**Expanded Work Plan for EPA QAPP Review**
**Non-regulatory Wetland Pilot Demonstration Grant**

# PRIORITIZING PROTECTION OF VULNERABLE WETLANDS IN THE QUEEN'S RIVER WATERSHED

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## 1. Introduction

Vernal pools are widely recognized as critical habitat for a variety of vertebrates and invertebrates. In recent years, their protection from human impacts has been a major conservation and regulatory goal throughout New England. These valuable wetlands are increasingly at-risk as a result of their small size (often <0.25 acre), isolated nature, and seasonal drying, which may make them difficult to identify at certain times of the year.

Recent research has shown that the presence, abundance, and diversity of amphibians breeding in an individual vernal pool may be influenced by both landscape characteristics and features within the pool itself. Since 1997, scientists at the University of Rhode Island's Department of Natural Resources Science (NRS) have identified many of these key characteristics and used them to develop methods for assessing the suitability and potential productivity of individual pools for breeding wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*). Much of this research has been conducted in the Pawcatuck River watershed. Among the most important factors affecting the presence and reproductive effort (number of egg masses) of these species were the hydroperiod, or duration of inundation of a pool, and the amount of forest cover, the extent of residential development, and road density within varying distances from the pool. During the last 5 years, NRS faculty and graduate students have developed two rapid assessment methods for estimating a pool's long-term hydroperiod—one based on plants growing in the deepest zone, and the other based on features such as basin depth, water chemistry, geology, and tree canopy cover. These accomplishments are highly significant because (1) hydroperiod appears to be the single most important within-pool factor controlling productivity of pond-breeding amphibians, and (2) these methods eliminate the need for prolonged monitoring of pools for hydroperiod determination.

Currently, vernal pool protection is largely a reactive process; wetland regulations are applied when vernal pools lie in the path of proposed land use changes. And vernal pool regulation, even if it is successful, may do little to maintain pond-breeding amphibian populations unless a way can be found to protect suitable terrestrial habitat around the pools as well. Limited funds preclude the acquisition of all upland habitats needed to sustain pond-breeding amphibian populations. What is urgently needed is a watershed-scale plan that identifies those specific geographic regions that support both highly productive vernal pools and high-quality upland habitats and that prioritizes these areas for protection. NRS scientists have generated the tools to accomplish such habitat assessment and prioritization; this workplan describes how these tools will be applied to develop a vernal pool acquisition plan at the watershed scale, using the Queen's River watershed as an example.

## 2. Key Objectives, Outcomes, and Products

*Objectives* - The overall objective of this project is to identify specific “hotspots,” or geographic areas that are capable of supporting unusually high productivity or an unusually diverse community of pond-breeding amphibians, as a basis for prioritizing land protection efforts.

Specific objectives are:

- To use hydroperiod estimation models, along with GIS analyses and both new and existing field data, to rank individual pools, pool clusters, and specific geographic areas (hotspots) in the Queen’s River watershed in terms of their probable contributions to pond-breeding amphibian abundance and diversity.
- To recommend for immediate protection specific hotspots, as well as upland-forested areas linking such hotspots to each other and to currently protected lands.
- To explain how future efforts to develop watershed-based vernal pool protection plans might be streamlined.

*Outcomes*
As a result of the project, state and federal agencies, municipal governments (e.g., Exeter, West Greenwich, South Kingstown, Richmond), land trusts (e.g., South County Conservancy and municipal land trusts), watershed associations (e.g., Wood-Pawcatuck), and non-governmental conservation organizations (e.g., The Nature Conservancy, Audubon Society of RI) will better understand which specific areas of the Queen’s River watershed need protection if pond-breeding amphibian populations and other vernal pool fauna are to be maintained. This information will help to guide open space acquisition, land-use management, and preservation of biodiversity. Results should be of particular interest to the DEM Division of Fish and Wildlife as it begins implementing its statewide habitat conservation plan under the State Wildlife Grants (SWG) program. At the same time, this project will help the landowners of the Queen’s River watershed to appreciate the important role that their individual parcels may play in maintaining vernal pool wildlife.

*Products* - The major products will include:

- A GIS database of vernal pools in the Queens’ River watershed, including data on attributes such as estimated hydroperiod, extent of forest cover within certain distances of each pool, parcel information and landowner names and contact information, and other landscape metrics.
- A final report that (1) identifies high-priority pools, high-priority pool clusters, geographic regions where high-priority pools or pool clusters are surrounded by suitable forested habitat (i.e., pond-breeding amphibian hotspots), and those areas where such pools or clusters lack suitable surroundings but where forest might be restorable; and (2) recommends protection of specific hotspots and upland forest areas linking such

hotspots to each other and to currently protected lands, as well as how to streamline future efforts to develop vernal pool protection plans at the watershed scale (separate memorandum).

## 3. Project Tasks and Environmental Outcomes

This project would involve use of new and existing data obtained in the field and through GIS analyses. It would also involve application of hydroperiod estimation models and other methods developed by NRS faculty and graduate students over the last 8 years. The basic tasks are as follows, in rough chronological order:

- Complete contracting to initiate project.
- Develop outreach strategy working with DEM, WPWA and other project partners.
- Conduct landscape analyses for all potential vernal pools mapped by the RI Chapter of The Nature Conservancy in the Queen's River watershed. These analyses will include measurements of forest cover within certain distances of each pool, as well as distances among pools to identify pool clusters. This step will allow pools to be prioritized for study should time become a factor in study site selection, egg-mass counts, or any other phase of the work; pools with more suitable landscape characteristics would be given higher priority for study.
- Identify pool landowners using town plat maps and seek permission for access to each site.
- Field-check accessible sites to verify suitability for study (e.g., upland context, lack of perennial water connection, and lack of disturbance).
- Recruit and train volunteers for egg-mass counts and vernal pool hydroperiod estimation (see Attachment 1).
- Develop field sampling QAPP for EPA approval.
- Count egg masses deposited by wood frogs and spotted salamanders in all study pools during the spring of 2006 with the help of volunteers (see Attachment 2). Egg-mass counts will serve as a check on potential productivity levels derived from hydroperiod model estimates.
- Monitor water levels in as many study pools as possible in order to determine hydroperiods in 2006. Hydroperiod is defined as the number of weeks from 1 March until a pool dries up for at least 2 weeks (Mitchell 2005). The help of landowners and other volunteers will be enlisted to accomplish this task (see Attachment 1). 2006 hydroperiod observations will serve as a check on hydroperiods estimated by the models. *Note*: *Project personnel obtained hydroperiod data on 10 vernal pools within the Queen's River watershed during 2001-2004. Data from those years will be compared to 2006 data from the same pools in order to place 2006 hydroperiod data from all other pools into a long-term hydrologic perspective.*

- At each study pool, collect data that are needed to estimate the long-term hydroperiod using one or both of the NRS models. The Skidds and Golet (2005) model requires data on surficial geology, basin depth, tree canopy cover, specific conductance of surface water, and soil parent material texture (see Attachment 3). The Mitchell (2005) model requires identification of plants growing within 1.5 m of the deepest point in the pool (see Attachment 4).
- Estimate the long-term hydroperiod of each study pool using the Skidds and Golet (2005) and Mitchell (2005) models and place each pool into one of four categories: Class 1, <20 weeks beginning on 1 March (i.e., drying by mid-July in most years); Class 2, 20-27 weeks (i.e., drying between mid-July and early September in most years); Class 3, 28-36 weeks (i.e., drying between early September and early November in most years); and Class 4, 37-44 weeks (i.e., drying after early November or not at all in most years).
- Use pool hydroperiod classifications and GIS data to identify (1) individual pools, pool clusters, and specific geographic areas within the Queen's River watershed that are capable of supporting unusually high productivity or an unusually diverse community of pond-breeding amphibians; and (2) specific geographic areas with potentially productive pools or clusters but unsuitable surroundings where forest could be restored.
- Prepare a final report documenting project work and recommending (1) protection of specific hotspots and upland forest areas linking such hotspots to each other and to currently protected lands, as well as (2) how to streamline future efforts to develop vernal pool protection plans at the watershed scale.
- Conduct a workshop to convey project results to interested parties.

## 4. Transfer of Project Results

The final report will be posted on the DEM website where it will be accessible to all interested parties. Agencies and organizations that are likely to find these results especially useful include: DEM Planning and Development Land Acquisition Program, DEM Division of Fish and Wildlife, DEM Natural Heritage Program, DEM Division of Forest Environment, DEM Wetland Programs, RI Chapter of The Nature Conservancy, Audubon Society of RI, RI Natural History Survey, Wood-Pawcatuck Watershed Association, South County Conservancy, and municipal land trusts in the Towns of Exeter, West Greenwich, Richmond, and South Kingstown.

## 5. Project Evaluation

This project will produce a prioritization of vernal pools and pool clusters in the Queen's River Watershed. It constitutes a characterization of habitat suitability for a portion of the State's vernal pools. The work involves continued validation of a modeling tool developed by URI. The success of the model will be evaluated based on rate of participation (willingness of landowners to allow access) and validation of model with field data. The modeling results will provide the basis for an acquisition plan to be used by state and local entities. Over time, RIDEM will track the success in acquisition in the watershed.

Review comments will be sought by the DEM Office of Water Resources on a draft copy of the final report. All or most of the above agencies and organizations will be encouraged to submit comments which will then be addressed in the final draft. At the same time, these groups will be surveyed by DEM with regard to the value of this study to them individually, and recommendations for future improvements in such studies will be solicited.

## 6. Timeline

This project will take place during 2006. The major tasks will follow the general schedule below:

- *Jan-Feb*: Landscape analysis, outreach strategy, landowner identification and contacts, field-checks to select study pools.
- *Mar-Apr*: Landowner identification and contacts, field-checks, egg-mass counts.
- *May-Jun*: Complete field-checks, begin hydroperiod monitoring, begin collection of field data for Skidds' hydroperiod estimation model.
- *Jul-Oct*: Monitor hydroperiods, collect data for Skidds' and Mitchell's models, begin pool hydroperiod classification.
- *Nov-Dec*: Complete hydroperiod classification; identify high-priority pools, pool clusters, and geographic areas for protection; prepare final report; conduct workshop.

## 7. Roles and Responsibilities/Distribution List

- Dr. Frank Golet, Principal Investigator: Overall coordination of project; direct supervision of Research Associates; preparation and submission of final products to DEM and EPA.
- Dr. Peter Paton, Co-investigator: Participation in design, data analysis and interpretation, and preparation of final report.
- Jon Mitchell, Research Associate: Design; landowner contacts; field-checks; landscape analyses; coordination of egg-mass counts and hydroperiod monitoring; collection of field data for hydroperiod estimations; estimation of pool hydroperiods, identification of high-priority pools, pool clusters, and geographic areas for protection; preparation of final report.
- Dennis Skidds, Research Associate: Participation in project design, landscape analyses, limited collection of field data, hydroperiod

estimation using the Skidds and Golet (2005) model, and review of draft final report.

- Susan Kiernan, Deputy Chief, RIDEM Office of Water Resources: Contract management and primary RIDEM contact.
- Matt Schweisberg, EPA Project Manager: Primary EPA contact.
- Steve DiMattei, EPA QA Chemist: Review of work plan to assure compliance with EPA QAPP requirements.

## 8. Literature Cited


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## Attachment 1

## Volunteer Recruitment and Training

Volunteers may be used to assist project personnel in amphibian egg-mass counts (see Attachment 2) and vernal pool hydroperiod observations. Volunteers will be recruited from one or more of the following groups: (1) vernal pool landowners in the Queen's River watershed, (2) undergraduate and graduate students in the URI Department of Natural Resources Science, (3) the Wood-Pawcatuck Watershed Association, and (4) the Rhode Island Association of Wetland Scientists.

*Egg-mass counts.* Prior to any actual counts, project personnel will take all volunteers into the field, teach them how to identify egg masses of wood frogs (*Rana sylvatica*) and spotted salamanders (*Ambystoma maculatum*), demonstrate how to conduct a thorough egg-mass search in each pond, and instruct them regarding the timing and frequency of counts (see Attachment 2).

*Vernal pool hydroperiod observations.* For this task, volunteers will be asked to visit their assigned site(s) at least biweekly, starting in April 2006, and to record the date on which each pool first goes dry (i.e., the pool basin lacks any visible surface water) and remains dry for at least 2 weeks.

The Principal Investigator will maintain a list of all active volunteers, along with their telephone numbers and e-mail addresses. We will provide each volunteer with a map and written directions to each assigned pool, as well as the name of the landowner and designated parking area. We will accompany volunteers on the first trip to any pools that may be difficult to locate. Volunteers will be asked to forward their field data (egg-mass counts by species and drying dates of pools) to project staff (Jon Mitchell or Frank Golet) within 1 week of data collection; communication shall be by e-mail (preferably) or regular mail.

## Attachment 2

## Amphibian Egg-mass Counts

If landowner contacts and vernal pool site suitability field-checks are completed prior to the completion of egg-laying by wood frogs and spotted salamanders (typically between late March and late April in most years), we will attempt to count egg masses of these two species in as many study pools as possible. The general procedure will be to wade the entire perimeter of each pool, counting all egg masses seen within a depth of 4 feet or less (see Crouch and Paton [2000] for details). Counts will be conducted once a week following the first indication that breeding has begun and will continue until no newly deposited egg masses are detected. The maximum daily count for each species shall be considered the official count for that pool in 2006.

## Attachment 3

### Vernal Pool Hydroperiod Estimation:  Skidds and Golet (2005)

During 2001 and 2002, the URI Department of Natural Resources Science conducted intensive field research on factors correlated with the hydroperiod, or duration of inundation, in 65 vernal pools (also known as seasonal forest ponds) in the Rhode Island section of the Pawcatuck River watershed.  The results of this research appear in a Master's thesis (Skidds 2003) and a scientific journal paper (Skidds and Golet 2005).

The primary objective of this work was to develop a model for estimating pool hydroperiod from other onsite data so that amphibian habitat suitability assessments could be made without prolonged monitoring of water levels.  Surface water levels were monitored at all pools for 2 years, and data were gathered on a large number of other site characteristics relating to pool morphology, surficial geology, water chemistry, and vegetation structure.  Ultimately, we produced a multivariate regression model that explained nearly 60% of the variation in pool hydroperiod among the 65 pools.  Using this model, we were able to correctly identify ponds with hydroperiods suitable for wood frog (*Rana sylvatica*) breeding 95% of the time and spotted salamander (*Ambystoma maculatum*) breeding 75% of the time.  The model contains six variables.  Two are dummy-coded variables describing surficial geologic setting (alluvium or dense till), while the other four are tree canopy cover, open basin depth, texture of soil parent material, and specific conductance of surface water.  Below is a brief description of how each characteristic is assessed.

*Surficial geology*.  The surficial geologic setting of a vernal pool is determined by overlaying an ArcInfo GIS coverage of pools mapped from 1995 aerial photographs by the Rhode Island Chapter of The Nature Conservancy on a surficial geology coverage developed by Rosenblatt (2000) from the Rhode Island Soil Survey (Rector 1981).  The geology of each pool is classified as loose till, dense till, glacial fluvial deposits, or alluvium.  The accuracy of the classification is checked in the field at each pool by soil augering and corrections are made, if necessary.  Pools that lie on alluvium or dense till are coded as such for the purposes of the regression model.  Pool hydroperiods tend to be relatively long on dense till and relatively short on alluvium (Skidds 2003).

*Tree canopy cover*.  Using a GRS densitometer, the canopy cover of all plants at least 3 meters in height is assessed at each pool.  Presence or absence of overhead foliage is noted at 1-meter intervals along each of three transects crossing the pool—one spanning the long axis of the pool and the other two perpendicular to the first at one-third and two-thirds of the distance along its length.  The transects extend from the high-water mark on one side of the pool to the high-water mark on the opposite side.  The number of points with overhead foliage is expressed as a percentage of the total number of sample points.  Tree canopy cover was negatively correlated with pond size ($r = -0.70$, $p<0.0001$) in the Skidds and Golet (2005) study.

*Open basin depth*. This variable is calculated by subtracting the elevation of the lowest point in a pool basin from the average elevation at the pondward limit of tree stems on the three vegetation sampling transects (see tree canopy cover section above). Elevations are determined using a Topcon AT-G6 autolevel and height rod and expressed relative to the deepest point in the basin. Basin depth pondward of the peripheral tree zone has been shown to be a stronger predictor of pool hydroperiod than maximum pool depth (Skidds and Golet 2005).

*Texture of soil parent material*. The texture of the soil in the C horizon is estimated at the deepest point in each pool and placed into one of four categories based on medium sand content (Soil Survey Division Staff 1993): (1) silts and silt loams with <30% medium sand, (2) fine sandy loams with 30-50%, (3) sandy loams or fine sands with 51-70%, or (4) loamy sands and sands with >70%.

*Specific conductance of surface water*. Three water samples are collected from widely scattered locations in each pool between mid-May and mid-June, before significant evaporative losses have occurred, and at least 3 days after the most recent rain event. If practicable, samples are collected at least 7 days after rain events of 1 inch (2.54 centimeters) or more. Samples are collected at least 2 meters from the current shoreline, and approximately 30 centimeters below the pool surface. Sample bottles are filled and capped under water, placed in a refrigerator at the end of the day, and allowed to return to room temperature before analysis. Analyses are done within 48 hours of sampling. Measurements (µS/cm) are made with an Oakton 35630-02 pH/conductivity meter. The three values from each pool are averaged. A 2-point calibration (1,000-µS and 147-µS potassium chloride solutions) is performed at the beginning and end of each measurement day. Values within ±10% of the standards are deemed acceptable.

For each pool, values for the six variables are entered into the multivariate hydroperiod estimation model (see below) and an average hydroperiod is calculated. Each pool is then placed into one of four hydroperiod categories, depending on the duration of inundation beginning on 1 March: Class 1, <20 weeks; Class 2, 20-27 weeks; Class 3, 28-36 weeks; and Class 4, 37-44 weeks.

*Hydroperiod estimation model:*

$$\text{Mean hydroperiod}_{(\text{weeks})} = 22.33 + [-2.50*\text{Alluvium}_{(0,1)}] + [5.41*\text{Dense till}_{(0,1)}] + [0.99*\text{Open basin depth}_{(\text{m})}] + [-10.52*\text{Canopy cover}_{(\text{proportion})}] + [0.05*\text{Specific conductance}_{(\mu\text{S/cm})}] + [1.24*\text{Parent-material texture}_{(\text{ordinal})}]$$

## Attachment 4

## Vernal Pool Hydroperiod Estimation: Mitchell (2005) Approach

One of our project personnel, Jon Mitchell, developed a method for estimating the hydroperiod class of a vernal pool (also known as a seasonal pond) from the hydroperiod classes of the plants growing in the deepest zone of the pool. His findings appear in his Master's thesis (Mitchell 2005).

From 2001 through 2003, Jon monitored surface water levels in 65 vernal pools in the Rhode Island section of the Pawcatuck River watershed. Toward the end of each growing season he sampled the plants in each pool using a line-intercept approach (Canfield 1941) along three transects—one spanning the long axis of the pool and the other two perpendicular to the first at one-third and two-thirds of the distance along its length. The transects extended from the high-water mark on one side of the pond to the high-water mark on the opposite side. Substrate elevations were recorded at 1-meter intervals along each transect using a Topcon AT-G6 autolevel and height rod and were related to biweekly shoreline elevations so that the hydroperiod (in weeks) could be calculated for each 1-centimeter elevation interval, and for each individual plant sampled, in each year.

Annual frequency distributions were then used to characterize the hydroperiod affinity of each plant species in 2001, 2002, and 2003; the distributions showed the number of ponds in which the species occurred at a particular hydroperiod. After testing a variety of hydroperiod statistics, Jon found that the 3rd quartile value from a plant's frequency distribution most accurately estimated a pool's hydroperiod when that plant occurred in the pool's deepest zone. He then converted the maximum 3rd quartile value that was attained or exceeded in 2 of 3 years into one of four hydroperiod classes and assigned the plant to that class. Hydroperiod classes, based on the duration of inundation starting 1 March, were: Class 1, <20 weeks; Class 2, 20-27 weeks; Class 3, 28-36 weeks; and Class 4, 37-44 weeks. Ultimately he found that, when he averaged the hydroperiod classes of the plant species growing in the deepest zone of a pool, the resulting value was an accurate estimator of the pool's observed hydroperiod 72% of the time. So he had demonstrated that it is possible to use plants as indicators of a vernal pool's hydroperiod in most years.

In the Queen's River project we intend to estimate the hydroperiod class of each pool using this method. The approach will involve identification (according to Gleason and Cronquist [1991]) of all plants growing within 1.5 meters of the deepest point in a pool and averaging the hydroperiod classes of those plants, as determined through Jon's thesis research (see Table 2 and Appendix B from the thesis on the following pages). Sampling will take place between mid-July and mid-September. Pool hydroperiod classes generated from this approach will be compared to those generated from application of the Skidds and Golet (2005) model (see Attachment 3), as well as actual hydroperiod observations during 2006, in an effort to accurately classify all of the ponds in the watershed.

Table 1. Plants that met the criteria for pond hydroperiod (hp) indicator plants (i.e., non-woody plants present in at least two ponds in each year). Twenty-four plants (as shown by *), which occurred in the deepest zone of ponds, were used to estimate pond hydroperiod class. Source: Mitchell (2005).

| Scientific name | Common name | Plant hp class[a] | No. ponds/yr |
|---|---|---|---|
| *Athyrium filix-femina* | Lady fern | 1 | 2, 4, 4 |
| *Carex stricta** | Tussock sedge | 1 | 11, 18, 14 |
| *Glyceria acutiflora** | Mannagrass | 1 | 5, 7, 10 |
| *Impatiens capensis* | Jewelweed | 1 | 2, 2, 2 |
| *Juncus effusus* | Soft rush | 1 | 2, 5, 7 |
| *Lycopus virginicus** | Virginia water-horehound | 1 | 7, 5, 5 |
| *Osmunda cinnamomea* | Cinnamon fern | 1 | 9, 9, 15 |
| *Symplocarpus foetidus* | Skunk cabbage | 1 | 2, 4, 2 |
| *Thelypteris palustris** | Marsh fern | 1 | 21, 25, 22 |
| *Carex bullata** | Button sedge | 2 | 4, 2, 3 |
| *Carex lasiocarpa* | Hairy-fruited sedge | 2 | 4, 2, 2 |
| *Dulichium arundinaceum** | Three-way sedge | 2 | 16, 15, 16 |
| *Galium tinctorium** | Southern three-lobed bedstraw | 2 | 6, 8, 5 |
| *Glyceria obtusa* | Coastal mannagrass | 2 | 4, 7, 11 |
| *Hypericum boreale** | Marsh St. John's wort | 2 | 4, 4, 7 |
| *Iris versicolor* | Northern blue flag | 2 | 4, 4, 5 |
| *Juncus canadensis** | Marsh rush | 2 | 11, 12, 10 |
| *Lysimachia terrestris** | Swamp candle | 2 | 19, 21, 6 |
| *Onoclea sensibilis* | Sensitive fern | 2 | 8, 10, 9 |
| *Osmunda regalis* | Royal fern | 2 | 16, 15, 17 |
| *Proserpinaca palustris** | Common mermaid weed | 2 | 8, 6, 8 |
| *Puccinellia pallida** | Pale mannagrass | 2 | 18, 24, 16 |
| *Sagittaria latifolia** | Common arrowhead | 2 | 3, 3, 4 |
| *Scirpus cyperinus** | Woolgrass | 2 | 16, 18, 15 |
| *Sparganium americanum** | Common bur-reed | 2 | 4, 5, 2 |
| *Sphagnum* spp.* | Sphagnum moss | 2 | 51, 45, 46 |
| *Triadenum virginicum** | Northern St. John's wort | 2 | 15, 16, 14 |
| *Typha latifolia** | Broad-leaved cattail | 2 | 2, 2, 2 |
| *Decodon verticillatus** | Swamp loosestrife | 3 | 3, 3, 3 |
| *Eleocharis palustris** | Marsh spike rush | 3 | 5, 4, 4 |
| *Glyceria canadensis** | Rattlesnake mannagrass | 3 | 4, 5, 7 |
| *Glyceria septentrionalis* | Eastern mannagrass | 3 | 4, 4, 4 |
| *Nymphaea odorata** | White water lily | 3 | 4, 5, 5 |
| *Utricularia* spp.* | Bladderwort | 3 | 5, 5, 11 |
| *Nuphar variegata** | Yellow water lily | 4 | 7, 9, 8 |
| *Potamogeton natans* | Floating pondweed | 4 | 5, 2, 4 |

[a] Plant hydroperiod class based on the 3rd quartile of the plant's hydroperiod frequency distribution in 2001, 2002, and 2003.

Table 2**.** Non-indicator plants with potential for pond hydroperiod estimation. Although these plants did not meet the criteria for pond hydroperiod class indicator plants (i.e., non-woody plants present in at least two ponds during all three years) and were not used in this study, field observations suggested that they might be accurate indicators. Trees that were found in only one pond are not listed here. Source: Mitchell (2005).

| Scientific name | Common name | Plant hydroperiod class[a] | No. ponds/yr |
|---|---|---|---|
| *Acer rubrum* | Red maple | 1 | 47, 47, 47 |
| *Betula alleghaniensis* | Yellow birch | 1 | 5, 5, 5 |
| *Betula lenta* | Sweet birch | 1 | 5, 5, 5 |
| *Betula populifolia* | Gray birch | 1 | 6, 6, 6 |
| *Chamaecyparis thyoides* | Atlantic white cedar | 1 | 5, 5, 5 |
| *Lycopodium obscurum* | Princess pine | 1 | 1, 2, 2 |
| *Nyssa sylvatica* | Black gum | 1 | 14, 14, 14 |
| *Pinus rigida* | Pitch pine | 1 | 2, 2, 2 |

*Pinus strobus*
White pine
1
11, 11, 11

*Quercus bicolor*
Swamp white oak
1
4, 4, 4

*Quercus palustris*
Pin oak
1
17, 17, 17

*Quercus velutina*
Black oak
1
3, 3, 3

*Rubus hispidus*
Swamp dewberry
1
1, 18, 17

*Sassafras albidum*
Sassafras
1
2, 2, 2

*Spiraea tomentosa*
Hardhack
1
7, 7, 7

*Viola lanceolata*
Strap-leaved violet
1
1, 5, 3

*Viola primulifolia*
Primrose-leaved violet
1
1, 3, 3

*Eleocharis acicularis*
Least spike rush
2
5, 5, 1

*Fraxinus* spp.

Ash
2
2, 2, 2

*Rhexia virginica*
Wing-stem meadow-beauty
2
1, 4, 6

*Spiraea alba*
Meadowsweet
2
13, 14, 14

*Vaccinium macrocarpon*
Cranberry
2
4, 6, 6

*Woodwardia virginica*
Virginia chain-fern
2
1, 1, 1

*Carex oligosperma*
Few-seeded hop sedge
3
1, 1, 1

[a] Plant hydroperiod class based on the 3rd quartile of the plant's hydroperiod frequency distribution in 2001,2002, and 2003.