Lessons Learned from the Finderne Mitigation Site, Bridgewater, NJ

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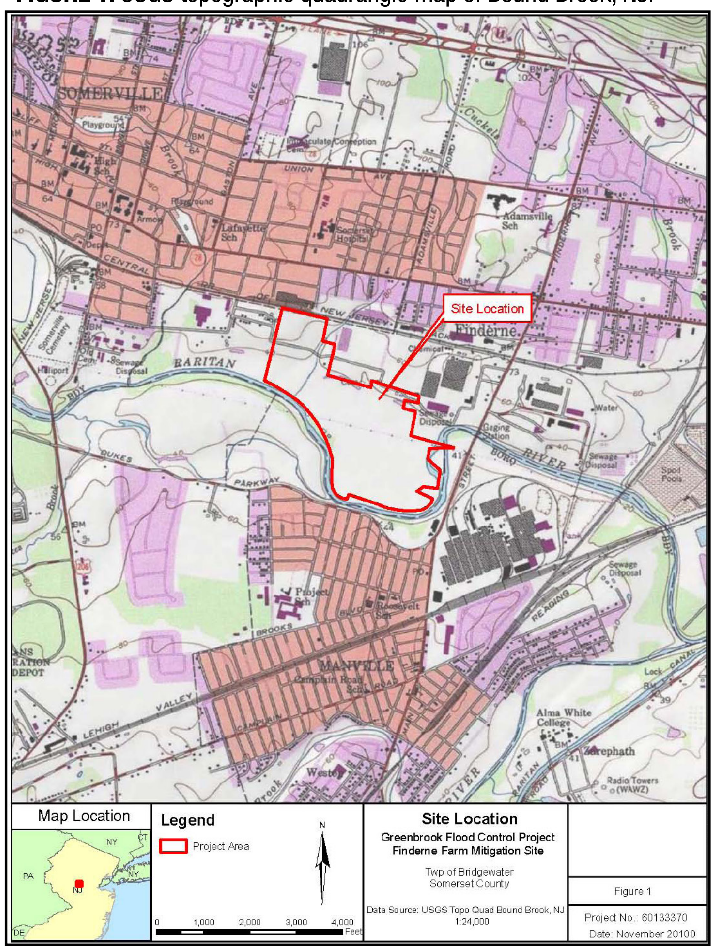
INTRODUCTION

The Finderne Farms wetland mitigation site is located in the Township of Bridgewater, Somerset County, New Jersey on the floodplain of the Raritan River (Figure 1). The Finderne Farms mitigation site (Site) itself is nearly flat and is bordered by the river on the east, south, and west sides. On August 5, 2005 the New Jersey Department of Environmental Protection, Division of Land Use Regulation Program (NJDEP LURP) approved the New York District of the U.S. Army Corps of Engineers' (Corps) wetland mitigation proposal for the Site. Wetland mitigation on the Site was initiated to mitigate for environmental impacts associated with the Green Brook Flood Control Project (e.g., levees and floodwalls) in accordance with the state permit. Construction of the Finderne Farms mitigation site was completed in July 2006 and monitoring occurred for six full growing seasons from 2007 to 2012 to ensure compliance with Corps policy and the NJDEP wetland mitigation regulations.

The Finderne Farms mitigation plan (Plan) was developed for the Site to provide a minimum of 8.87 hectares of created palustrine forested wetland to mitigate for anticipated wetland impacts. Table 1 provides the description of topography and vegetation for the mitigation plan. The overall design goal of the mitigation was to provide in-kind mitigation for wetlands impacted by the Green Brook Flood Control Project at a minimum ratio of 2:1. The Plan also included enhancement areas but the focus of this article will be limited to Creation Area C1 (Figure 2) since it represents nearly half (i.e., 4.13 ha) of the 8.87 ha mitigation project area. Creation Areas C2 and C3 account for 3.82 and 0.92 ha, respectively, of the Site. While many questions may exist regarding the success of a mitigation project, the most basic one involves whether the created site is a wetland.

To evaluate whether Creation Area C1 is a wetland or not the Regional Supplement to the Corps of Engineers Wetland Delineation Manual for the Eastern Mountains and Piedmont Region (USACE 2012) was used. The Regional Supplement included a section focused on how to evaluate hydric indicators for problematic hydric soils and contained more indicators than the Federal Interagency Manual (Federal Interagency Committee for Wetland Delineation 1989) that is used for regulatory purposes in New Jersey. Since the methodology currently used by the Corps nationwide is consistent with the Intermediate-Level Onsite Determination Method outlined in the Federal Interagency Manual, the use of the Regional Supplement in combination with the Federal Interagency Manual satisfied both Corps and NJDEP requirements for identifying wetlands. Wetland identification is typically determined by the presence of hydrophytic vegetation, hydric soils, and signs of wetland hydrology (Environmental Laboratory 1987). Problematic wetlands are defined as those which contain conditions that may make wetland identification difficult. These circum-

FIGURE 1. USGS topographic quadrangle map of Bound Brook, NJ.



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Note: The opinions and conclusions are those of the author and are not intended to represent the official opinion of the U.S. Army Corps of Engineers.

TABLE 1. Description of topography and vegetation for the mitigation design at the Site. The density of trees and shrubs relate to planting design.

Feature	Description	
Topography	Elevation: 9.45 – 10.06 m (NGVD88) Bedding harrow was used to create microtopography.	
Tree Plantings: 1,680 stems/ha	**Scientific Name**	**Common Name**
	Quercus bicolor	Swamp white oak
	Quercus phellos	Willow oak
	Fraxinus pensylvanica	Green ash
	Platanus occidentalis	American sycamore
	Quercus palustris	Pin oak
	Nyssa sylvatica	Black gum
	Alnus serrulata	Smooth alder
Shrub Plantings: 479 stems/ha	*Clethra alnifolia*	Coastal sweet pepperbush
	Cornus amomum	Silky dogwood
	Vaccinium corymbosum	Highbush blueberry
	Viburnum dentatum	Southern arrowwood
Wet meadow seed mix: 56 kg/ha	*Echinochloa crusgalli*	Wild grass
	Poa palustris	Fowl meadow grass
	Elymus virginicus	Virginia wild rye
	Agrostis alba	Black bent grass
	Panicum virgatum	Switchgrass
	Carex spp.	Sedges

stances can occur because field indicators of one or more of the three factors may be obscured or are absent. The Finderne Farms mitigation site is such a site as it is situated in a floodplain with depositional soils derived from red parent material making identification of hydric soil a challenge.

RED PARENT MATERIAL SOILS ON SITE

Soils derived from red parent material are present throughout the Site. These soils are potentially problematic from a wetland delineation perspective due to the red colorization which prevents typical hydric soil indicators from forming. Soils with colors redder than 7.5YR - red parent material soils - fail to develop the low-chroma dominant colors normally found in wetland soils due to the presence of the iron mineral hematite. Some wet red parent material soils may show faint mottling within the A-horizon, however many do not. In these instances, other indicators for wetland determination including observing hydrology and vegetation are heavily relied upon. Berkowitz and Noble (2015) recognized the difficulty with field indicators in the identification of hydric soils and provided guidelines for data collection and submission for the purpose of develop-

FIGURE 2. Finderne Farms mitigation site aerial planting zone location map.

ing and recommending changes to the National Technical Committee for Hydric Soils.

Most of the Site consists of alluvial fine-grained deposits overlying red-brown siltstone and mudstone (shale) of the Jurassic-Triassic aged Passaic Formation (USACE 2014). Lithic material is limited to gravel material along the Raritan River bank, while the only rock outcrops on Site were observed within the slope that borders the northern side of the Site (Figure 3). Red lithic materials of the Passaic Formation are also exposed in northern portion of Finderne Brook, a tributary to the Raritan River on the northwest end of the Site. The Passaic Formation underlies the entire project area. Soils primarily consist of Rowland silt loam. Rowland soils are described as "very deep, moderately well drained to somewhat poorly drained soils formed in alluvial sediments weathered from red and brown shale, sandstone, and conglomerate" (https://soilseries.sc.egov.usda.gov/OSD_Docs/R/ROWLAND.html). The water table "fluctuates between 2 and 6 feet" and the soils are "flooded by streams during wet periods."

METHODS

Since the Site is a floodplain and one dominated by red parent material soils, the guidance provided in the Eastern Mountains and Piedmont Regional Supplement (USACE 2012) was used to evaluate the degree of site wetness and hydric soil properties. This supplement outlines problematic scenarios encountered in the field and contains protocols for dealing with them. While the Federal Interagency Manual also included discussion of red parent material wetlands, the Regional Supplement contains the latest guidance. The red parent material hydric soil indicator (F21) consists of a layer of at least 10 cm starting within the top 25 cm of the surface with a hue of 7.5YR or redder and a value and chroma greater than 2 and less than or equal to 4, containing at least 10 percent depletions or distinct or prominent redoximorphic concentrations as soft masses or pore linings. Depletions should differ in color by having a value one or more higher and chroma one or more lower than the matrix, or have a value of 4 or more and chroma of 2 or less. This indicator was developed for use in areas of red parent material such as residuum in the Piedmont Province Triassic lowlands section or the Paleozoic red beds of the Appalachian Mountains. Ford (2014) cautioned that problematic soils can cause erroneous interpretations and the F21 indicator, although helpful, does not identify all red parent material hydric soils.

Soil borings and data collection at Creation Area C1 were performed from April 4-21, 2014. A series of soil

FIGURE 3. Outcrop of red-brown siltstone and mudstone (shale) at the Finderne Farms mitigation site.

FIGURE 4. View of soil profiles taken from Creation Area C1, from left to right, C1-Ditch, C1-RCG, C1-SG, and C1-Mugwort.

cores were evaluated along a transect from inundated areas to obvious upland (non-wetland) areas to observe changes in soil properties along a topographic gradient. Soil borings were taken with a hand-held auger to depths of approximately 45.7-61.0 cm or to the depth of refusal to examine the soil profile for redoximorphic features. Information collected for each soil profile included horizon depth, texture, color, and the absence or presence of redoximorphic features. Colors of the soil matrix and redoximorphic features were identified using Munsell Color Charts (1975). Hydric soil determinations were based on criteria established in the Federal Interagency Manual (FICWD 1989) and the Regional Supplement (USACE 2012). Soils were also investigated using alpha, alpha-dipyridyl, a reagent that reacts with reduced iron. This reagent can be used to provide evidence that a soil is hydric when other indicators are obscured or lacking. Alpha, alpha-dipyridyl will normally result in changing the soil to a pink or red coloration in soils that are moist or wet and are in a reducing condition.

At each sampling location along the transect, observations were also recorded for the vegetation and hydrology to determine if the location was within a wetland or upland. Species abundance was visually estimated by percent cover within each vegetation stratum. Dominant trees, saplings/shrubs, and herbaceous plants were recorded within sample plots of 9.14-meter, 4.57-meter, and 1.52-meter radius, respectively. The wetland indicator status of each species was identified using the "National Wetland Plant List" (Lichvar et al. 2014).

RESULTS

Hydrology. The Site receives water from several sources including direct precipitation, surface runoff from offsite areas, and flooding from the Raritan River. Water losses include evapotranspiration and runoff. Due to the low permeability of the soils (hydraulic conductivity, K_s = 16.42 cm/day), groundwater likely has little influence on the site's hydrology. The technical standard for wetland hydrology based on monitoring requires 14 or more consecutive days of flooding or ponding, or a water table 30 cm (12 in.) or less below the soil surface, during the growing season at a minimum frequency of 5 years in 10 (50 percent or higher probability) unless an alternative standard has been established for a particular region or wetland type (USACE 2012). Wetland hydrology can be verified by recorded data and/or field observations. Recorded data can be obtained from tide gauges, stream gauges, flood predictions, historical data (i.e., aerial photographs and soil surveys) and piezometers. In the absence of such data, field indicators of wetland hydrology can be used to verify wetland hydrology. For wetland hydrology indicators, there must be a minimum of one primary or at least two secondary indicators in order to satisfy the requirement. Table 2 contains a list of primary and secondary wetland hydrologic indicators observed at Creation Area C1. Within the Site there were five locations (Ditch, RCG, SG, W1, and W2) that exhibited sufficient primary and/or secondary indicators to meet the wetland hydrology requirements. There were two locations (Mugwort and U1) that did not meet the minimum hydrologic indicators.

TABLE 2. Wetland hydrology indicators for the Eastern Mountains and Piedmont Region observed at Creation Area C1. One primary indicator is sufficient to verify wetland hydrology, or in the absence of any primary indicator, at least two secondary indicators are required (USACE 2012).

Planting Area ID	Data Point ID	Primary Indicators	Secondary Indicators	Wetland Hydrology
C1 (PEM)	C1-Ditch	Surface Water (A1) High Water Table (A2) Saturation (A3)	---	Yes
	C1-Mugwort	---	---	No
	C1-RCG	Surface Water (A1) Saturation (A3)	---	Yes
	C1-SG	Surface Water (A1) Saturation (A3)	Geomorphic Position (D2) Microtopographic Relief (D4)	Yes
	C1-U1	---	---	No
	C1-W1	Surface Water (A1) Saturation (A3)	Geomorphic Position (D2) Microtopographic Relief (D4)	Yes
	C1-W2	Surface Water (A1) Saturation (A3) Oxidized Rhizospheres on Living Roots (C3)	Geomorphic Position (D2) Microtopographic Relief (D4)	Yes

Vegetation. Table 3 identifies the species per vegetative strata observed at Creation Area C1 and provides the corresponding wetland indicator status. Four of the seven sampling locations (Ditch, RCG, SG, and W2) had a positive indicator for hydrophytic vegetation, while location W1 was dominated by a *Dicanthelium* grass of undetermined species in association with FACW species. The hydrophytic vegetation status of W1 could not be established by vegetation alone due to lack of identification to the species level, but was later confirmed due to the presence of hydric soil indicators and sufficient indicators of wetland hydrology observed during field work.

Soils. Table 4 summarizes the soil data reported on the standard wetland delineation field forms for each sample location. For C1, both W1 and W2 exhibited red parent material with the corresponding hydric soil indicator F21.

TABLE 3. Vegetation data at Creation Area C1. Dominants were identified following the 50/20 rule in the Regional Supplement.

Planting Area ID	Data Point ID	Stratum	Scientific Name (Common Name)	Absolute % Cover	Dominant Species	Indicator Status	Hydrophytic Vegetation
C1 (PEM)	C1-Ditch	H	*Phalaris arundinacea* (reed canary grass)	50	D	FACW	Yes
		H	*Panicum virgatum* (switchgrass)	45	D	FAC	
		H	*Artemisia vulgaris* (mugwort)	5	ND	UPL	
	C1-Mugwort	H	*Artemisia vulgaris*	90	D	UPL	No
		H	*Humulus japonicus* (Japanese hops)	5	ND	FACU	
		H	*Phalaris arundinacea*	2	ND	FACW	
	C1-RCG	S/S	*Quercus palustris* (pin oak)	3	D*	FACW	Yes
		S/S	*Quercus bicolor* (swamp white oak)	2	D*	FACW	
		H	*Phalaris arundinacea*	70	D	FACW	
	C1-SG	T	*Quercus palustris*	7	D	FACW	Yes
		T	*Quercus bicolor*	2	D	FACW	
		H	*Panicum virgatum*	80	D	FAC	
		H	*Phalaris arundinacea*	2	ND	FACW	
		H	*Juncus effusus* (soft rush)	2	ND	FACW	
	C1-U1	H	*Artemisia vulgaris*	55	D	UPL	No
		H	*Panicum virgatum*	5	ND	FAC	
		H	*Solidago gigantea* (goldenrod)	40	D	FACW	
	C1-W1	H	*Lythrum salicaria* (purple loosestrife)	15	ND	FACW	Yes**
		H	*Bidens frondosa* (devil's beggartick)	10	ND	FACW	
		H	*Dicanthelium sp.*	75	D	Not determined	
	C1-W2	S/S	*Quercus palustris*	5	D	FACW	Yes
		H	*Phalaris arundinacea*	100	D	FACW	

NOTES:

H – herb, S/S – sapling/shrub, and T – tree.

* *Quercus palustris* and *Q. bicolor* are both considered dominant trees since the stratum contains 5% or more absolute cover (USACE 2012).

**Based on indicators of hydric soil and wetland hydrology.

The alpha, alpha-dipyridyl test did not produce a positive reaction. However, a reddish or pink color induced by the reagent (evidence of reduced iron in the soil) is hard to see on red parent material soil.

DELINEATED WETLAND

Creation Area C1 is dominated by palustrine emergent vegetation, with planted saplings of FACW tree species also present. Hummocks were part of the original design of this creation area and varied in height from 0.152 – 0.457 m. The western portion of the wetland, which was also dominated by emergent vegetation, has larger hummocks, e.g., > 0.457 meters. In the eastern portion of the wetland, the hummocks were smaller and the vegetation contained numerous planted tree saplings (see Table 1). Although the presence of hummocks was a feature of the original design, it is likely that post construction size differential occurred as a result of erosion and scour from flooding (i.e., Raritan River overbank inundation) even though the frequency of such events was limited. Switchgrass and planted saplings are found at the southern portion of the wetland, followed by an expanse of reed canary grass with much fewer surviving woody plantings (i.e., *Quercus palustris* and *Q. bicolor*) and a narrow depression (i.e., ditch) running along the northern boundary of the wetland. The ditch is dominated by reed canary grass, purple loosestrife, and soft rush. The soil profile textures were dense clays with faint to distinct mottling and matrix color typically 5YR3/3. The wetland was delineated by taking a series of soil cores in the various communities and identifying the presence or absence of hydric features in the soil profiles. Figure 4 shows the soil cores from the ditch (C1-Ditch), reed canary grass (C1-RCG), switchgrass (C1-SG), and mugwort (C1-Mugwort). Although often obscured by red parent material, redoximorphic features were observed in the ditch, reed canary grass, and switchgrass soil cores. The delineated wetland line often corresponded with the toe-of-slope of the created cut-slopes surrounding the wetland. Uplands adjacent to C1 wetlands were elevated 0.30 m or more above C1 and were dominated by common mugwort along the perimeter. Upland soils were observed to be similar to wetlands however with fewer (e.g., ≥ 50% fewer) redoximorphic concentrations. The upland soils were also loose and friable and showed no evidence of saturation or inundation. The wetland classification system developed by Cowardin et al. (1979) was utilized to classify the delineated wetland vegetated community as palustrine emergent wetland (PEM). Table 5 is a summary of the data for Creation Area C1 showing the results from the hydrology, vegetation, and soil evaluations.

LESSONS LEARNED

From the outset, we should have realized that hydrology indicators would be very important in making a wetland determination in this red parent material floodplain. Although the data for the 2014 wetland delineation indicates success, initial performance criteria from the six-year (2007 – 2012) post-construction monitoring period were not sufficient to

TABLE 4. Soil profile description data at Creation Area C1.

Planting Area ID	Data Point ID	Depth (cm)	Matrix Color (moist)	Matrix	Redoximorphic Features (%, Color, Type, Location)	Texture	Hydric Soil
C1 (PEM)	C1-Ditch	0 - 20.3	5YR4/2	70%	30%, 5YR3/4, Type[1] C, Loc[2] M	SCL	Yes
		20.3	Gravel	---	---		
		20.3 - 45.7	5YR3/4	85%	15%, 7.5YR4/6, Type[1] C, Loc[2] M	SCL	
	C1-Mugwort	0 - 45.7	5YR3/3	98%	2%, 5YR3/4, Type[1] C, Loc[2] M	SCL	No
	C1-RCG	0 - 45.7	5YR3/3	80%	20%, 5YR3/4, Type[1] C, Loc[2] M	SCL	Yes
	C1-SG	0 - 45.7	5YR3/3	90%	10%, 5YR3/4, Type[1] C, Loc[2] M	SCL	Yes
	C1-U1	0 - 5.1	5YR3/3	100%	---	SCL	No
		5.1 - 15.2	5YR3/4	100%	---	SCL	
		15.2 +	---	---	---	Gravel	
	C1-W1	0 - 15.2	7.5YR3/3	90%	10%, 7.5YR3/7, Type[1] C, Loc[2] M	SCL	Yes
		15.2 -20.3	7.5YR3/3	---	---	SCL	
	C1-W2	0 - 15.2	5YR3/3	93%	3%[3], 5YR3/4, Type[1] C, Loc[2] PL	Clay Loam	Yes
		15.2 - 30.5	5YR3/3	80%	20%, 5YR4/6, Type[1] C, Loc[2] PL	Clay Loam	
		30.5 - 45.7	5YR3/3	80%	20%, 5YR4/6, Type[1] C, Loc[2] M	Clay	

1. Type: C = Concentration.
2. Location: PL = Pore Lining, M = Matrix.
3. Remaining 4% not determined.

adequately evaluate the success of establishing wetland hydrology at the Site. Performance standards for success of the Finderne Mitigation Site included:

1. At the end of year-six, the Corps must submit a field wetland delineation of the mitigation project based on the Federal Interagency Manual (FICWD 1989) which shows the exact area of the wetland mitigation project.
2. The Site has an 85 percent survival and 85 percent area coverage of the mitigation plantings or target hydrophytes which are species native to the area and similar to ones identified on the mitigation planting plan. All plant species in the mitigation area are healthy and thriving. All trees are at least 1.52 meters in height.
3. The Site is less than 10 percent occupied by invasive or noxious species such as, but not limited to, *Phalaris arundinacea* (reed canary grass), *Lythrum salicaria* (purple loosestrife), and *Berberis thunbergii* (Japanese barberry).
4. The hydrologic regime will provide sufficient flood storage to impart approximately 7 to 10 days of inundation followed by 7 to 11 days of soil saturation within the upper 30.48 cm of the soil profile during the growing season. The total hydroperiod should range from 14 to 21 days in duration which represents 6.5 to 10 percent of the growing season between March and October (approximately 215 day).

Problems meeting these performance criteria and other issues led the Corps to extend monitoring beyond the initial six-year period. In 2014 the wetland delineation was performed to determine the extent of wetland, recognizing that the original performance criteria may not have adequately addressed critical issues of site hydrology and hydric soils, especially given the red parent materials dominating the site. Evaluating these performance criteria in retrospect provided a valuable opportunity to establish lessons learned that should help in establishing practical criteria for monitoring and evaluating success of future mitigation projects.

Since the Site was designed to be a palustrine wetland and the planted trees were initially at a nominal height (i.e., 0.305 to 0.914 m) it would take a few decades of growth before shading by the canopy could even begin to diminish the presence and persistence of the invasive or noxious species (e.g., *Phalaris arundinacea*, *Lythrum salicaria*, and *Berberis thunbergii*). Once the planted trees attain a height adequate to inhibit the invasive species, the performance criteria could potentially be satisfied; however, the canopy would have to be quite dense to accomplish this and *Berberis* would likely persist as an understory shrub unless targeted for control. Additionally, the time required for the tree canopy to develop that could potentially restrict emergent growth would take a very long time. Due to limited project funding there were no protocols in place for the physical removal or chemical treatment of invasive species. An important lesson learned is therefore to include removal and control of invasive species as part of any mitigation plan. Moreover, if an invasive species is common in adjacent communities it should not be included in the performance standard as it is highly unlikely to keep it out in the long-term, without costly annual control. Performance criteria must be practicable and recognize site limitations. In this case reed canary grass was a dominant species in the neighboring floodplain and therefore it is unlikely to be kept out of Creation Area C1 without a drastic change in wetland hydrology (i.e., permanent or near permanent inundation) or by application of herbicides or other control means. Another consideration is how the establishment of mature trees (i.e., forested condition) will affect the hydrology of the site in the long-term. Trees will dominate the evapotranspiration process and will significantly change the site's hydrology, especially the underlying water tables during the growing season.

The proposed hydrology in performance criteria men-

TABLE 5. Summary of wetland and nonwetland data within Creation Area C1. PEM – palustrine emergent wetland according to Cowardin et al. (1979); DT – passed dominance test for hydrophytic vegetation.

Planting Area ID	Data Point ID	Class	Wetland Hydrology Indicator	Hydrophytic Vegetation Indicator	Hydric Soil Indicator	Wetland
C1 (PEM)	C1-Ditch	PEM	A1, A2, A3	Y-DT	F3	Yes
	C1-Mugwort	Not wetland	---	---	---	No
	C1-RCG	PEM	A1, A3	Y-DT	F8, F19	Yes
	C1-SG	PEM	A1, A3, D2, D4	Y- DT	F8	Yes
	C1-U1	Not wetland	---	---	---	No
	C1-W1	PEM	A1, A3, D2, D4	Y*	F8, F21	Yes
	C1-W2	PEM	A1, A3, C3, D2, D4	Y-DT	F19, F21	Yes

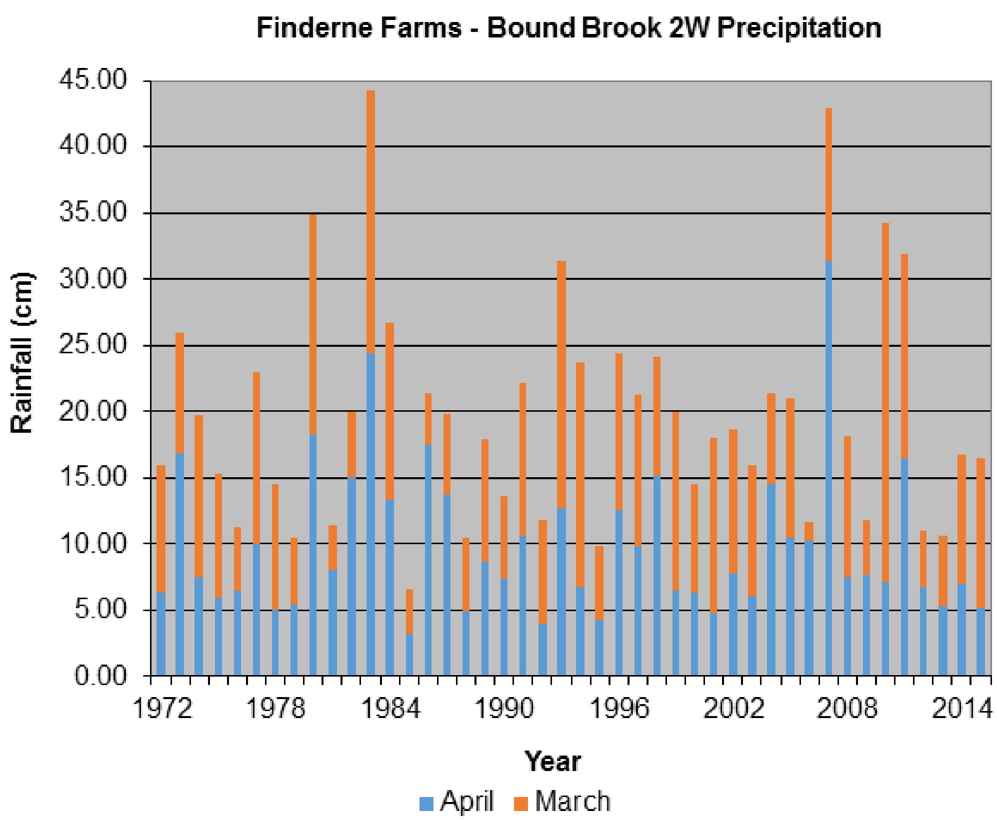
*Problematic vegetation since species of dominant plant could not be established, so based decision on indicators of hydric soil and wetland hydrology and consideration of associated species (all FACW).

tioned above, anticipated a certain frequency of Raritan River overbank inundation (i.e., a minimum of four inundations per year). During the monitoring period (2006 – 2012) the reported incidence of Raritan River overbank flooding did not occur on frequent basis, i.e., less than two times per year on average. When overbank inundation did occur, it was associated with high river discharge velocities (e.g., > 1 m/s) which may have caused the observed vegetation loss/washout. An important lesson learned is planting and stabilizing/securing tree species so they can endure river discharge velocities before they are well established. A viable option would also be to start with larger trees and have them secured with suitable tree staking and straps. It would also be prudent to adequately understand the floodplain dynamics for this Site that included frequency of inundations in addition to maximum discharge velocities. Given the frequency of occurrence for Raritan River overbank flow, inundation did not have a significant contribution to the overall water budget as originally anticipated.

TABLE 6. Rainfall data for the indicated time period.

Time Period	Rainfall (cm) in Reported Time Period		
	1972 - 2015	2007 - 2012	2014
March	9.83	12.17	9.78
April	9.91	12.85	7.01
March+April	19.74	25.02	16.79

FIGURE 5. Total rainfall (cm) for March and April from 1972 to 2015. Note that average rainfall during March and April in these years was 19.74 cm, so rainfall during these months in 2014 was below average.



The performance criteria were developed with the intent of satisfying requirements for a jurisdictional wetland and for establishing a certain plant community that included reducing the spread of invasives. Adequate consideration may not have been given to the challenges of working with red parent material and the presence of invasive species in neighboring wetlands. Clearly more attention needs to be given to monitoring site hydrology, with wet season observations a must.

The initial monitoring program (2007 – 2012) for the Site focused more on the vegetation with less emphasis on hydrology or soils. Considering the limited soil boring sampling time points and more importantly that efforts to evaluate hydrology during the wet season were absent, an evaluation of historic precipitation data was considered to be worthwhile as part of this current effort (2014 delineation). In other words, since an assessment of the Site's hydrology during the six-year monitoring program did not occur, the evaluation of historic rainfall data was considered useful. Moreover, evaluating hydrology during the wet season would be useful in problematic situations involving red parent material; it should be a requirement.

Table 6 is a summary of the rainfall data (Bound Brook 2W precipitation gage) for three time periods: 1) 1972 – 2015, 2) 2007 – 2012, and 3) 2014. The historic monthly average rainfall data for 1972 to 2015 for March and April (combined) was 19.74 cm. For the period of the six-year monitoring program (2007 – 2012) the monthly average rainfall was higher for these months: 25.02 cm for March and April and an average of 12.17 cm for March and 12.85 cm for April. In 2014 the total rainfall for March and April was 16.79 cm which was below the long-term average, yet hydrology observations for Creation Area C1 from April 4-21, 2014 recorded sufficient hydrology indicators for a wetland determination. Since precipitation was actually higher for March and April during the initial monitoring period 2007 – 2012 than rainfall in 2014 where signs of wetland hydrology were documented, it may be reasonable to expect that the hydrology had been adequate for a wetland determination during the six-year monitoring period (2007 – 2012). In other words, since the Finderne Farms

Wetland Delineation Report dated June 15, 2014 (USACE 2014) showed sufficient indicators of wetland hydrology during the more than two-week field investigation it may safely be implied that wetland hydrology likely occurred from 2007 to 2012. Figure 5 is a plot of the historic rainfall data illustrating the total rainfall (cm) for March and April (combined) for 1972 to 2015. As mentioned above, the frequency of Raritan River overbank inundation did not have a measurable benefit to the water budget as was originally anticipated. A valuable lesson learned is that adequately quantifying the temporal aspects of rainfall and understanding long-term conditions can be important to the planning a water budget for any wetland creation project.

The six-year monitoring protocol (2007 – 2012) was less than ideal for the reasons outlined above. For assessing hydrology in red parent materials, a 14-day observation would enable a more thorough evaluation of site wetness and for documenting a hydric soil. Through follow-up monitoring in 2014, the Corps had demonstrated that the original performance criteria did not adequately address the Site's hydrology which was critical for making a jurisdictional wetland determination. The NJDEP gave consideration to lessons learned and accepted the 2014 wetland delineation that documented sufficient wetland area to meet their concerns.

CONCLUSIONS

An adequate understanding of the hydrology at the Site and the challenges of working with red parent material have been significant issues for this mitigation project. After giving special attention to site wetness in 2014 which documented sufficient signs of wetland hydrology for a jurisdictional determination, an evaluation of historic rainfall data (1972 – 2015) further suggested that the Site was likely inundated or saturated at a frequency and duration sufficient during that period to satisfy the wetland hydrology requirement. Finally, it was a more thorough documentation of hydrology and more careful examination of soil properties that resulted in a positive wetland delineation for Creation Area C1 in 2014. Monitoring of wetland hydrology should be an essential element of any wetland mitigation project involving wetland creation. Such monitoring should also include evaluation of site conditions at reference wetlands of the targeted wetland type, even prior to mitigation planning to help with project design. The use of reference wetlands is especially important for problematic wetland types, such as floodplain wetlands where inundation from river flow is the major source of water. ■

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