Connecticut Association of Wetland Scientists

Vernal Pool Monitoring Program

Interim Report

November 2020

Dedication

We dedicate this report to the memory of our deceased colleague, Penni Sharp. Penni was a founding member of CAWS, and was active in many aspects of the organization since its inception. Penni monitored some of the more challenging vernal pools in our program, and did so with her typical good cheer and attention to detail. As with all her professional work, Penni was dedicated to the advancement of our understanding of the natural world, which she cherished.

Photo 1. Recently laid Wood frog egg masses

Photo 2. Recently laid Spotted salamander egg masses

1.0 Introduction

CAWS members conduct extensive baseline natural resource inventories on properties to assist clients in submitting complete wetland permit applications to municipal, state and federal regulators. These inventories often include surveys of potential and confirmed vernal pools. Wetland consultants use the results of these surveys to recommend site plan designs that avoid impacts to vernal pools and the amphibian populations they support, and to guide analyses of impacts that might result from different site development alternatives.

Wetland consultants rarely have an opportunity to monitor vernal pools during or post-construction. As a result, they typically are unable to compare actual impacts to pool-breeding amphibians with their predictions of impacts. Studying the pools before, during and after development would provide an opportunity to refine future assessments and better guide site plan designs to minimize or eliminate negative biological impacts.

Planning professionals (engineers, landscape architects, planners, etc.), as well as the regulatory community, are similarly constrained by a lack of information on how pool-breeding amphibian populations respond to different development scenarios.

In an attempt to address this data gap, the Connecticut Association of Wetland Scientists (CAWS) initiated a vernal pool monitoring program ("the program") in 2007, and has run it continuously since. More than 50 vernal pools, located in 15 towns (four counties) in Connecticut, have been monitored. More than 320 vernal pool monitoring inspections took place under the program. Some pools were monitored for only several years, while others have been monitored annually since the beginning of the program.

2.0 Program Elements

2.1 Voluntary Landowner Participation

Land-use attorneys advised CAWS that municipal wetland commissions could not legally compel applicants to participate in the program. Commissions could not deny a permit application for not enrolling vernal pools on their property in the CAWS program. Landowner participation needed to be voluntary.

2.2 Standard Monitoring Protocol

Monitoring was performed by CAWS members, as a benefit of membership. CAWS developed a simplified monitoring protocol, and offered training sessions to members who participated in the program on a pro bono basis. A standardized data sheet was developed as well. Details on the protocol and data sheet can be found at the CAWS website, www.ctwetlands.org.

The monitoring protocol recommends that pools be inspected twice each spring, although in practice most monitors were unable to conduct a second spring inspection. Therefore, the data reflects one annual spring inspection unless otherwise noted.
The target species were the two most common "obligate" amphibian vernal pool-breeders in Connecticut: Wood frog (*Lithobates sylvatica*) and Spotted salamander (*Ambystoma maculatum*). Monitors counted or estimated the number of egg masses deposited by each of these species in the vernal pools, along with other data such as vegetation, surrounding land use, etc. Data sheets were submitted to a central repository for storage.

2.3 Development and Reference Pools

Once the monitoring program was formally rolled out, CAWS began publicizing it to landowners and municipal wetland commissions. This was accomplished in professional workshops and through professional newsletters. Vernal pools enrolled by landowners/applicants during the regulatory review process were classified as "development" pools, since they were located on landscapes where some form of development was approved, and a land cover alteration was likely imminent. Monitors were encouraged to inspect these pools prior to, during and following construction to observe conditions during each of these critical phases.

Additionally, CAWS volunteers began to monitor vernal pools on protected lands such as dedicated Open Space, Land Trust and other properties where development was prohibited. These "reference" pools were intended to serve as points of comparison in the event that "macro" changes occurred during the monitoring period, such as extended drought or heat waves, which might impact pool productivity. The "reference" pools would help determine whether any changes in amphibian populations observed were due to pool-specific conditions, or those of a larger scale (e.g., regional drought, etc.).

2.4 Data Disclosure

CAWS recognized the sensitivity of the data they were collecting, and that landowners might be reluctant to participate in the program if data collected were released in an unauthorized manner. Accordingly, all CAWS monitors were required to sign a data disclosure form in which they agreed not to release any of the data collected in the program without the approval of the CAWS Board of Directors.

In compliance with this policy, identifying data (e.g., project name, pool location, etc.) are withheld in this report.

3.0 Program Challenges

3.1 Landowner Participation

Landowner participation in the program was less robust than expected. There are at least two potential explanations for this. First, despite a broad information campaign in which the goals and elements of the monitoring program were described in detail at professional workshops and publications, it is possible that municipal wetland commissions and land-use consultants were unaware of the program, and thus did not encourage landowners to participate in it during the wetland application permit process.

Additionally, some landowners may not have recognized a benefit to participating in the program. A primary goal of the program was to identify development designs that promote amphibian conservation. If successful, it would allow developers to design projects that are viewed more favorably by local, state and federal wetland agencies, which would benefit the regulated community.

3.2 Number of Monitoring Inspections

As noted above, CAWS originally proposed two early spring season inspections of each vernal pool in the program. However, this proved to be impractical for most monitors. As a result, most monitors inspected their pools once each spring (late March through mid-April).

This presented significant logistical difficulties due to the timing of migrations and egg-laying of the two target amphibian species. Wood frogs typically migrate to, and breed in, vernal pools one or more weeks before Spotted salamanders. Depending upon weather conditions, Wood frog egg masses begin to swell and become undistinguishable from one another within one to two weeks of their deposition in vernal pools. Thus, in a vernal pool that supports the breeding of both Wood frogs and Spotted salamanders, by the time that Spotted salamanders have completed egg deposition in the pool, Wood frog eggs may have begun to hatch, precluding an estimate of the number of egg masses. In most cases it proved impossible to characterize the breeding effort of both species in one monitoring inspection.

Additionally, the migration and breeding of a population of Wood frogs or Spotted salamanders is often protracted over a period of a week or more. Thus, annual migration and egg-laying of a target species may not yet be completed at the time of a single monitoring inspection, which may underestimate the total annual reproductive effort.

3.3 Logistical Factors

Following several years of monitoring it became apparent that physical features of some vernal pools made it difficult to observe amphibian egg masses in these pools. These constraints included the following: surface algae and/or tree pollen, dark tannin-colored water, deep water, turbidity and dense shrub growth in the pools. CAWS amended the datasheet to include a list of these factors, prompting monitors to record and rate the severity of any factors that impaired their ability to accurately identify and enumerate amphibian egg masses in the pools. Where available, these factors are included in the data tables in Appendix 1, and provide some context to the numerical data that was collected at the pools.

3.4 Implications for Data Analysis

Given the constraints listed in Sections 3.2 and 3.3 above, it is necessary to view the data collected by the program qualitatively, rather than quantitatively. Because in the majority of years monitoring was conducted on only one date, and often with one or more physical factors that impaired the ability to identify all egg masses in the pools, the data tables in Appendix 1 do not necessarily reflect a highly accurate accounting of the reproductive efforts of the two target species each spring. However, they have value when reviewed qualitatively, particularly in the examples where the breeding of one or both of the target species was eliminated or reduced, or in the cases where obvious physical water quality impairments to the pools resulted from nearby development (e.g., sedimentation, turbidity, etc.).

4.0 Land Cover Analysis

The Connecticut Land Cover Map Series (Version 2.3) (https://clear.uconn.edu/) was used to perform the land cover change analysis. The map series produced by the University of Connecticut consists of seven dates of land cover data (1985, 1990, 1995, 2002, 2006, 2010 and 2015) created from satellite imagery. The land cover data were produced from Landsat satellite images using a computer image processing application. Landsat images are composed of pixels, which each represents an area on the ground measuring 30 meters by 30 meters. For each pixel, the Landsat image records the amount of reflected energy in 6 narrow bands of the electromagnetic spectrum (red, green and blue visible light, a near-infrared and two mid-infrared bands). Because landscape features reflect light differently, reflectance data can be used to classify those landscape features.

Of the seven years of land cover data, five were used for this study: 1995, 2002, 2006, 2010, and 2015. Each dataset year includes twelve consistently interpreted land cover classes: developed, turf & grass, other grasses, agricultural field, deciduous forest, coniferous forest, water, non-forested wetland, tidal wetland, barren and utility rights-of-way (https://clear.uconn.edu/projects/landscape/about/classes.htm). The data were

produced in a way to ensure consistent comparison, especially for land cover change studies.

For this study, an assessment of the land cover in the vicinity of the vernal pools was conducted using geographic information system (GIS) and its associated analysis tools. Three vernal pool management areas were identified for each vernal pool: vernal pool depression (VPD), vernal pool envelope (VPE) and critical terrestrial habitat (CTH) (Calhoun and Klemens 2002). The VPD is the limit of the vernal pool proper up to the spring high water mark. The VPD was estimated based on field observation and/or aerial imagery interpretation. The VPE is the 100-foot wide area around the VPD. The CTH Zone is the 650-foot area around the VPE.

Using a GIS clipping tool for each of the vernal pools, each of the five years of land cover data for Connecticut were cropped to the limits of the both the VPE and CTH Zones. From this data, the quantified areas of each land cover class were summarized as both absolute area and percentage of total area.

5.0 Lessons Learned

Twelve of the monitored pools (5 Reference, 7 Development) were selected as Case Studies for this report (Appendix 1). They represent the range of conditions and results encountered in the program. CAWS analyzed land cover changes, as described in Section 4.0, around these pools, and looked for trends in amphibian reproductive effort in the monitoring data. The results of this analysis are presented below.

5.1 Amphibian Breeding Effort May Vary from Year to Year

In the "Reference" pools (#s 6, 9-12), and the "Development" pools around which no landscape alterations occurred during the study period (#s 7 and 8), amphibian reproduction effort varied, sometimes considerably, from year-to-year. As discussed in Section 3.2 above, some of this variability is likely due to the limitations of single-year monitoring events. However, research has shown that pool-breeding amphibians can experience reproductive failure in some years due to physical factors such as rapid drying during drought years (Semlitsch and Skelly 2008), which can reduce the number of breeding adults in subsequent years.

Because of this, when possible, vernal pool assessments conducted as part of a wetland permit application should be performed over more than one year to account for this variability in reproductive effort.

5.2 Amphibian Egg-Laying May be Protracted

When Case Study pool #3 was inspected on March 10, 2020, there was a loud chorus of adult male Wood frogs in the pool, but as of that date no egg masses had been deposited. When the pool was reinspected six days later 151-200 egg masses were present – egg mass deposition had occurred over the six days since the prior inspection.

Similarly, the second inspection of the Case Study pool #5 in 2020 found approximately 30 more Wood frog egg masses than the inspection six days prior.

This protracted egg-laying has important implications for biodiversity studies in support of wetland permits. A vernal pool characterization/assessment study should include multiple inspections to account for the fact that egg mass deposition may be protracted. Otherwise, it may significantly underestimate amphibian productivity in the pool.

5.3 Amphibian Populations Can Persist on Moderately-Altered Landscapes

Case Study pool #1 resides on a landscape that contains a long-standing habitat alteration that reduced the size of the VPE by 20-30 percent, and the CTH Zone by approximately 20 percent. Calhoun and Klemens (2002) recommend, among other things, maintaining 75 percent of the CTH Zone in contiguous, unfragmented forest habitat. Coincidentally, Case Study #1 complies with this management recommendation. Its productivity varied during the monitoring period, which may be due in part to the limitations of this study described in Section 3.2 above. However, based upon these limited monitoring data, it appears that the unfragmented forested habitat that remains around this pool is sufficient to maintain its productivity.

Case Study pool #3 experienced a moderate decrease in the amount of deciduous forest within the CTH Zone due to the construction of several nearby houses. However, the amount of unfragmented terrestrial forest and forested wetland remained high (82 percent). Wood frog productivity varied in this pool during the monitoring period, but in 2020 the pool remained productive post-development.

5.4 Sedimentation Impacts to Vernal Pool Ecology and Productivity are Long-Term

Several of the monitored pools experienced damaging sediment inputs from nearby construction. For example, silty sediments were first observed within Case Study pool #2 in 2016, causing the water in this pool and a hydrologically connected pool to turn chocolate brown. A dense stand of emergent vegetation volunteered into the pool in conjunction with the sediments. This major sediment event resulted from land clearing in very close proximity to this pool (the percentage of deciduous forest in the VPE dropped from 100 to 32 percent). The amount of deciduous forest in the CTH Zone also decreased dramatically. Following these terrestrial habitat and water quality impacts, the two target amphibian species stopped breeding in this pool.

Case Study pool #4 also experienced one or more major sedimentation events associated with land clearing in the CTH Zone, before and during the monitoring period. It appears that this sediment input dramatically increased the nutrient status of the pool, as it was associated with a bloom of filamentous green algae and the appearance of a stand of *Typha latifolia* in subsequent years. Amphibian productivity was modest or absent in many of the monitoring years. Unfortunately, there is no data for this pool prior to nearby landscape alterations. However, given its relatively large size and connectivity with a large unfragmented wooded landscape, its productivity was much lower than expected. This is likely due to sedimentation and nutrient enrichment.

5.5 Habitat Connectivity is Critical to Vernal Pool Productivity

Case Study pool #5 illustrates the principle that vernal pools are intimately connected with, and dependent upon, the larger landscape of which they are a part.

This vernal pool is located within a relatively large landscape block that includes a small farm pond, upland deciduous forest, forested wetlands, and a group of hayfields. Beyond this landscape block the land has been moderately developed, mostly with residential housing, and it appears likely that amphibians that breed in this vernal pool utilize the forested upland and wetland habitats that lie within this landscape block.

At first glance, the very high Wood frog productivity in 2007 and 2008 (estimated number of egg masses: 1,000-1,250) is surprising, considering that the percentage of Deciduous Forest in the CTH Zone is quite modest (37%). However, beyond the CTH Zone lies a relatively large forested block (approximately 900+ feet from the vernal pool) separated by hayfields and wooded hedgerows. Wood frogs are capable of crossing these agricultural fields and migrating between the vernal pool and large forest block beyond the CTH Zone (Semlitsch and Skelly 2008).

According to aerial photographs on Google Earth Pro, prior to the CAWS monitoring the landscape on which this vernal pool is situated changed little. Several years after the monitoring began, a subdivision road was constructed between the vernal pool and much of the adjacent forested habitat block beyond the CTH Zone. In subsequent years houses were constructed along this road. This development appears to have severed the landscape connection between the vernal pool and a large portion of the available forested habitat beyond the CTH Zone.

Wood frog productivity declined precipitously following the construction of the subdivision road and houses, and has never recovered:

Year(s)	Estimated # of Wood frog Egg Masses
2007	1,000-1,250
2008	1,000-1,250
2010	150-200
2011-2018	<100 each year
2020	111

The only significant landscape change that occurred during the monitoring period was the construction of the subdivision road and associated houses described above, and it appears very likely that this was responsible for the sharp decline in Wood frog productivity in this vernal pool.

The amount of deciduous forest and forested wetland in the CTH Zone of this pool was unchanged from 1995 through 2015. The development occurred within previously cleared agricultural fields, and is reflected in the land cover table by the conversion of these fields to "Other Grasses", and a small increase in the amount of "Developed" land.

A simple analysis of the land cover changes that occurred in the CTH Zone of this pool (conversion of hayfields to developed land) would underestimate the impact upon pool-breeding amphibians. It would have missed the critical linkage between the pool and non-breeding forested habitat beyond the CTH Zone that would be severed by the development. This case study demonstrates the importance of placing a vernal pool in a broader landscape context by looking beyond the CTH Zone, and identifying whether critical habitat linkages will be maintained or severed, when predicting impacts upon amphibian productivity.

6.0 Conclusions

Despite the challenges enumerated in this report, the monitoring program has provided data trends that can help inform better site plan design in the future. It confirmed that, at least for the relatively short monitoring period, it is feasible for land development and pool-breeding amphibian conservation to coexist. This requires site plans that recognize and preserve critical linkages between vernal pools and landscape features such as terrestrial non-breeding habitats, wetlands, and other vernal pools.

The program demonstrated that once sediments and excess nutrients enter a vernal pool, impacts to water quality and amphibian productivity can be long-term. Monitored pools that were surrounded by an intact 100-foot wide VPE were much less likely to be impacted by sediments and nutrients from land development.

Because of protracted amphibian egg-laying, multiple spring inspections are required to properly characterize pool productivity. Multi-year investigations are less subject to year-to-year fluctuations in amphibian productivity.

References

Calhoun, A.J.K. and M.W. Klemens 2002. Best development practices: Conserving pool-breeding amphibians in residential and commercial developments in the northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

Semlitsch, R.D. and D.K. Skelly 2008. Ecology and conservation of pool-breeding amphibians. In: Science and Conservation of Vernal Pools in Northeastern North America. Eds. Calhoun, A.J.K. and P.G. deMaynadier. CRC Press.

APPENDIX 1. CASE STUDY DATA TABLES

Case Study VP 1

Pool Type: Development

		Land Cover Types (%)								
Zone	Year	Agri-culture	Barren	Conifer Forest	Decid. Forest	Deve-loped	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	0	0	0	81	0	15	4	0	0
	2000	0	2	0	83	0	15	0	0	0
	2005	0	5	0	80	0	15	0	0	0
	2010	0	14	0	72	0	15	0	0	0
	2015	0	15	0	70	0	15	0	0	0
CTH	1995	0	18	0	79	0	1	2	0	0
	2000	0	16	0	80	0	1	3	0	0
	2005	0	19	0	80	0	1	1	0	0
	2010	0	17	0	78	0	1	4	0	0
	2015	0	16	0	82	0	1	2	0	0

(*) VPE=Vernal Pool Envelope (0-100’ from VP boundary)

CTH=Critical Terrestrial Habitat (100-750’ from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
4/15/2003				300+				13	
4/12/2010	0	0	✓	?	66	0	0	66	3
4/8/2011	0	50-75	0	50-75	2	0	0	2	3 (H)
4/8/2013	100-150	0	0	100-150	0	0	0	0	

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 2

Pool Type: Development

		Land Cover Types (%)								
Zone	Year	Agri-culture	Barren	Conifer Forest	Decid. Forest	Deve-loped	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	0	0	0	100	0	0	0	0	0
	2000	0	0	0	100	0	0	0	0	0
	2005	0	0	0	100	0	0	0	0	0
	2010	0	0	0	100	0	0	0	0	0
	2015	0	47	0	32	0	0	21	0	0
CTH	1995	0	0	1	57	0	8	34	0	0
	2000	0	0	1	57	0	8	34	0	0
	2005	0	0	1	57	0	8	34	0	0
	2010	0	0	1	54	5	6	34	0	0
	2015	0	12	1	40	5	6	37	0	0

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
4/8/2010	0	0	✓	?	0	0	0	0	
4/19/2011	0	4	0	4	27	0	0	27	
4/4/2012	0	✓	✓	50-75	50+/-	0	0	50+/-	
4/15/2013	0	✓	✓	15+/-	12	0	0	12	
4/9/2014	26-49	0	0	26-49	28	0	0	28	
4/17/2015	✓	✓	0	17+/-	7	0	0	7	
3/29/2016	0	0	0	0	0	0	0	0	
4/12/2017	0	0	0	0	0	0	0	0	
3/10/2020	0	0	0	0	0	0	0	0	

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Notes:

- Land clearing around vernal pool first observed during 2015 inspection, at which time leaf litter at the bottom of the pool was covered with algae for the first time.

- Silty sediments were first observed in the pool during the 2016 inspection. Water in the pool was chocolate brown. A dense stand of emergent vegetation (beggars ticks, etc.) was growing in the pool for the first time. An adjacent, hydrologically connected pool also contained brown water. This adjacent pool, dropped from 100+/- Spotted Salamander egg masses in 2012 to none in 2016.

Case Study VP 3

Pool Type: Development

		Land Cover Types (%)								
Zone	Year	Agri-culture	Barren	Conifer Forest	Decid. Forest	Deve-loped	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	0	0	0	100	0	0	0	0	0
	2000	0	0	0	100	0	0	0	0	0
	2005	0	0	0	100	0	0	0	0	0
	2010	0	0	0	100	0	0	0	0	0
	2015	0	0	0	99	1	0	0	0	0
CTH	1995	0	0	2	75	0	23	0	0	0
	2000	0	0	2	75	0	23	0	0	0
	2005	0	0	2	75	0	23	0	0	0
	2010	0	0	2	67	9	21	1	0	0
	2015	0	1	2	61	14	21	1	0	0

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
4/2/2010	✓	✓	0	100-150	51	0	0	51	
4/11/2011				17	37	0	0	37	
4/4/2012		✓	✓	?	19	0	0	19	
4/15/2013				75-100	21	0	0	21	3,6 (L)
4/9/2014	150-200	0	0	150-200	2	0	0	2	
4/17/2015	✓	✓	0	50-75	6	0	0	6	
3/31/2016	0	45+/-	0	45+/-	26	0	0	26	2,3 (M)
4/18/2017	0	0	0	0	16	0	0	16	2,3 (L-M)
3/10/2020	0	0	0	0	0	0	0	0	3 (M-H)
3/16/2020	✓	✓	0	151-200	0	0	0	0	3,4 (L)

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Notes:

- Forest clearing within 60+/- feet of one side of the pool, and the start of house construction, was first observed in 2013. The forest around the remaining ¾ of the pool remained intact throughout the monitoring.

- No sediment was observed in the pool throughout the monitoring.

Case Study VP 4

Pool Type: Development

		Land Cover Types (%)								
Zone	Year	Agri-culture	Barren	Conifer Forest	Decid. Forest	Deve-loped	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	0	0	0	100	0	0	0	0	0
	2000	0	0	0	100	0	0	0	0	0
	2005	0	0	0	100	0	0	0	0	0
	2010	0	0	0	98	2	0	0	0	0
	2015	0	0	0	97	3	0	0	0	0
CTH	1995	2	0	2	64	14	19	0	0	0
	2000	2	0	2	63	14	19	1	0	0
	2005	2	0	2	62	14	19	1	0	0
	2010	1	0	2	53	24	19	1	0	0
	2015	1	3	2	51	32	11	0	0	0

(*) VPE=Vernal Pool Envelope (0-100’ from VP boundary)

CTH=Critical Terrestrial Habitat (100-750’ from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
4/15/2009	0	0	0	0	29	0	0	29	1,6
4/2/2010	0	3	0	3	23	0	0	23	1,6
4/11/2011	0	0	0	0	9	0	0	9	6
4/4/2012	0	0	0	0	16	0	0	16	6
4/10/2014	47+/-	0	0	47+/-	3	0	0	3	5,6
4/17/2015	0	19	0	19	8	0	0	8	6
3/31/2016	0	25-30	0	25-30	16	0	0	16	1,3,6
4/18/2017	0	0	0	0	3	0	0	3	3,6
3/24/2020	0	25+/-	0	25+/-	1	0	0	1	1,6

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Notes:

- A sediment plume originating from nearby land clearing/development entered this pool during the monitoring period. Once it entered the pool, evidence of this sedimentation was observed during all subsequent monitoring inspections. Thick, soft, anoxic sediments were present throughout the pool, leaf litter in the pool was covered with brown silt, and wading through the pool produced a thick plume of brown sediments in the water column. In the years following the sedimentation, the amount of filamentous green algae in the water column increased dramatically, and a small stand of *Typha latifolia* became established.

Case Study VP 5

Pool Type: Development

		Land Cover Types (%)								
Zone	Year	Agri-culture	Barren	Conifer Forest	Decid. Forest	Deve-loped	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	51	0	0	49	0	0	0	0	0
	2000	51	0	0	49	0	0	0	0	0
	2005	51	0	0	49	0	0	0	0	0
	2010	0	0	0	49	0	0	51	0	0
	2015	0	0	0	49	0	0	51	0	0
CTH	1995	38	0	0	37	18	4	0	2	0
	2000	38	0	0	37	18	4	0	2	0
	2005	38	0	0	37	18	4	0	3	0
	2010	0	1	0	36	21	4	35	3	0
	2015	0	1	0	36	22	4	30	8	0

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
3/26/2007	Most	Some		1,000-1,250	Most			8	
4/15/2008				1,000-1,250		Some	Most	10	
4/15/2009	Very Few	Most		?	Most			5	
4/1/2010	Many	Some	Some	150-200	Most			8	
4/8/2011	Most	Few	None	50-75				7	
3/26/2012	Most	None	None	<50	All	None	None	7	
4/11/2013	Many	Some	Few	50-75	Most			5	
4/2/2014	Many	Some	None	26-49	Most			3	
3/24/2016	✓	✓	✓	50-75				7	
4/24/2018		9		9	9			9	1,2 (Low)
3/6/2020	81			81				1	
3/12/2020	30+/-	81+/-	0	111+/-	3	0	0	3	2,3 (M-H)

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 6

Pool Type: Reference

		Land Cover Types (%)								
Zone	Year	Barren	Conifer Forest	Decid. Forest	Deve-loped	Non-Forested Wetland	Forested Wetland	Other Grasses	Turf & Grass	Water
VPE	1995	0	0	84	0	0	0	9	7	0
	2000	0	0	92	1	0	0	0	7	0
	2005	0	0	81	9	0	0	0	10	0
	2010	0	0	81	9	0	0	0	10	0
	2015	0	0	81	9	0	0	0	10	0
CTH	1995	0	8	41	23	1	0	5	14	10
	2000	0	10	43	22	1	0	0	13	10
	2005	1	10	41	23	1	0	0	13	10
	2010	1	10	41	23	1	0	0	13	11
	2015	0	10	41	24	1	0	0	13	10

(*) VPE=Vernal Pool Envelope (0-100’ from VP boundary)

CTH=Critical Terrestrial Habitat (100-750’ from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
Mar./Apr. 2008			✓	?				0	
4/5/2009		✓	✓	?	6			6	
Mar./Apr. 2010	6			6				0	
4/2,8/2011		Most	Some	20+/-				0	
Mar./Apr. 2012	10			10				0	
Mar./Apr. 2013	64			64				0	
Mar./Apr. 2014	111			111	2			2	
Mar./Apr. 2015	120+/-			120+/-				0	
Mar. 2016	73+/-			73+/-	4			4	
Mar./Apr. 2017	562+/-			562+/-				0	
Mar./Apr. 2018	288+/-			288+/-	2			2	
3/25/2019	46			46				0	
3/22/2020	82			82				0	

Case Study VP 7

Pool Type: Development (not yet developed)

		Land Cover Types (%)			
Zone	**Year**	**Deciduous Forest**	**Agriculture**	**Other Grasses**	**Turf & Grass**
VPE	2000	100	0	0	0
	2005	100	0	0	0
	2010	100	0	0	0
	2015	100	0	0	0
CTH	2000	77	17	0	6
	2005	77	17	0	6
	2010	77	17	0	6
	2015	74	20	1	6

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Visibility Factors(*)**
4/17/2015	0	0	0	0	16	0	0	16	1, 2. 3
3/30/2016	0	18	0	18	32	0	0	32	3
4/20/2017	1	34	0	35				41	3, 7
4/21/2018	17	4	3	24	30	3	0	33	---

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 8

Pool Type: Development (not yet developed)

		Land Cover Types (%)							
Zone	**Year**	**Deciduous Forest**	**Forested Wetland**	**Agriculture**	**Barren Land**	**Coniferous Forest**	**Developed**	**Other Grasses**	**Turf & Grass**
VPE	2000	87	13	0	0	0	0	0	0
	2005	91	9	0	0	0	0	0	0
	2010	87	13	0	0	0	0	0	0
	2015	91	9	0	0	0	0	0	0
CTH	2000	72	4	1	0.1	1	11	4	7
	2005	73	4	1	0	1	11	3	7
	2010	72	5	1	0	1	11	3	7
	2015	73	4	1	4	1	11	3	6

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				**# of Spotted Salamander Egg Masses**				
Date	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Visibility Factors(*)**
4/7/2009	Most	Some		50-75	5			5	
4/8/2010			100-150	100-150	20			20	
4/14/2011			50-75	50-75	13			13	
3/30/2012		✓	✓	50-75	28			28	
4/11/2013		✓	✓	100-150	4			4	
4/18/2014	✓	✓	✓	75-100	16			16	
4/28/2015		✓	✓	300-400	38			38	
3/24/2016	150-200			150-200	34			34	
4/13/2017		✓	✓	75-100	5			5	
4/5/2018				0				0	
4/23/2018		✓	✓	75-100	14			14	1,3
4/9/2019	151-200			151-200	11			11	1

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 9a

Pool Type: Reference

		Land Cover Types (%)					
Zone	**Year**	**Deciduous Forest**	**Agriculture**	**Other Grasses**	**Turf & Grass**	**Developed**	**Forested Wetland**
VPE	2000	90	0	0	10	0	0
	2005	97	0	0	3	0	0
	2010	90	0	0	10	0	0
	2015	97	0	0	3	0	0
CTH	2000	35	11	2	16	36	1
	2005	37	10	2	16	35	0
	2010	34	11	3	16	36	1
	2015	34	10	2	16	37	0

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Visibility Factors(*)**
4/8/2008		✓	✓	300-400	28	0	0	28	---
4/18/2009	Some	Many	Some	75-100	25	0	0	25	---
4/2/2010	Some	Some	Many	150-200	22	0	0	22	---
4/11/2011	Most	Some	Some	150-200	✓	✓	0	19	---
3/30/2012	None	Many	Many	100-150	Most	Some	0	31	---
4/13/2013	Some	Many	Many	100-150	Most			26	

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 9b

Pool Type: Reference

		Land Cover Types (%)					
Zone	**Year**	**Deciduous Forest**	**Agriculture**	**Other Grasses**	**Turf & Grass**	**Developed**	**Forested Wetland**
VPE	2000	90	0	0	10	0	0
	2005	97	0	0	3	0	0
	2010	90	0	0	10	0	0
	2015	97	0	0	3	0	0
CTH	2000	35	11	2	16	36	1
	2005	37	10	2	16	35	0
	2010	34	11	3	16	36	1
	2015	34	10	2	16	37	0

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Visibility Factors(*)**
4/18/2009	Most	Some	0	36	4	0	0	4	---
4/23/2010	Some	Most	0	34	Most	0	Some	11	---
4/11/2011	0	Most	Some	<50	Many			13	---
3/30/2012	0	Many	Many	50-75	Most	Some		18	---
4/13/2013	Most	Some	Some	50-75	19	0	0	19	---

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 10

Pool Type: Reference

		Land Cover Types (%)					
Zone	**Year**	**Deciduous Forest**	**Agriculture**	**Turf & Grass**	**Developed**	**Coniferous Forest**	**Forested Wetland**
VPE	2000	100	0	0	0	0	0
	2005	100	0	0	0	0	0
	2010	100	0	0	0	0	0
	2015	100	0	0	0	0	0
CTH	2000	78	1	1	8	11	1
	2005	79	1	1	8	11	1
	2010	78	1	1	8	11	1
	2015	79	1	1	8	11	1

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Intact**	**Breaking Up**	**Hatching**	**Total**	**Visibility Factors(*)**
4/14/2008	Most	Some		150-200				0	
4/4/2010	Most			100-150	5			5	
4/25/2011	Most			100-150				15	
4/17/2013	100-150			100-150	14			14	
4/30/2015		75-100		75-100				1	
4/15/2018				50				1	7

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 11

Pool Type: Reference

		Land Cover Types (%)							
Zone	Year	Agriculture	Coniferous	Deciduous Forest	Developed	Forested Wetlands	Other Grasses	Turf & Grass	Water
VPE	2000	3	97	0	0	0	0	0	0
	2005	3	97	0	0	0	0	0	0
	2010	2	97	0	0	0	0	0	0
	2015	3	97	0	0	0	0	0	0
CTH	2000	12	40	42	0	1	3	1	1
	2005	13	39	39	0	3	3	1	1
	2010	14	40	37	0	4	5	1	1
	2015	13	39	39	0	3	3	1	1

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
4/7/2009	<50			<50	112			112	
4/9/2010	<50			<50	155			155	
4/18/2011			<50	<50	246			246	
4/11/2012		100-150		100-150	33			33	3
4/14/2014	Most		Few	250-300	84			84	
4/16/2015	Most	Few	Few		Most			55	

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).

Case Study VP 12

Pool Type: Reference

		Land Cover Types (%)							
Zone	Year	Deciduous Forest	Agriculture	Other Grasses	Turf & Grass	Barren Land	Developed	Forested Wetland	Utility ROWs
VPE	2000	43	0	0	2	10	45	0	0
	2005	41	0	13	2	0	44	0	0
	2010	52	0	0	2	0	46	0	0
	2015	56	0	0	2	0	42	0	0
CTH	2000	46	0	14	3	21	12	1	4
	2005	50	0	25	3	4	14	1	3
	2010	51	0	24	4	4	12	1	4
	2015	53	0	24	4	2	13	1	3

(*) VPE=Vernal Pool Envelope (0-100' from VP boundary)

CTH=Critical Terrestrial Habitat (100-750' from VP boundary)

Monitoring Data									
	# of Wood Frog Egg Masses				# of Spotted Salamander Egg Masses				
Date	Intact	Breaking Up	Hatching	Total	Intact	Breaking Up	Hatching	Total	Visibility Factors(*)
2008	50-75			50-75				0	
2009		<50		<50				0	
2010	50-75			50-75				0	
4/15/2011		✓	✓	50-75				0	
3/23/2012		30		30				0	
4/11/2013			9	9				0	
4/11/2014				0				0	
4/21/2016	26-49			26-49				0	2,3,4,5,6
4/9/2017	26			26				0	2,3,4,5,6
4/12/2018	14			14	1			1	2,3,4,5,6

(*) These are factors that limit the ability of the monitor to locate egg masses:

1=Surface algae 2=Surface pollen 3=Dark, tannin-colored water 4=Deep water 5=Turbidity 6=Dense shrubs 7=Other

The severity of these factors was rated as low (L), moderate (M) or high (H).