MITIGATING POTENTIAL IMPACTS OF HERPETILE HABITAT LOSS AND FRAGMENTATION FROM NEW ROADWAY CONSTRUCTION IN SOUTHERN NEW YORK STATE

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Abstract: Construction of a 6.5-kilometer (4-mile) two-lane access roadway has been proposed to provide airport patrons with improved access to Stewart International Airport in Orange County, New York. The project design, environmental review and permitting process were a joint effort between the New York State Department of Transportation (NYSDOT) and the New York State Thruway Authority (NYTA).

While the majority of the new access roadway will utilize an existing road network, an approximately one-mile portion will pass through extensive secondary growth forest on the southwest side of the airport. This area is in close proximity to the 6,000-acre Stewart State Forest. A 1.12-kilometer (0.7-mile) length of this alignment passes through a valley containing a complex of emergent and forested wetlands and a headwater stream. In order to minimize potential impacts to two New York State Species of Special Concern, the spotted turtle (Clemmys guttata) and the Jefferson salamander (Ambystoma jeffersonianum), as well as other wildlife species, a mitigation plan was devised to replace wetland habitat utilized by these species. The mitigation plan also includes four underpasses to maintain a connection between upland forest and wetland habitats on either side of the roadway.

The mitigation plan was developed in a collaborative effort with the New York State Department of Environmental Conservation (NYSDEC), NYSDOT, NYTA and The Louis Berger Group, Inc. (Berger). Berger developed a design plan for the construction of 12 vernal pools in close proximity to the impacted wetlands to provide supplemental breeding habitat for several herpetile species. The 12 pools range in size from 0.01 to 0.13 hectares (0.04 to 0.33 acre), with a combined total area of 0.55 hectares (1.37 acres). The site selection, vernal pool design, water budget analysis, and plan and specification preparation was a collaborative effort between biologists and engineers.

Several criteria were used to select the best possible sites for pool construction. These criteria took multiple factors into consideration including proximity to existing wetlands, upslope drainage areas, forest quality, site topography, soil characteristics, and availability of adjacent upland buffer habitat. The design places major emphasis on site hydrology since this would be the determining factor for target species use of these habitats. The intended inundation hydroperiod (March through July) was based on the target species breeding requirements and was the basis of determining if an individual vernal pool site could be successful. Water budgets were developed for each proposed site to determine the necessary design elements required to establish naturally functioning vernal pool hydrology. Controlling influences such as pool watershed, subsoil infiltration rates, precipitation rates, and substratum composition were all accounted for in the water budget analysis. Other elements such as maintaining a closed tree canopy and incorporating leaf litter to provide an appropriate substrate were addressed in the design.

The mitigation plan also calls for the minimization of habitat fragmentation through the incorporation of wildlife passages. The roadway design incorporates the use of amphibian barriers at three locations to prevent herpetiles from entering the travel lanes of the new road and to direct them to pairs of culverts designed to provide passage through the roadway embankment. Two larger 12-ft by 6-ft con-spans were also incorporated into the design to provide deer, coyote and other mammals a safe point to cross beneath the roadway. The underpasses are open-bottom box culverts with an openness ratio of 0.85. Upon construction, a five-year monitoring program will be implemented by NYSDOT that will include monitoring both the herpetile colonization and use of the vernal pools, wildlife utilization of the wildlife underpasses, and road kills along the road segment. Information gathered from this mitigation plan would be adapted to other projects undertaken by NYSDOT and NYTA as appropriate.

Introduction

Construction of a 6.5-kilometer (4-mile) two-lane access roadway has been proposed to provide airport patrons with improved access to Stewart International Airport in Orange County, New York. The project design, environmental review and permitting process were a joint effort between the New York State Department of Transportation (NYSDOT) and the New York State Thruway Authority (NYTA). An approximately one-mile portion will pass through extensive secondary growth mixed oak-hickory forest on the southwest side of the airport. This area is in close proximity to the 6,000-acre Stewart State Forest. A 1.12-kilometer (0.7-mile) length of this alignment passes through a valley containing an extensive complex of emergent and forested wetlands and a headwater stream. The spotted turtle (Clemmys guttata), a state species of special concern, is known to occur within these wetland areas, and a second species of special concern, the Jefferson salamander (Ambystoma jeffersonianum) is also thought to occur within the affected wetlands.

The New York State Thruway Authority (NYSSTA) and the New York State Department of Transportation (NYSDOT) have developed a wetland mitigation plan to compensate for unavoidable impacts that will be incurred as a result of the proposed project. The mitigation plan includes the construction of approximately 6.1 hectares (15.1 acres) of compensatory mitigation at an offsite location. The East-West Connector segment of the roadway is expected to impact approximately 0.99ha (2.44 acres) of state-regulated wetlands. The NYSDEC requested that an additional 0.40 to 0.61 total hectares (1.0 – 1.5 acres) of compensatory mitigation be provided on-site in the form of vernal pool habitat.
As shown in Figure 1, the 87.5-hectare (216-acre) project area is located on the Stewart Airport Property, in the Town of New Windsor, Orange County, New York. The project area is located in woodlands located to the southwest of Stewart International Airport, and is bordered by extensive emergent and forested wetlands along the proposed East-West Connector.

The construction of vernal pools for amphibians and the colonization of mitigation sites with pool features have been studied previously (Pechmann et al. 2001, Lehtinen and Galatowitsch 2001, Weyrauch and Amon 2002). The design of vernal pools as salamander breeding habitat has not been well published, though literature describing habitat requirements for individual species is generally readily available. The design of the vernal pools relied on the life history requirements of the target species to establish the most critical site and habitat features to be incorporated into the design of each pool. The design process was initiated in the summer of 2001.

NYSDEC is also providing additional wildlife underpasses and amphibian barriers along this portion of the roadway to further minimize the potential for wildlife-vehicle collisions and improve safety. The design of the amphibian/wildlife underpasses and barrier are based on previous designs accepted by NYSDEC and modified to meet site conditions and roadway design.

Vernal Pool Hydrology and Biota
Vernal pools are seasonally flooded depressions that play a critical role in the life cycle of many invertebrate, amphibian, and reptile species (Wiggens et al. 1980). One of the defining characteristics of these unique wetland systems is their yearly cycle of flooding and drying. Generally, from mid-July through September (when evaporation and transpiration rates are highest) woodland vernal pools dry out and appear to be nothing more than leaf-littered depressions with little or no vegetation. From October through February these depressions fill with rain, snow and ice (when evaporation and transpiration rates are low). With the onset of warmer air temperatures in March and early April the snow and ice melt, leaving the depressions filled with several inches to several feet of water. The pools will usually remain inundated through the spring and into early summer. Additional water will be supplied by direct precipitation, via runoff from upslope drainage areas and possibly through input from seasonally high groundwater. The length of inundation can vary considerably between different pools, and, in extreme cases, a vernal pool can remain inundated for several years before drying out.

Since vernal pools in a given region generally have the potential to receive the same amount of direct precipitation during the year, other landscape-related characteristics would control individual pool hydroperiod (i.e., length of inundation and saturation). These include the size, cover types, slope and soil types of the drainage area surrounding each pool, the total volume of the pool, substrate characteristics of the pool and the presence and duration of a seasonal high water table. All of these elements where examined during the site selection and design process.
From a biological perspective, the hydrologic design was on the end of the hydrologic cycle when the pools dry up. For example, two ponds of equal dimensions in the same geographic region may contain equal volumes of water in late March yet may dry weeks or even months apart based on differing physical features related to their landscape position (i.e., substrate permeability, canopy coverage). Therefore, in planning an appropriate water budget for constructed vernal pools for the purpose of supplying a viable habitat for a target species, emphasis should be put on the duration of inundation required for target species. Species that breed early in the year generally develop and leave pools earlier and thus are more tolerant of shorter duration pools than species that breed later in the season. As a result of this variation in pool hydroperiod, the species associated with different pools may also vary.

Jefferson and blue-spotted salamanders are two closely related species that are among the first salamanders to breed in the late winter and early spring. Jefferson salamanders are the earliest breeders of all *Ambystomid* salamanders, sometimes initiating breeding activity when pools are still slightly frozen, generally between early March and early April in northern locales (Petranka 1998). Blue-spotted salamanders breed soon after, generally from mid March to mid April. The incubation period for the eggs of both species generally takes three-four weeks. Once hatched, the larval period for both species is approximately two-four months (Kenney and Burne 2000). Therefore, when taking all aspects of reproduction into account (i.e., breeding time, egg incubation, and aquatic larval development), a hydroperiod of approximately five to six months is necessary within breeding pools to allow for successful development and metamorphosis of the young salamanders. A simplified list of the potential breeding cycle is presented below. It should be noted that this is a range that will vary regionally and yearly based on weather patterns.

- Breeding Period: 1 March to 15 April
- Incubation: 15 April to 15 May
- Larval Development: 15 May to 15 August
- Total Annual Hydroperiod: 5 to 6 Months

Water chemistry is also an important hydrological element that should be taken into account when mitigating specifically for amphibian species. Several chemicals, both organic and inorganic, can have negative impacts on amphibian development (Rowe and Dunson 1993, Semlitsch 2000). Nitrates and ammonia have been shown to have negative effects on growth and survivorship. Deicing salts used on road surfaces can introduce sodium and chloride ions into ponds, increasing specific conductance, and negatively affecting amphibian populations by reducing embryonic survivorship (Turtle 2000). Additionally, egg mass deposition has been found to decrease in increasingly acidic conditions (Rowe and Dunson 1993). Elevated concentrations of aluminum have a negative association with egg production. The placement of vernal pool sites should consider land use activities within the watershed of the pool and the potential for pollutant sources.

**Methods**

**Site Selection**

Prior to the selection of the final vernal pool sites, eight (8) potential site locations were identified by NYSDEC during a field reconnaissance of the project area. NYSDEC staff indicated that the site selection and design process should seek to avoid placing the vernal pools within existing wetlands, and should avoid or limit the removal of trees with a diameter-at-breast-height (DBH) of 30.5 centimeters (12 inches) so as to minimize the potential impact to the existing forest.

In July and August of 2001, a site selection study was conducted utilizing specific site selection criteria. All sites were analyzed using a series of site evaluation criteria. For a site to be selected as a candidate vernal pool site, it was necessary that it conform to most, if not all, of the evaluation criteria. Site evaluation criteria were based on seven primary elements including: (1) the presence of low-quality or early-succession forest habitat; (2) an adjacent upslope drainage area for conveyance of surface water into the pool; (3) the absence of bedrock, large rocks, and stones within the excavation area; (4) close proximity to existing wetlands without entering the wetland; (5) the presence of soils with a confining layer within 0.91m (3.0 feet) of the surface; (6) relatively flat topography to minimize the need for excavation; and (7) site accessibility for construction equipment. One to two soil pits were dug at each proposed vernal pool site. Pits were dug to a depth of approximately one meter (three feet), where possible, to characterize the soil texture, evidence of seasonal groundwater fluctuation, and presence and extent of rocks or gravel. Soil logs were recorded for each pit.

Relevant site features including trees to be preserved, soil pit locations, rock walls and trails were located using a Trimble Pro XRS GPS unit. The approximate limits of each pool were marked in the field with flagging and
located using the GPS unit. These data were used in subsequent phases of the design process. Following the site selection and evaluation, comment was sought from NYSDOT, NYTA and NYSDEC on the candidate sites prior to developing the water budget and preliminary designs for each pool.

**Water Budget Analysis**

The water budget methodology presented here is based on methods suggested by Pierce (1993). Following the selection of each vernal pool site and completion of the preliminary grading to establish pool depth, size, and drainage area, a water budget was prepared to evaluate its performance of each pool based on 30 years of precipitation data. The water budget for a vernal pool is an application of the conservation of mass law expressed by the equation of continuity:

\[ \Delta S = \left\{ P + \frac{Q_R}{4} \right\} \text{inflow} - \left\{ E_p + \frac{Q_D}{4} \right\} \text{outflow} \]  

Where:
- \( DS \) = Change in storage
- \( P \) = Precipitation
- \( Q_R \) = Groundwater recharge
- \( R_o \) = Runoff from contributing drainage areas
- \( E_p \) = Evapotranspiration
- \( Q_D \) = Groundwater discharge

Equation 1 is expressed in units of volume for each month. By dividing equation 1 by the pool area, it can be expressed in terms of depth of water per month in the following manner:

\[ EL_2 = EL_1 + \frac{(P + Q_R + R_o - E_p - Q_D)}{A} \]  

Equation 2 is in units of depth of water for each month.

- \( EL_2 \) = Water elevation at the end of the period, meters
- \( EL_1 \) = Water elevation at the beginning of the period, meters

Since there is potential for significant vertical and lateral loss of water in several of the vernal pool sites, a design considering a low permeability clay-bentonite layer at the bottom of the pool was considered. Clay layers were proposed for all of the potential sites as the subsoil in many of the vernal pool sites were silt loam, stony silt loam, or similar materials that have a high permeability rate and a low water holding capacity.

Since the sites were underlain by the nearly impermeable clay-bentonite layer, ground water recharge and discharge into and out of the pools were assumed to be negligible and not considered in the water budget. Thus, equation 2 for water depth in the vernal pools, between the top of the clay layer and the top of the pool, can be rewritten as follows:

\[ EL_2 = EL_1 + \left\{ P + R_o - E_p - C \right\} \]  

Where:
- \( C \) = Percolation through the clay-bentonite layer

The water budget for the vernal pools was performed by applying equation 3 on a monthly basis using historical weather data. The sources and losses in equation 3 were derived using the equations described below.

Historical monthly rainfall data was used as precipitation. Potential evapotranspiration (PET) was estimated from historical pan evaporation data by reducing the data by a Pan-to-PET coefficient, and is given by the relation:

\[ PET = C_{ET} \times E_p \]  

Where:
- \( PET \) = Potential evapotranspiration (inches/month)
- \( C_{ET} \) = Pan-to-PET coefficient
- \( E_p \) = Pan evaporation (inches/month)
The Pan-to-PET coefficient ranged from 0.7 in summer months to 0.5 in winter months (Saxton 1982).

Runoff from contributing drainage areas was determined using the SCS Runoff Curve Number method (NRCS 1986). According to this method, runoff volume is determined as:

\[ R_o = \frac{(P - 0.2S)^2}{(P + 0.8S)} \]  

(5)

Where:
- \( R_o \) = Runoff, mm/month
- \( P \) = Rainfall, mm/month
- \( S \) = Potential maximum retention after runoff begins, mm/month

Potential maximum retention, \( S \), is related to soil and cover conditions of the drainage area through the curve number (CN). CN has a range of 0 to 100, and \( S \) is related to CN by:

\[ S = \frac{1000}{CN} - 10 \]  

(6)

Percolation through the subsoil layer was estimated using Darcy’s Law:

\[ C = \frac{K_s H}{L} \]  

(7)

Where:
- \( C \) = Percolation rate through the subsoil layer, mm/month
- \( K_s \) = Vertical hydraulic conductivity of the subsoil layer, mm/month
- \( H \) = Head of water above the bottom of the subsoil layer, mm
- \( L \) = Thickness of the subsoil layer, mm

**Results and Discussions**

**Site Selection Results**

Berger identified a total of twelve candidate sites for vernal pool creation. These sites are generally located close to existing wetlands, and near to the eight sites originally recommended by the NYSDEC. Each site is located within a secondary growth, mixed oak/sugar maple hardwood forest community. Figure 2 illustrates the location of the vernal pool sites.

The topography of the project area is characterized by three parallel ridges that run north to south, with forested or emergent wetlands present within the valleys (figure 2). The physical character of landscape greatly influenced the locations identified for the proposed vernal pools. Due to topographic constraints, each of the pool sites was located in close proximity of existing wetlands. Examination of redoximorphic features within each soil pit indicated that seasonal groundwater could not be relied upon as a source of hydrology. In addition, the soil pits indicated that the subsoil ranged from silt loam to silty clay with a high percentage of stones. The majority of the sites did not have a continuous subsoil that could serve as a confining layer.

In general, each site was located in a location that avoided the removal of large trees, would allow for the retainage of a full or partial tree canopy, and had reasonable access routes for construction equipment. Once selected as a potential vernal pool site, a concept design was prepared and a water budget developed for each site.

**Vernal Pool Habitat Design Elements**

In an effort to encourage colonization and establishment of biotic communities within vernal pools, several essential habitat components were developed and incorporated into the vernal pool design plan. These features are intended to provide amphibians with breeding and developmental microhabitat crucial to successful mitigation efforts and are described below.

Vegetation. During the site evaluation, the perimeter of each site was established in the field and the location of each large tree to be retained on the perimeter of the site was identified. The tree locations were plotted...
on the design plan and the limit of cut adjusted to the drip line of the tree. In addition to protecting adjacent trees, vegetation removed from the sites will be used to create brush piles near the pools, thus avoiding the expense of removing the material and providing additional habitat features. DeMaynadier and Hunter (1999) demonstrated that wood frogs show an emigration preference for closed canopy environments, with the maximum number of emigrating adults and juveniles found within habitats characterized by dense foliage in the understory and canopy layers. This further supported the need to minimize the removal and disturbance of trees and shrubs bordering each vernal pool location.

There is no plan to seed or establish wetland plants within the vernal pools. In time, most of the pools will have a nearly closed canopy that will inhibit or reduce the growth of herbaceous plants. Each pool will be inoculated with a layer of leaf litter and organic material, described below, which will provide a seed source for wetland plants. The presence of wetland vegetation, particularly grasses, spike rush (Eleocharis), sedges (Carex) and rushes (Juncus), have been observed in salamander breeding pools (Thompson et al. 1980), and are expected to become established in portions of some of the vernal pools.

Fig. 2. Location of 12 proposed vernal pools.

_Egg Anchors Sites._ Tree limbs and twigs provide sites on which amphibians can anchor their egg masses. An ample amount of such anchors (10-20) would be placed in each pool prior to the first breeding season utilizing trees removed from each vernal pool construction site. A minimum of two trees (referred to as snags) will be placed into each pool at the completion of all other elements.

_Leaf Litter Layer._ Amphibians require cover for protection. Cover items generally include leaves, pieces of tree bark, and other forms of organic debris. The vernal pool design calls for the placement of a 20-cm (8-inch) layer of leaf litter and organic matter across the floor of each pool. The leaf litter layer will be on top of a 10-cm (4-inch) mineral soil layer. Spotted turtles reportedly hibernate, aestivate, and sleep in the soft aquatic substrates at depths in excess of 20cm (Ernst et al. 1994). In addition to providing this function, the leaf litter layer will support the establishment of detritus food web within the pools.

_Organism Inoculation._ The collection of leaf litter and organic material from the proposed roadway right-of-way will allow for the inoculation of the vernal pools with bacteria, fungi and invertebrates (i.e. insects, amphipods, isopods) that can serve as the basis of the food chain within the pool. Aquatic invertebrates will benefit from the presence of certain fungi, which they will consume. In turn the invertebrates can be consumed by developing amphibians. While transferring amphibian egg masses from the impacted wetlands (prior to disturbance) or other sites into the constructed pools will improve the likelihood of permanent amphibian colonization (Weyrauch and Amon 2002), this action has not been proposed at this time.

Due to the limitations posed by the topography of the landscape and desire to avoid large trees, the vernal pools were designed with a maximum depth of one meter (3.3 feet) and with 2:1 to 3:1 side slopes. Rowe and
Dunson (1993) identified a positive correlation between pool volume and the number of egg masses of *Rana sylvatica* and *Ambystoma maculatum*, though a similar relationship was not found with *A. jeffersonianum*. They point out that pools with greater water volumes tend to dry out later in the season and *A. maculatum* is one of the last salamanders to complete metamorphosis, whereas *A. jeffersonianum* metamorphose earlier and may not be as dependent on pools with a longer hydroperiod. The use of steeper side slopes in the vernal pool design maximized pool volumes, avoided the removal of large trees, and reduced the amount of material excavated from each site.

The desire to limit material and vehicle movement through the adjoining forest led to the incorporation of soil disposal areas near the pools. These areas were contoured to complement existing topographic features, capture additional drainage area when possible, and minimize soil handling during construction. This approach provided a construction cost savings by reducing vehicle use.

### Water Budget Hydrologic Analysis

The vernal pool water budget developed using the methodologies and input data presented above was implemented in a spreadsheet. The results from the water budget for four vernal pool sites B, C, H, and Z are presented here. The four vernal pool sites presented here have varying drainage-area-to-pool-area ratio (table 1), with site B having the largest drainage-area-to-pool-area ratio among all vernal pool sites and site C having one of the smallest drainage-area-to-pool-area ratio.

### Input Data and Parameters

The water budget analysis for the vernal pools was performed using historical weather data for the 28-year period, 1973 to 2000, from the nearest National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) weather stations where long-term weather data were available. Rainfall data were obtained from the Walden, NY, weather station; whereas, pan evaporation data were obtained from the New Brunswick, NJ, weather station.

Runoff contributing areas to each site were delineated using topographic survey maps and are tabulated in table 1. Weighted runoff curve numbers for contributing drainage areas were determined from the TR-55 Manual (NRCS 1986), using land use information from aerial surveys and hydrologic soil group of soils in the contributing drainage areas from the NRCS Soil Survey of Orange County (NRCS 1981). The weighted runoff curve numbers for the contributing drainage areas ranged from 70 to 79.

The vernal pool design specified a 100mm (4-inches) thick mineral soil layer and a 200-mm thick leaf, and a subsoil clay layer (clay-bentonite) lining the pool. As the leaf litter is expected to settle over a period of time, the actual thickness of leaf litter in the pools was assumed to be only 100-mm. The top of the clay layer was simulated in the water budget by taking into account the thickness of the mineral soil layer and the actual thickness of the leaf litter. The thickness of the clay layers in the pools were specified as 100-mm or 160-mm, based on drainage-area-to-pool-area ratio after performing preliminary runs of the water balance model. All sites that had a drainage-area-to-pool-area ratio of greater than 2:1 were specified a 100-mm clay layer, and all sites that had a drainage-area-to-pool-area ratio of less than 2:1 were specified a 160-mm clay layer (table 1). The vertical hydraulic conductivity of the clay-bentonite layer was conservatively assumed to be $1 \times 10^{-6}$ cm/sec for all pools, even though the Hydrologic Evaluation of Landfill Performance (HELP) model documentation (Schroeder et al. 1994) suggests a value of $3 \times 10^{-9}$ cm/sec as the vertical hydraulic conductivity of bentonite soils.

### Table 1

<table>
<thead>
<tr>
<th>Vernal Pool Site</th>
<th>Pool Area (ha)</th>
<th>Drainage Area (ha)</th>
<th>Ratio of Drainage Area to Pool Area</th>
<th>Thickness of Clay Liner (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>0.0291</td>
<td>0.3543</td>
<td>12.18</td>
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<tr>
<td>C</td>
<td>0.0348</td>
<td>0.0333</td>
<td>0.96</td>
<td>160</td>
</tr>
<tr>
<td>D</td>
<td>0.0306</td>
<td>0.2725</td>
<td>8.91</td>
<td>100</td>
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<tr>
<td>F</td>
<td>0.0219</td>
<td>0.0536</td>
<td>2.45</td>
<td>100</td>
</tr>
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<td>H</td>
<td>0.0392</td>
<td>0.2240</td>
<td>5.71</td>
<td>100</td>
</tr>
<tr>
<td>T</td>
<td>0.0286</td>
<td>0.0462</td>
<td>1.62</td>
<td>160</td>
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<td>U</td>
<td>0.0199</td>
<td>0.0104</td>
<td>0.52</td>
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<td>V</td>
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<td>0.0772</td>
<td>0.75</td>
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<tr>
<td>W</td>
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<td>0.0770</td>
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<tr>
<td>X</td>
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<td>0.0363</td>
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<td>Y</td>
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<tr>
<td>Z</td>
<td>0.1315</td>
<td>0.2100</td>
<td>1.60</td>
<td>160</td>
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Table 2
Average Annual Water Balance Components for Potential Vernal Pool Sites

<table>
<thead>
<tr>
<th>Water Balance Component</th>
<th>Site B</th>
<th>Site C</th>
<th>Site H</th>
<th>Site Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall (mm)</td>
<td>1123.95</td>
<td>1123.95</td>
<td>1123.95</td>
<td>1123.95</td>
</tr>
<tr>
<td>Runoff from Contributing Drainage Area (mm)</td>
<td>3704.84</td>
<td>291.08</td>
<td>2260.35</td>
<td>485.90</td>
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<tr>
<td>Evapotranspiration (mm)</td>
<td>600.20</td>
<td>600.20</td>
<td>600.20</td>
<td>600.20</td>
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<tr>
<td>Percolation through Clay Layer (mm)</td>
<td>2285.75</td>
<td>823.21</td>
<td>2127.50</td>
<td>1005.33</td>
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<td>Net Storage (mm)</td>
<td>+1942.84</td>
<td>-8.38</td>
<td>+656.60</td>
<td>+4.32</td>
</tr>
</tbody>
</table>

The annual water balance components for the four vernal pool sites are given in table 2. Rainfall was assumed to be constant for all four sites. Runoff from contributing drainage areas for the four sites were almost directly proportional to the contributing drainage area, as the curve numbers for sites B, C, and Z were all 72, and the curve number for site H was 79. Even though there may be slight differences in tree canopy area and hence evapotranspiration between the sites, these differences were not considered in the water budget as evapotranspiration was assumed to be equal to potential evapotranspiration. Percolation losses through the clay-bentonite layer varied between the sites as the head of water above the confining layer varied between the four sites and at different parts of the year. The net storage values in table 2 shows that the average annual sources into the pool were much greater than the average annual losses from the pool for sites B and H, sources were slightly greater than losses for site Z, and sources were slightly less than losses for site C.

Fig. 3a. Predicted monthly water elevations at vernal pool site B based on historical weather data from January 1973-December 2000.
Fig. 3b. Predicted monthly water elevations at vernal pool site C based on historical weather data from January 1973-December 2000.

Fig. 3c. Predicted monthly water elevations at vernal pool site H based on historical weather data from January 1973-December 2000.

Fig. 3d. Predicted monthly water elevations at vernal pool site Z based on historical weather data from January 1973-December 2000.
Fig. 4a. Predicted water level in vernal pool site B during hydroperiod months (March to September based on historical climatic data from 1973 to 2000).

Fig. 4b. Predicted water level in vernal pool site C during hydroperiod months (March to September based on historical climatic data from 1973 to 2000).
The simulated water elevations for vernal pool sites B, C, H, and Z for the 28-year period are graphically presented in figures 3a, 3b, 3c, and 3d, respectively. It should be noted that the model compares water surface elevation with the average pool bottom elevation, and does not account for the presence of deep pools that have been incorporated into each pool. The water levels in the vernal pools with respect to the pool bottom and several depth increments above pool bottom during the breeding and larval development months of salamanders (March to September) for sites B, C, H, and Z are summarized in figures 4a, 4b, 4c, and 4d, respectively, and in tables 3a, 3b, 3c, and 3d, respectively. Figure 4 shows graphically the months in which the pools had some amount of water, 152mm of water, 305mm of water, 457mm of water, and water near the top of pool (approximately 533mm of water). Table 3 sums the number of years over the simulation period of 28 years, when water is 152mm, 305mm, 457mm, and 533mm (near top of pool) above the bottom of pool for the months March to September. Figure 2 and table 3 shows that among the four vernal pools, site B was the vernal pool with the most water, followed by site H, site Z, and site C. The amount of water in the vernal pools generally followed the drainage area to pool area ratio (table 1) with the site with the highest ratio having the most water and the site with the lowest ratio having the least water.

Site B had water near the top of pool (533mm of water) from March to September for at least 43 percent of the 28-year simulation period (table 3a). For the salamander breeding and incubation months of March, April, and May, Site B had water near the top of pool (533mm of water) for at least 57 percent of the 28-year simulation period.
period. From March to September, site H had 457mm of water for at least 35 percent of the 28-year simulation period and water near the top of pool (533mm of water) for at least 21 percent of the 28-year simulation period. For the salamander breeding and incubation months of March, April, and May, site H had 457mm of water for at least 50 percent of the 28-year simulation period and water near the top of pool (533mm of water) for at least 32 percent of the 28-year simulation period. From March to September, site Z had 152mm of water at least 25 percent of the 28-year simulation period. For the salamander breeding and incubation months of March, April, and May, site Z had 152mm of water for at least 46 percent of the 28-year simulation period. From March to September, site C had 152mm of water at least 7 percent of the 28-year simulation period. For the salamander breeding and incubation months of March, April, and May, site C had 152mm of water for at least 32 percent of the 28-year simulation period.

<table>
<thead>
<tr>
<th>Table 3a</th>
<th>Summary of Results from the Water Balance Model for Site B during the hydroperiod months for the Simulation Period from 1973 to 2000.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of years water is 152 mm above bottom of pool</td>
<td>28</td>
</tr>
<tr>
<td>No. of years water is 305 mm above bottom of pool</td>
<td>25</td>
</tr>
<tr>
<td>No. of years water is 457 mm above bottom of pool</td>
<td>19</td>
</tr>
<tr>
<td>No. of years water is near top of pool</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 3b</th>
<th>Summary of Results from the Water Balance Model for Site C during the hydroperiod months for the Simulation Period from 1973 to 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>No of years water is 152 mm above bottom of pool</td>
<td>10</td>
</tr>
<tr>
<td>No. of years water is 305 mm above bottom of pool</td>
<td>0</td>
</tr>
<tr>
<td>No. of years water is 457 mm above bottom of pool</td>
<td>0</td>
</tr>
<tr>
<td>No. of years water is near top of pool</td>
<td>0</td>
</tr>
</tbody>
</table>
The percentage of simulation periods when water is at least 152 mm (6 inches) above the bottom of the pool for the four vernal pool sites is shown in table 4. The water budget model results in table 4 show that, except for site C in the months of June through September, the selected vernal pool sites were capable of providing sufficient hydrology. As mentioned previously, a conservative estimate of $1 \times 10^{-6}$ cm/sec was used as the vertical hydraulic conductivity of the clay-bentonite layer for all four vernal pool sites. If a vertical hydraulic conductivity of $7 \times 10^{-7}$ cm/sec was used in the water budget model, all sites including the ones with the lowest drainage area to pool area ratio, sites C, V, and U, would have 152 mm of water in the pool for at least 25 percent of the 28-year simulation period in the months of March through September. Clay-bentonite layers, if properly constructed, are capable of yielding vertical hydraulic conductivity of $7 \times 10^{-7}$ cm/sec or lower. Therefore, it can be concluded that the proposed vernal pool sites exhibited the required vernal pool hydrology for a majority of the simulation period.

Table 4
Percentage of simulation period (1973-2000) water is at least 152 mm above bottom of pool elevation at Sites B, C, H and Z

<table>
<thead>
<tr>
<th>Vernal Pool</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site B</td>
<td>100%</td>
<td>96%</td>
<td>100%</td>
<td>93%</td>
<td>93%</td>
<td>82%</td>
<td>93%</td>
</tr>
<tr>
<td>Site C</td>
<td>36%</td>
<td>39%</td>
<td>32%</td>
<td>21%</td>
<td>21%</td>
<td>7%</td>
<td>14%</td>
</tr>
<tr>
<td>Site H</td>
<td>93%</td>
<td>100%</td>
<td>96%</td>
<td>89%</td>
<td>82%</td>
<td>79%</td>
<td>86%</td>
</tr>
<tr>
<td>Site Z</td>
<td>61%</td>
<td>71%</td>
<td>46%</td>
<td>43%</td>
<td>39%</td>
<td>29%</td>
<td>25%</td>
</tr>
</tbody>
</table>
Based on the vernal pool water budgets, it can be observed that the vernal pool designs will provide a range of hydroperiods, with three of the twelve pools providing marginal results. Of the 12 vernal pool sites examined, site Z has the driest hydroperiod and is the least likely to support amphibian breeding in most years. This is attributable to the fact that this pool has the greatest pool volume and greatest surface area of all of the vernal pool sites. Several vernal pools have lower pool-area-to-watershed ratios that are offset by their smaller volumes. Because the water budget model used a conservative approach to estimate the hydroperiod of each vernal pool design, it is anticipated that the observed pool hydrology will extend for longer periods than predicted in the model due to effects of seasonal high groundwater and the effectiveness of the clay liner.

Wildlife Passage Elements

**Amphibian Box Culverts.** Three box culverts measuring 1200mm x 1200mm (4 ft x 4 ft) will be installed to connect the wetland systems in the western portion of the East-West Connector and to provide safe passageways for breeding amphibians. The culverts will be installed partially below ground surface and filled with native soil material to meet existing ground elevation to provide a substrate suitable for amphibian use. The position of the culverts at the low point in the landscape and opening to an existing wetland should improve the potential for salamander use of the culvert by increasing the soil moisture within the culvert. Amphibian barriers will be installed in conjunction with each culvert opening to divert migrating amphibians into the culverts rather than across the roadway. The amphibian barriers will extend an average of 50 meters (164 feet) to tie into elevated upland forest sites. The barriers are designed to provide a minimum height of 450mm (14 inches), and the terminal ends of the barrier will be turned back toward the culvert at 45-degree angles. The use of this angle has been shown to be effective in causing salamanders to turn around and move back toward culvert openings (A. Breisch, persn. comm. 2001) The barrier will be constructed of reinforced concrete to both reduce the need for maintenance and to provide structural support to the roadway embankment.

**Wildlife Conspans/Culverts.** Two conspans measuring 3600mm x 2100mm (12 ft x 7 ft) and two 900mm (3 ft) RCP culverts have been incorporated into the roadway design to facilitate wildlife movement beneath the roadway. The structures will be three sided to provide a natural substrate. The conspans and culverts are located within the western portion of the East-West Connector where it crosses through a valley containing a large emergent and forested wetland. In this section, the roadway footprint has been minimized to reduce wetland impacts through the use of retaining walls. The roadway will be approximately 6 meters (20 feet) high above the adjoining ground, forming an effective barrier for wildlife movement. The wildlife passages are expected to provide adequate sites for wildlife movement. The two conspans provide an openness ratio of 0.85, indicating that these structures will be suitable for use by deer, the largest mammal likely to use these crossings.

Monitoring Plan

Several different monitoring components will be required to track the success of the constructed vernal pools. The monitoring period shall be for five years with a period of more intensive surveys being conducted during the first three years following construction of the pools to determine usage levels by target species. The intensive monitoring period shall include monitoring of pool hydrodynamics and herpetological breeding composition between March and July, and again in October. Following the initial three years of monitoring, a revised monitoring program may be employed following consultation with NYSDEC for the remaining two years.

**Hydrology.** Vernal pool hydrodynamics will be monitored on a monthly schedule between March and July. Monitoring will include visual observation of soil saturation and depth of surface water. A YSI meter will be used to obtain data on parameters such as dissolved oxygen, pH, conductivity, and temperature. Additional daily information on water elevation will be collected using data loggers. Twelve data loggers will be installed in each pool to monitor surface water level fluctuations.

**Amphibian Breeding Surveys.** Amphibian presence/absence surveys will be conducted weekly during the peak breeding period of March and April. The surveys will consist of active surveying techniques (i.e., evening frog call surveys, spotlight surveys) and additional standard survey methods, such as general wading surveys, dip netting, and minnow traps (for amphibian larvae) as appropriate, until documentation of breeding activity by target amphibian species is observed. Once the presence of any target species is confirmed in a specific pool, monitoring of that pool will revert to a monthly schedule through the end of July. In pools where no target species are observed, weekly surveys will continue until the end of the peak-breeding season in April. From May through July, monitoring for all pools will shift to a monthly schedule through the end of July. During the monthly surveys, occupancy, species composition, and breeding success will be monitored using standard survey methods. Reptile and invertebrate species observed during surveys will also be documented and reported.
During the month of October, all pools will be surveyed weekly for the presence of marbled salamanders. These salamanders will be surveyed by searching beneath cover objects (i.e., logs) where they hide during their fall-breeding period. If marbled salamanders are found in a specific pool, the information will be documented and the survey will be complete for the year. In pools where marbled salamanders are not found, weekly surveys will continue until the end of October. At the end of October, all survey activities will cease until the following spring.

**Vegetation.** Vegetation monitoring will be conducted between March and July. Monitoring will include monitoring of native and invasive vegetation colonization, and monitoring of preserved trees and tree and shrub recruitment.

If problems and/or inadequacies are identified during monitoring, supplemental plans may be developed to ensure the successful establishment of the vernal pools and the intended biotic communities. These plans may include additional grading, soil amendments, invasive species removal and manipulation of hydrology, in selected areas.

**Wildlife Crossings.** The NYSTA has worked with the NYSDEC and its consultant team to design wildlife passages throughout the alignment of the East-West Connector. Seven culverts in total will be installed to allow for wildlife passage, with special attention given to migratory breeding amphibians.

**Amphibian Box Culverts.** To monitor the amphibian use and overall success of these culverts, multiple 3-cm-thick plywood coverboards (30 x 30cm) will be scattered within the culverts to provide shelter to amphibians. During the migration period, these coverboards can be lifted and monitored to survey migrating species. This monitoring will be conducted at least once during each site visit between March and July. In the event that coverboard surveys prove to be inconclusive, several other monitoring strategies may be used including pitfall traps and dust traps that will be carefully monitored. These monitoring tools will need to be monitored more frequently, in two to three hour intervals during all field visits and then disengaged when the monitoring team is not present on site.

**Wildlife Consplans/Culverts.** The two wide consplans (3600mm x 2100mm) and two RCP culverts (900mm) will be monitored for wildlife use. While amphibians may use these culverts in addition to the box culverts, the culverts are intended to provide passage to a wider assortment of wildlife that may include mammals, reptiles, and invertebrates. Track surveys will be used to monitor mammal movement through the culverts. The sampling period will coincide with the field visits for amphibian/vernal pool monitoring events. Track beds will be established on each end of the passages and examined for wildlife signs.

**Conclusion**

Full plans, specifications and cost estimates were prepared for construction of the vernal pools and wildlife passage elements of the mitigation plan and incorporated into the roadway bid documents. The 12 vernal pools range in size from 0.01 to 0.13 hectares (0.04 to 0.33 acre), with a combined total area of 0.55 hectares (1.37 acres). After construction, each pool will be monitored over a five-year period to evaluate hydrologic performance and recruitment of amphibians. Likewise, the utilization of the four wildlife underpasses will be monitored for use by small and large mammals and amphibians to assess the performance of the crossings.

**Acknowledgements:** The authors wish to thank Ms. Debra Nelson and Ms. Lisa Weiss from New York State Department of Transportation, and Mr. Al Breisch from the New York State Department of Environmental Conservation, for their technical review and comments throughout the design process. Additional thanks go to Mr. Jeremy Feinburg who provided the initial literature review into vernal pool habitats and species requirements. Their insight and knowledge was invaluable in developing the mitigation plan and ensuring that the design will be both functional and successful.

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Edward Samanns is a principal environmental scientist with The Louis Berger Group, Inc. He is a certified Professional Wetland Scientist with over 18 years of experience developing and implementing wetland and wildlife studies and restoration designs. Mr. Samanns has a bachelor’s degree in biology from Slippery Rock University in Slippery Rock, PA, and master’s of science degree in Geography from Rutgers University in New Brunswick, NJ.

**References**


