2, Updated April 2005
# Dragonfly Observation Form

**Date:**

**Name of Observer:**

**Transect Name/Location:**

**Air Temperature:**

**Water Temperature:**

<table>
<thead>
<tr>
<th>Number of exoskeletons</th>
<th>Location found</th>
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**Additional Information:**


**Birds Observation Form**

**Date:**  
**Name of Observer:**  
**Location:**  
**Air Temperature:**  
**Water Temperature:**

Species list:

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Abundance monitoring:

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<th>Species</th>
<th>Tally</th>
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Demographic monitoring (list species if possible):

<table>
<thead>
<tr>
<th>Nest count</th>
<th>Breeding activity</th>
<th>Mist netting (if applicable)</th>
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Additional Information (behaviour):
**Vegetation Observation Form**

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<tbody>
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<tr>
<td>Quadrat Name/Location:</td>
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<td>Water Temperature:</td>
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<table>
<thead>
<tr>
<th>Shrub</th>
<th>Small tree</th>
<th>Ground cover</th>
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**Additional Information:**


14.0 APPENDIX III: FROG SONGS
Source: (FrogWatch, 2002)

American Toad (*Bufo americanus*)
http://www.naturewatch.ca/databases/frogs/audio/bufo_americanus.wav

Blanchard's Cricket Frog (*Acris crepitans blanchardi*)
http://www.naturewatch.ca/databases/frogs/audio/acris_crepitans.wav

Boreal Chorus Frog (*Pseudacris maculata*)
http://www.naturewatch.ca/databases/frogs/audio/pseudacris_maculata.wav

Bullfrog (*Rana catesbeiana*)
http://www.naturewatch.ca/databases/frogs/audio/rana_catesbeiana.wav

Fowler's Toad (*Bufo fowleri*)
http://www.naturewatch.ca/databases/frogs/audio/bufo_fowleri.wav

Gray Treefrog (*Hyla versicolor*)
http://www.naturewatch.ca/databases/frogs/audio/hyla_versicolor.wav

Green Frog (*Rana clamitans*)
http://www.naturewatch.ca/databases/frogs/audio/rana_clamitans.wav

Leopard Frog (*Rana pipiens*)
http://www.naturewatch.ca/databases/frogs/audio/rana_pipiens.wav

Mink Frog (*Rana septentrionalis*)
http://www.naturewatch.ca/databases/frogs/audio/rana_septentrionalis.wav

Pickerel Frog (*Rana palustris*)
http://www.naturewatch.ca/databases/frogs/audio/rana_palustris.wav

Spring Peeper (*Pseudacris crucifer*)
http://www.naturewatch.ca/databases/frogs/audio/pseudacris_crucifer.wav

Western/Striped Chorus Frog (*Pseudacris triseriata*)
http://www.naturewatch.ca/databases/frogs/audio/pseudacris_triseriata.wav

Wood Frog (*Rana sylvatica*)
http://www.naturewatch.ca/databases/frogs/audio/rana_sylvatica.wav
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Murphy, Stephen (a). "Questions for report." E-mail to 'Andrew Dean'. 26 Jan 2009.


