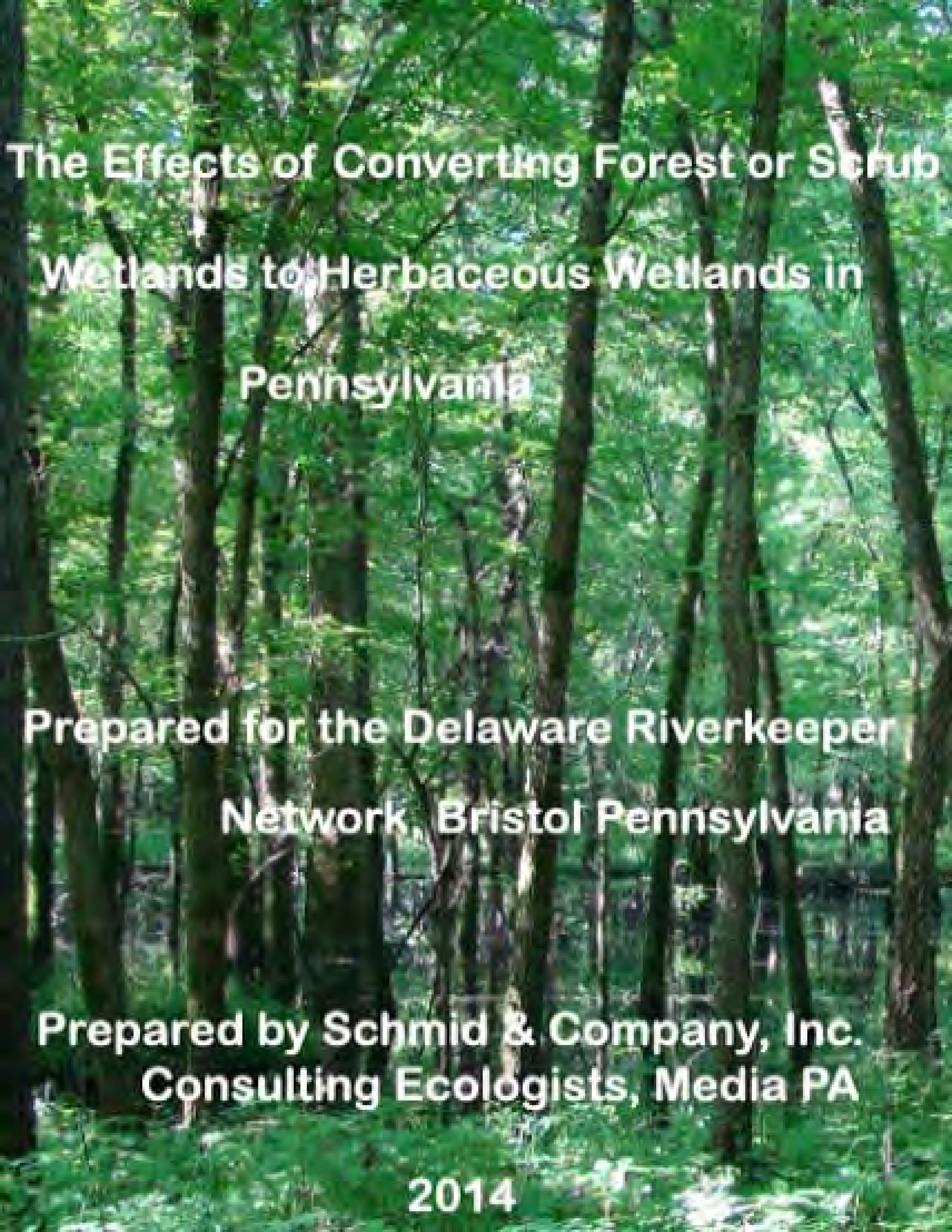


The Effects of Converting Forest or Scrub Wetlands to Herbaceous Wetlands in Pennsylvania

Prepared for the Delaware Riverkeeper Network, Bristol Pennsylvania

Prepared by Schmid & Company, Inc.
Consulting Ecologists, Media PA

2014

Table of Contents

The Effects of Converting Forest or Scrub Wetlands to Herbaceous Wetlands in Pennsylvania

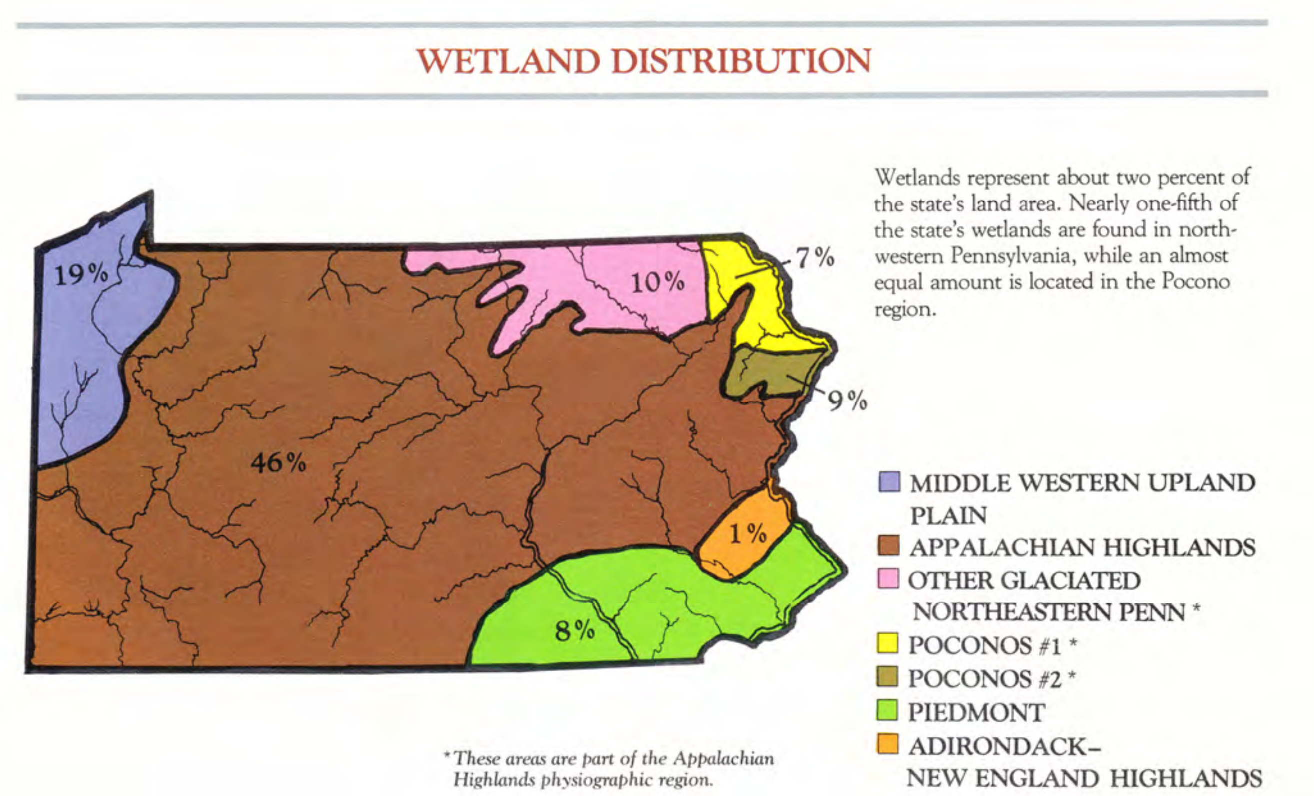
Wetlands are tracts of land characterized by the recurrent and prolonged presence of surface water and/or near-surface groundwater. Their vegetation, wildlife, and soil properties are greatly influenced by wetness, that is, by their hydrology. Wetness has a profound effect on the biogeochemical reactions that occur in the top foot of wetland soil, allowing bacteria to render such soils anaerobic (oxygen-free) and thereby affecting the chemistry of the soil particles as observed in soil color and organic matter, determining the kinds of microorganisms present, selecting the kinds of rooted plants able to survive and compete, and in turn affecting the quality of habitat for animals including humans. Like streams, ponds, lakes, rivers, and oceans, wetlands today are deemed to be bodies of surface water, peculiar places transitional between (1) permanent open waters and (2) dry lands wet only during precipitation events. Some wetlands are associated with areas where surface waters and groundwater interconnect.

For many years wetlands were regarded as wastelands, and public policy encouraged their physical conversion to accommodate more highly valued land uses of many kinds (farms, cities, roads, residential and commercial development). In response, millions of acres of wetlands were destroyed across the United States, including more than half of Pennsylvania's wetlands (more than 600,000 acres). Not until the latter half of the twentieth century were the environmental and societal values of suddenly scarce wetlands broadly appreciated and subjected to legal protection against unnecessary alteration in the United States (Schmid 2000). Today most construction activities in wetlands are regulated by public agencies concerned with environmental protection. Regulators at the federal, State, and/or municipal level may be involved in permit review and approval. Most construction activities that would affect wetlands are unlawful, unless previously authorized by permit, but the applicable laws vary greatly from place to place in their scope and stringency.

Wetness (above-ground inundation or in-ground saturation within the uppermost foot of topsoil) for periods of two weeks or more, at least seasonally recurrent, is the primary characteristic that locally distinguishes individual wetlands from non-wetland areas that may display similar climate, exposure (aspect), slope, geology (rock type), soils, and biota (plants, animals, bacteria, fungi). The prolonged presence of surface water at relatively shallow depth (< 6 feet) and the presence of emergent vegetation distinguish wetlands from the deep, open waters of lakes and the flowing channels (some with submerged or floating plants) of streams---other bodies of surface water with which wetlands often are closely associated. Wetlands often occupy a landscape zone transitional between open waters and the seldom-wet uplands found at higher elevations. Along with groundwater, surface streams, rivers, lakes, ponds, and wetlands are regulated Waters of the Commonwealth of Pennsylvania. Many, but not all, of the wetlands and other surface water bodies in Pennsylvania are also Waters of the United States (USEPA and USACE 2014).

In the large and diverse Commonwealth of Pennsylvania there are many kinds of wetlands. Pennsylvania wetlands in the aggregate occupy a small proportion of the land surface, and are most extensive in formerly glaciated areas such as the plateaus of the northeastern and northwestern counties, as shown below in a National Wetland Inventory drawing (from Tiner 1987). Individual wetlands can range in size from a few square feet to many acres. Wetlands today are recognized as contributing to water quality, wildlife habitat, endangered species protection, and the human landscape far out of proportion to their percentage share of the Pennsylvania land surface, and thus warrant stringent protection from human modifications to the extent practicable. These values increase as human population and population density increase. At the same time, the economic value of property where the destruction of wetlands has been authorized can greatly exceed the cash value of that property in its natural condition. Hence the extent to which public agencies can protect wetland resources often conflicts with the desire of private landowners to alter the property which they own.

Pennsylvania Wetlands Are Geographically Concentrated.



Agencies tasked with implementing the federal Clean Water Act (P.L. 92-500, 86 Stat. 816) and the Pennsylvania Dam Safety and Encroachments Act (32 P.S. 693) and Clean Streams Law (35 P.S. 691), long have defined wetlands as

> Areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, including swamps, marshes, bogs and similar areas (25 *Pa. Code* 105.1.)

Accurate wetland identification and delineation depend upon a careful analysis of plants, soils, and hydrology using the best available scientific guidance to apply the official definition in each real situation on the surface of the earth. In the central sections of most wetlands the general public can readily ascertain the distinctive conditions that characterize tree-filled swamps and herb-dominated marshes. Precisely locating the boundaries of a wetland, however, in gently sloping transitional areas where the requisite field indicators gradually drop out, typically requires specialized training in the visual appearance of vegetation, soils, and hydrology as they occur outdoors in all seasons, along with thorough knowledge of relevant agency rules for consistent decisionmaking. The details of scientific knowledge of wetland functions and regulatory adjustments in setting regulatory boundaries and analyzing impacts have changed over recent decades as our understanding of wetlands has increased.

To apply the regulatory definition of wetlands in the field, federal and Pennsylvania regulators (25 *Pa. Code* 105.451) employ the Army Corps of Engineers *Wetland Identification and Delineation Manual* (ERL 1987) in conjunction with its recent regional supplements (for example, USACE 2012) and other technical support documents (including Lichvar *et al*. 2014, Vasilas *et al*. 2010, USACE 2014). These official documents provide the guidance necessary for recognizing the current extent of regulated wetlands under various conditions of season, wetness, and human disturbance, using field indicators of vegetation, soil, and hydrology.

In Pennsylvania the Army Corps of Engineers provides, in response to landowner requests, formal written Jurisdictional Determinations (JDs) that confirm the accurately mapped extent of wetlands and bodies of surface water eligible for regulation at the federal, State, and municipal level on specific tracts of land. Absent the issuance of a valid JD, there is no way for a landowner or the public to ascertain accurately the limits of a regulated wetland. Topographic maps, National Wetland Inventory maps, floodplain maps, soil survey maps, and planning maps of many kinds can provide useful technical information, but do not identify in detail the limits of regulated wetlands (or streams) that need to be considered by the sponsors of construction projects. Consultants typically document sites on behalf of landowners and prepare paperwork for agency review. Careful documentation of wetlands whose proffered boundaries are superimposed onto a land ownership survey is required as part of a request for a

JD, and Corps staff typically inspect each property in the field prior to approving a JD. JDs remain valid for five years, in recognition of the fact that wetland boundaries can change over time as a result of natural changes as well as unregulated human activities nearby. Only the Natural Resources Conservation Service (NRCS), an arm of the US Department of Agriculture, issues permanent wetland identifications for purposes of eligibility for federal programs that support crop production. Such NRCS determinations apply only to farming, not to general construction activities.

Delineated wetlands are best avoided when new construction projects are proposed, and permit applicants are expected to minimize unavoidable impacts insofar as practicable. The JD forms the informational basis for permit calculations and for designing compensatory mitigation to offset agency-approved impacts to the extent practicable.

Recent experience confirms that applicant-proffered wetland boundaries continue to warrant detailed scrutiny by the Army Corps of Engineers and other regulators. In one 2010 mining application in Greene County, National Wetland Inventory maps disclosed 4 wetlands on a 642-acre site. The applicant's consultant submitted a proposed delineation to PADEP showing 10 wetlands. After field inspection by the Corps, the JD drawing of the same tract of land showed 27 wetlands (Schmid & Co., Inc. 2013). In Sullivan County a gas company consultant delineated streams and wetlands in a 50-foot wide right-of-way along some 4,000 feet of unpaved township road. After the adjoining landowners secured Corps JDs, the square footage of regulated streams and wetlands increased to 700% of that flagged for the gas company within the same 4-acre strip of land (Schmid & Co., Inc. 2011b). The Corps field representative commented that significant under-identification of wetlands had occurred at several recent gas well installations where he had been involved with enforcement actions. None of those permittees had secured a Corps JD, and PADEP as usual had approved their permits without questioning the accuracy of information in the applications. It is not possible to overemphasize the necessity for JD applications followed by field-checking by Corps staff of proffered delineations as critical to the identification of wetlands in Pennsylvania prior to permit approval. Unidentified wetlands are not protected at all.

Wetland Permits

Regulated activities in Pennsylvania wetlands and other bodies of water cannot legally be initiated prior to permit approval by the Department of Environmental Protection (PADEP), except for waivered activities (25 *Pa. Code* 105.12) and registered activities that conform to the requirements of pre-approved general permits (25 *Pa. Code* 105.441 *et seq*.). Above established minimum thresholds of impact, regulated activities in federally regulated wetlands and waters also require approval from the Army Corps of Engineers. Except for those areas and activities excluded from regulation by waiver or authorized via general permits, wetland functions by regulation must be identified by an applicant when permit approval is sought for activities that will encroach upon wetlands and other bodies of water in Pennsylvania (25 *Pa. Code* 105.13). Permit applications for relatively small encroachments may be reviewed only by State agencies; larger or more damaging activities must be considered independently also by federal agencies. Few of the more than 2,500 Pennsylvania municipalities have adopted any ordinances protective of wetlands, but some have included wetlands as among resources to be reviewed at the local level, and their wetlands may be protected over and above what State and federal agencies require. Like PADEP, local agencies generally lack the staff resources to identify jurisdictional boundaries for wetlands.

After wetlands have been identified, permit applicants are expected to avoid impacts, and where unavoidable, to make every practicable effort to minimize impacts when planning their construction projects; PADEP is to review such efforts to avoid and minimize impacts [25 *Pa. Code* 105.14(b)(7)]. Where encroachments are proposed into wetlands, it is the responsibility of the permit applicant to identify onsite conditions in every affected wetland as a basis for ascertaining the probable alteration of functions when analyzing unavoidable adverse impacts and providing appropriate compensatory mitigation (25 *Pa. Code* 105.14, .15, and .18a). Impacts are to be analyzed in an Environmental Assessment (§105.15). The extent and nature of unavoidable impacts become the basis for developing the applicant's proposal for site restoration and compensatory mitigation. The quality of wetland assessment depends on the thoroughness and accuracy of underlying wetland inventory as well as the professional competence of the delineator and agency reviewer. Wetland functions form a principal aspect of the environmental assessment.

PADEP and district offices of the Army Corps of Engineers have adopted a joint permit application (Form 3150-PM-BWEW0036A, March 2013) and related forms that solicit the minimum information needed for agency decisionmaking regarding affected wetlands and other bodies of water on properties where construction is planned that may damage these resources. Public notice is required for individual joint permit applications, but not for waivered activities or for registrations of applicant intent to rely upon general permits. PADEP staffers are charged with reviewing each application to insure its completeness, its accuracy, and the applicant's proposed compliance with applicable regulations. Permit files, application data, and related correspondence are public records and can be examined by persons concerned about wetland protection through the procedures of Pennsylvania's Right to Know Law (Act 3 of 2008) and the federal Freedom of Information Act (5 USC 552 *et seq*.). Upon approval of a PADEP permit, the window for filing appeals to the Pennsylvania Environmental Hearing Board by any aggrieved party remains open for thirty days. Applicants are required to conform to the conditions and limitations set forth in general and individual permits. All recipients of individual permits by regulation are required to file a statement of compliance with permit requirements within 30 days of work completion and to file final as-built plans within 90 days showing any changes from original plans and specifications (25 *Pa. Code* 105.107).

In Pennsylvania some wetlands are deemed more valuable than others. Exceptional Value wetlands deserve *specia*l protection. Such wetlands exhibit one or more of the following characteristics (25 *Pa. Code* 105.17):

1. Serve as habitat for fauna or flora listed as threatened or endangered under federal or Pennsylvania law.
2. Are hydrologically connected to or located within 0.5 mile of the above and maintain the habitat of the endangered species.
3. Are located in or along the floodplain of the reach of a wild trout stream or waters listed as having Exceptional Value and the floodplain of their tributary streams, or within the corridor of a federal or Pennsylvaia designated Wild or Scenic River.
4. Are located along an existing public or private drinking water supply and maintain the quantity or quality of that surface water or groundwater supply.
5. Are located in State-designated natural or wild areas within State parks or forests, in federally designated Wilderness Areas or National Natural Landmarks.

Wetlands that qualify as having Exceptional Value are defined as surface waters of Exceptional Ecological Significance (25 *Pa. Code* 93.1), and thus (like Pennsylvania streams that have been designated or have attained Exceptional Value uses) are to be treated as Tier 3 Outstanding National Resource Waters in the language of the Clean Water Act of 1972 (as amended, 33 *USC* §1251 *et seq*.; *US Environmental Protection Agency Water Quality Handbook* - Chapter 4: Antidegradation [40 *CFR* 131.12]). These highest-quality resources are to be protected from degradation. Wetlands that do not exhibit any of the above-listed characteristics are deemed “Other” wetlands.

Permits for structures and activities in Exceptional Value wetlands are not to be approved unless PADEP finds that: the dam, water obstruction, or encroachment will not have an adverse impact on the wetland, as determined in accordance with §§ 105.14(b) and 105.15; the project is water dependent, requiring access to, proximity to, or siting within the wetland to fulfill its basic purpose; there is no practicable alternative that would not involve a wetland or that would have less adverse effect on the wetland and not have other significant adverse effects on the environment; the project will not cause or contribute to a violation of an applicable State water quality standard; the project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses; and the applicant replaces the affected wetland in accordance with criteria at § 105.20a [25 *Pa. Code* 105.18a(a)]. Yet Corps Jurisdictional Determinations are not required for Exceptional Value wetlands in Pennsylvania, so these wetlands are equally likely to be overlooked as those lacking exceptional value.

“Other” wetlands also are deemed “a valuable public natural resource” (25 *Pa. Code* 105.17) that is to be protected from significant impacts in similar fashion to

Exceptional Value wetlands. Permits are to be granted to dams, water obstructions, or encroachments affecting Other wetlands only when PADEP finds that: the project will not have a significant adverse impact considering the areal extent of the impacts, values, and functions of the wetlands, the uniqueness of the wetland functions and values in the area or region; comments from environmental agencies have been addressed; adverse impacts on the wetland are to be avoided or reduced to the maximum extent possible; there is no practicable non-wetland impacting alternative; the applicant has convincingly demonstrated that non water-dependent projects have no practicable alternative, overcoming the rebuttable presumption that such alternatives exist; the project will not cause or contribute to violation of an applicable State water quality standard; the project will not cause or contribute to pollution of groundwater or surface water resources or diminution of resources sufficient to interfere with their uses; the cumulative effect of this project and other projects will not result in a major impairment of the Commonwealth's wetland resources; and the applicant replaces the affected wetland in accordance with criteria at § 105.20a [25 *Pa. Code* 18a(b)]. On paper, Pennsylvania offers stringent protection to its wetlands.

Wetland Functions

Nine wetland functions are specifically identified in the definitions section of Pennsylvania's Dam Safety and Encroachments regulations (25 *Pa. Code* 25.1). By regulation, these functions are the minimum that require consideration as PADEP evaluates every encroachment permit affecting 1 acre or less of wetlands. Larger wetlands, as well as Exceptional Value wetlands smaller than 1 acre may require more complex assessment of additional functions and values in addition to these [25 *Pa. Code* 105.13(d)(3)]:

Wetland Functions Requiring Analysis in PADEP Permits

1. Serving natural biological functions, including food chain production; general habitat; and nesting, spawning, rearing and resting sites for aquatic or land species.
2. Providing areas for study of the environment or as sanctuaries or refuges.
3. Maintaining natural drainage characteristics, sedimentation patterns, salinity distribution, flushing characteristics, natural water filtration processes, current patterns or other environmental characteristics.
4. Shielding other areas from wave action, erosion, or storm damage.
5. Serving as a storage area for storm and flood waters.
6. Providing a groundwater discharge area that maintains minimum baseflows.
7. Serving as a prime natural recharge area where surface water and groundwater are directly interconnected.
8. Preventing pollution.
9. Providing recreation.

Different wetlands exhibit different combinations of functions. Some mutually exclusive functions (for example, groundwater recharge and groundwater discharge) can alternate over time within a single wetland. The functions performed by a wetland may vary over seasons and from year to year. The functions that any given wetland is capable of performing result from both the internal characteristics of the wetland itself and the surrounding context in which that wetland exists, including its connection with other natural areas and with watercourses. Corridors for wildlife movement, for example, are important to allow populations of animals to move between areas of wetland habitat, and many streams function as wildlife corridors. Similarly, only a wetland located on the shore of an open water body can shield other areas from wave action. The success of a wetland in performing functions can be affected greatly by past or ongoing human activity. Most wetland functions are disrupted permanently or temporarily by construction activities that impinge upon the wetland vegetation, soils, or hydrology directly. Human activities that increase performance of one function can accompany decreasing performance of other functions by that wetland.

Wetland functions also can be affected by construction outside the wetland itself out to a distance of 1,500 feet or more (Houlahan *et al*. 2006). For example, wildlife that breed in wetlands, such as reptiles and amphibians including frogs and salamanders, normally range into the adjoining uplands for distances of many hundreds of feet in eastern North America during the course of an annual cycle. If the adjacent lands are deforested or paved, or the wetland isolated by an intervening road or fence, the wetland habitat can be rendered useless to such creatures. By way of further example, altering the light and wind by removing the surrounding forest can cause a major change in the plants and animals that can survive in a wetland. Surface disturbances outside a wetland also can have major impact on the hydrology of the wetland, profoundly altering its ecosystem by draining or flooding it.

There is no State-regulated wetland buffer in Pennsylvania, such as exists in New Jersey or New York. Those States have expressed concern for the variable boundaries of wetlands that result from differing weather conditions year to year. They wisely recognize that the associated transitional areas adjacent to wetlands comprise essential parts of the functioning ecosystem of each wetland. Hence they long have considered the preservation of ecosystems adjacent to a wetland to be an essential part of protecting that wetland’s functions and values. The absence of regulated buffers around wetlands in Pennsylvania renders its wetlands at risk of unavoidable degradation, especially in areas of concentrated human populations. A few Pennsylvania municipalities have recognized or sought to remedy this environmental risk through local ordinances that provide for maintenance of some amount of undeveloped protective buffer outside the wetland.

.

Wetland Classification

The functions and values of a wetland differ according to the placement of the wetland in the landscape and the manner in which it gains its wetness.

Functional analysis logically addresses different classes of wetlands differently when addressing their potential for damage or rehabilitation. Wetlands and shallow water bodies are usefully categorized at the most basic level by general hydrogeomorphic system. Across most of the Pennsylvania landscape, wetlands and small ponds are assigned to the Palustrine (P) system, which is distinguished from tidal estuarine and marine classes, lakes, and large rivers. Wetlands along the boundaries of water bodies are assigned to the Riverine (R) or Lacustrine (L) systems, although many floodplain wetlands are labeled as Palustrine. Marine (M) and Estuarine (E) classes are of limited extent in Pennsylvania.

The following table identifies the most recent hydrogeomorphic classifications under development by the PADEP (draft Technical Guidance Document 310-2137-002, 7 March 2014, p. 27). The classification is significant as it affects the functional analysis of all water bodies including wetlands.

Mid-Atlantic HGM Wetland Classification:

- Classes
    - Subclasses
        - Modifiers
- Marine
    - subtidal
    - intertidal
- Estuarine
    - subtidal
    - lunar intertidal
    - wind intertidal
    - impounded
- Riverine
    - lower perennial
    - floodplain complex
    - upper perennial
    - headwater complex
    - intermittent
        - beaver impounded
        - human impounded
- Lacustrine (fringe)
    - permanently flooded
    - semipermanently flooded
    - intermittently flooded
    - artificially flooded
- Palustrine
    - Flat
        - Flat mineral soil
        - Flat organic soil
    - Slope
        - Stratigraphic
        - Topographic
            - mineral soil
            - organic soil
    - Depression
        - perennial
        - seasonal
        - temporary
            - human impounded
            - human excavated
            - beaver impounded

PADEP goes on to offer additional detail on the principal kinds of wetlands in Pennsylvania classed by location associated with hydrology that require consideration during functional assessments. The modifiers give an idea of the variability of the basic types (draft Technical Guidance Document 310-2137-002, 7 March 2014, p. 24-25). Once these distinctions have been formally adopted by PADEP for consideration in each permit application, the precision and quality of data provided by applicants' consultants should improve, along with the quality of impact analysis.

Pennsylvania Hydrogeomorphic Wetland Classification Key.

1.	Wetland found along tidal fringe of a marine ecosystem (ocean, beach, rocky shore)	**2**
1.	Wetland not associated with marine ecosystem	**3**
2.	Continuously submerged littoral zone	**Marine subtidal** (MF1)
2.	Alternately flooded and exposed to air	**Marine intertidal** (MF2)
3.	Wetland associated with shallow estuarine ecosystem (Mixture of saline and freshwater)	**4**
3.	Wetland not associated with shallow estuarine ecosystem	**7**
4.	Wetland not impounded	**5**
4.	Wetland impounded	**Estuarine impounded** (EFh)
5.	Wetland continuously submerged	**Estuarine subtidal** (EF1)
5.	Wetland alternately flooded and exposed to air	**6**
6.	Wetland regularly or irregularly flooded by semidiurnal, storm, or spring tides	**Estuarine lunar intertidal** (EF2l)
6.	Wetland flooding induced by wind	**Estuarine wind intertidal** (EF2w)
7.	Wetland associated with freshwater stream or river	**8**
7.	Wetland not associated with freshwater stream or river	**11**
8.	Wetland associated with permanent flowing water from surface sources	**9**
8.	Wetland dominated by ground water or intermittent flows	**10**
9.	Wetland associated with low gradient tidal creek (see Estuarine types 3)	
9.	Wetland associated with low gradient and low velocities, within a well-developed floodplain (typically >3rd order)	**Riverine lower perennial** (R2)
9.	Wetland part of a mosaic dominated by floodplain features (former channels, depressions) that may include slope wetlands supported by ground water (see Slope 17)	**Riverine floodplain complex** (R2c)
9.	Wetland associated with high gradient and high velocities with relatively straight channel, with or without a floodplain (typically 1st - 3rd order)	**Riverine upper perennial** (R3)
10.	Wetland part of a mosaic of small streams, depressions, and slope wetlands generally supported by ground water	**Riverine headwater complex** (R3c)
10.	Wetland associated with intermittent hydroperiod	**Riverine intermittent** (R4)

Note:	For any riverine type that is impounded, distinguish between:	
	Wetland impounded by beaver activity	**Riverine...beaver impounded** (R...b)
	Wetland impounded by human activity	**Riverine...human impounded** (R...h)
11.	Wetland fringing on a lake or reservoir	**12**
11.	Wetland not fringing on lake or reservoir	**14**
12.	Wetland inundation controlled by relatively natural hydroperiod	**13**
13.	Wetland inundation is permanent with minor fluctuations (year round)	**Lacustrine permanently flooded** (LFH)
13.	Wetland inundation is semipermanent (growing season)	**Lacustrine semipermanently flooded** (LFF)
13.	Wetland inundation is intermittent (substrate exposed often)	**Lacustrine intermittently flooded** (LFJ)
12.	Wetland inundation controlled by dam releases	**Lacustrine artificially flooded** (LFK)
14.	Wetland water source dominated by precipitation and vertical fluctuations of the water table due to low topographic relief	**15**
14.	Wetland differs from above	**16**
15.	Wetland substrate is primarily of mineral origin	**Flat mineral soil** (FLn)
15.	Wetland substrate is primarily of organic origin	**Flat organic soil** (FLg)
16.	Wetland water source is primarily ground water and has unidirectional and horizontal flows	**17**
16.	Wetland forms a depression	**18**
17.	Water source for wetland derived from structural geologic discontinuities resulting in discharge of groundwater from distinct point(s) on slope	**Stratigraphic slope** (SLs)
17.	Water source for wetland accumulates at toe-of-slope before discharging	**Topographic slope** (SLt)
Note:	For any slope type, distinguish between: Wetland substrate is primarily of mineral origin	**...slope mineral soil** (SL...n)
	Wetland substrate is primarily of organic origin	**...slope organic soil** (SL...g)
18.	Wetland with frequent surface connections conveying channelized flow	**Depression perennial** (DFH)
18.	Wetland with infrequent surface water connections conveying channelized flow	**Depression seasonal** (DFC)
18.	Wetland with no surface outlet, often perched above water table	**Depression temporary** (DFA)
Note:	For any depression type that is impounded or excavated distinguish between:	
	Wetland is impounded by human activities	**Depression...human impounded** (DPh)
	Wetland is excavated by human activities	**Depression...human excavated** (DPx)
	Wetland is impounded by beaver activities	**Depression...beaver impounded** (DPb)

Another of the basic classifications of wetlands derived from their appearance and germane to assessing their functions is their vegetation type. The descriptive framework for vegetation structure was devised by the US Fish and Wildlife Service (Cowardin *et al*. 1979) and is used for small-scale mapping by the National Wetlands Inventory. Vegetation and hydrogeomorphic location are combined to identify the principal habitat types identified by PADEP in Pennsylvania (Draft Technical Guidance Document 310-2137-001, March 2014,

p. 7). Notably, PADEP to date has not identified any nontidal Riverine wetland habitat types:

Some Pennsylvania Wetland Habitat Types.

LAB	Lacustrine Aquatic Bed
LEM	Lacustrine Emergent
LFL	Lacustrine Flat
PAB	Palustrine Aquatic Bed
PEM	Palustrine Emergent
PFL	Palustrine Flat
PFO	Palustrine Forested
PSS	Palustrine Scrub/Shrub

Lacustrine Emergent Wetland and Lacustrine Aquatic Bed.

Palustrine wetlands are the most numerous and widespread kinds in Pennsylvania, accounting for 97% of the wetlands mapped in the Commonwealth by the National Wetland Inventory from high-elevation aerial photos taken during the late1970s and early 1980s (Tiner 1990). National Wetland Inventory mapping is a useful tool whose results are valuable for regional wildlife resource management, but it significantly omits many forested wetlands in Pennsylvania and is not a reliable guide to regulated wetland locations or boundaries.

Nevertheless, its incomplete and approximate data are readily available online and often are displayed on maps generated by geographical information systems. Hydric soil map units in county soil maps and wetland patterns on US Geological Survey topographic quadrangles also offer clues to wetland locations. But the actual extent of wetlands and streams can be determined only by field delineation of specific properties when construction activities are proposed.

The principal kinds of vegetation found in Palustrine wetlands are classed as forest (PFO), scrub (PSS), and herbland (PEM) based on visual observation and/or aerial photographs. Available statistics probably underestimate the proportion of forested wetlands in Pennsylvania, inasmuch as they are based on aerial photographs rather than field investigation and omit forested wetlands not distinguishable remotely. Palustrine flats (FL) devoid of vegetation are not common. The focus of vegetation classification is on the size and structure of the general mass of vegetation present in the landscape. An individual plant, depending on species, can pass through the structural stages of herb, shrub, and tree as it grows in wetlands or uplands. The US Fish and Wildlife Service has reported their estimate of cover types of National Wetland Inventory wetlands in Pennsylvania based on 1975-1985 aerial photographs (Tiner 1990):

Palustrine Forests.

Delhaas Woods, Bucks County. Photograph by Roger Earl Latham.

Columbus Bog, State Game Lands 197, Warren County. Photograph by Paul Wiegman.

Acres of National Wetland Inventory Wetlands in Pennsylvania, 1975-1985.

Palustrine Wetlands	
Emergent	*52,338 a*
Deciduous Forested	*146,715 a*
Evergreen Forested	*31,204 a*
Deciduous Scrub-Shrub	*47,539 a*
Evergreen Scrub-Shrub	*1,849 a*
Mixed Deciduous Shrub-Emergent	*25,000 a*
Open Water	*61,841 a*
Other Mixed Types	*26,242 a*
Total Palustrine Wetlands	*392,728 a*
Lacustrine Wetlands	*8,521 a*
Riverine Wetlands	*2,675 a*
PENNSYLVANIA WETLANDS	*403,924 a*

Forest vegetation (FO) is dominated by trees at least 3 inches in minimum trunk diameter measured 4.5 feet above the ground and at least 20 feet tall. Shrubs and herbs can grow beneath the canopy trees, or the forest floor can be essentially bare. Scrub (SS) is dominated by shrubs with multiple stems less than 3 inches in diameter and rarely taller than 20 feet. Herbs can be abundant beneath the shrubs but trees are few; light tends to reach the land surface to a much greater degree than in forests. Herblands (EM) are generally devoid of woody plants but instead support various kinds of non-woody, herbaceous higher plants that emerge from the soil surface. Their plant cover can be sparse or dense. Tracts of land that qualify as forest, scrub, or herbland may intergrade and are mapped as mixed types (for example, FO/SS). The forest, scrub, and herbland categories each can be subdivided into numerous subtypes, depending on the purpose of such classification and appropriate level of detail. For example, Palustrine forest and scrub polygons on maps can be broadleaf deciduous (assigned the modifier “1” by the National Wetland Inventory, as in “PFO1”) or needleaf evergreen (“PFO4”); emergent herbs can be persistent year-round (“1” as in “PEM1”) or nonpersistent (“PEM2”), and any of these modifiers can be further supplemented by codes for dominant plant genus or species or for other ecosystem attributes where more precise distinctions are needed.

In Pennsylvania Palustrine ecosystems, forested wetlands are more extensive than scrub and herbaceous wetlands. Natural plant succession generally trends toward forest conditions in eastern North America (Braun 1950, Küchler 1964), and thus herbaceous and scrub wetlands tend to reflect earlier stages of natural post-disturbance succession than forested wetlands. The first-approximation airphoto mapping of Pennsylvania wetlands by the US Fish and Wildlife Service reported deciduous forests making up 37% of Palustrine wetlands; evergreen forest, 8%; deciduous scrub, 12%; evergreen scrub, <0.1%; mixed deciduous scrub-herbland, 6%; herbland, 13%; open water (including farm ponds), 16%; and other mixed types, 7% based on 1975-1985 aerial photographs (Tiner 1990). Under natural conditions the forest community is disrupted occasionally by storms, fire, and beaver activity. Human activities today are a much more common source of forest removal. Not all herblands, however, are rapidly changing categories of plant succession on their way to becoming forests; some can persist naturally for long periods of time as viewed by humans. The plants found in particular wetland communities can range from diverse species to almost monotypic where invasives have become established.

State and federal agencies that keep records of wetlands and wetland modifications use these vegetation types for data collection and analysis. Each distinctive vegetation type also is associated with characteristic functions. Herbaceous wetland vegetation is capable of being reestablished relatively quickly following temporary disturbance, within only a few growing seasons, if soil and hydrologic conditions are favorable. Shrubs require additional years to reach full size, and forest trees require decades for canopy closure, even where soil disturbance has not been severe. Diverse populations of desirable native species can require long periods of time to become established in disturbed or newly created wetlands.

Functions of Pennsylvania Wetlands

This section discusses the functions listed above (as set forth in 25 *Pa. Code* 105.1) that are typically associated with Palustrine forested (PFO) wetlands and compares them with similar functions in scrub (PSS) and herbaceous (PEM) wetlands. These functions are subject to disruption by human activities as well as by catastrophic occurrences of weather (hurricanes, tornadoes), ice storms, landslides, floods, and fires. Reductions in some functions may accompany increases in others.

The PADEP list of nine wetland functions in Chapter 105 regulations is reasonably comprehensive and suited to project-scale analysis based on the specific acreage of wetlands affected by an individual permittee. Current regulations do not focus on quantitative annual productivity of timber or wildlife, removal of air pollutants, carbon sequestration, or less tangible functions such as aesthetic or historic/cultural appreciation. Nor do they require measurement of the values of any identified functions to individuals or groups. They do not specify how to compare the relative values of different functions, how to index current, past, or future functions of specific wetlands to generally accepted "reference" natural wetlands, call attention to the context of land surrounding a wetland, address the scarcity of a vegetation type, or provide for actual consideration of cumulative wetland impacts beyond an individual permit. PADEP long has found it virtually impossible to consider cumulative impacts, even for a single large project, because of its longstanding willingness to consider permits for fragments of a project on a piecemeal basis independently. PADEP does not expect an applicant to address its entire single project in a joint permit submission, much less analyze its proposed impacts cumulatively with those of other permittees over large areas. PADEP also does not focus on the uniqueness or heritage value of specific wetlands (aside from their potential for classing a wetland as having Exceptional Value) or a wetland's actual replaceability or irreplaceability, should damage be authorized.

1. Natural Biological Functions and General Habitat

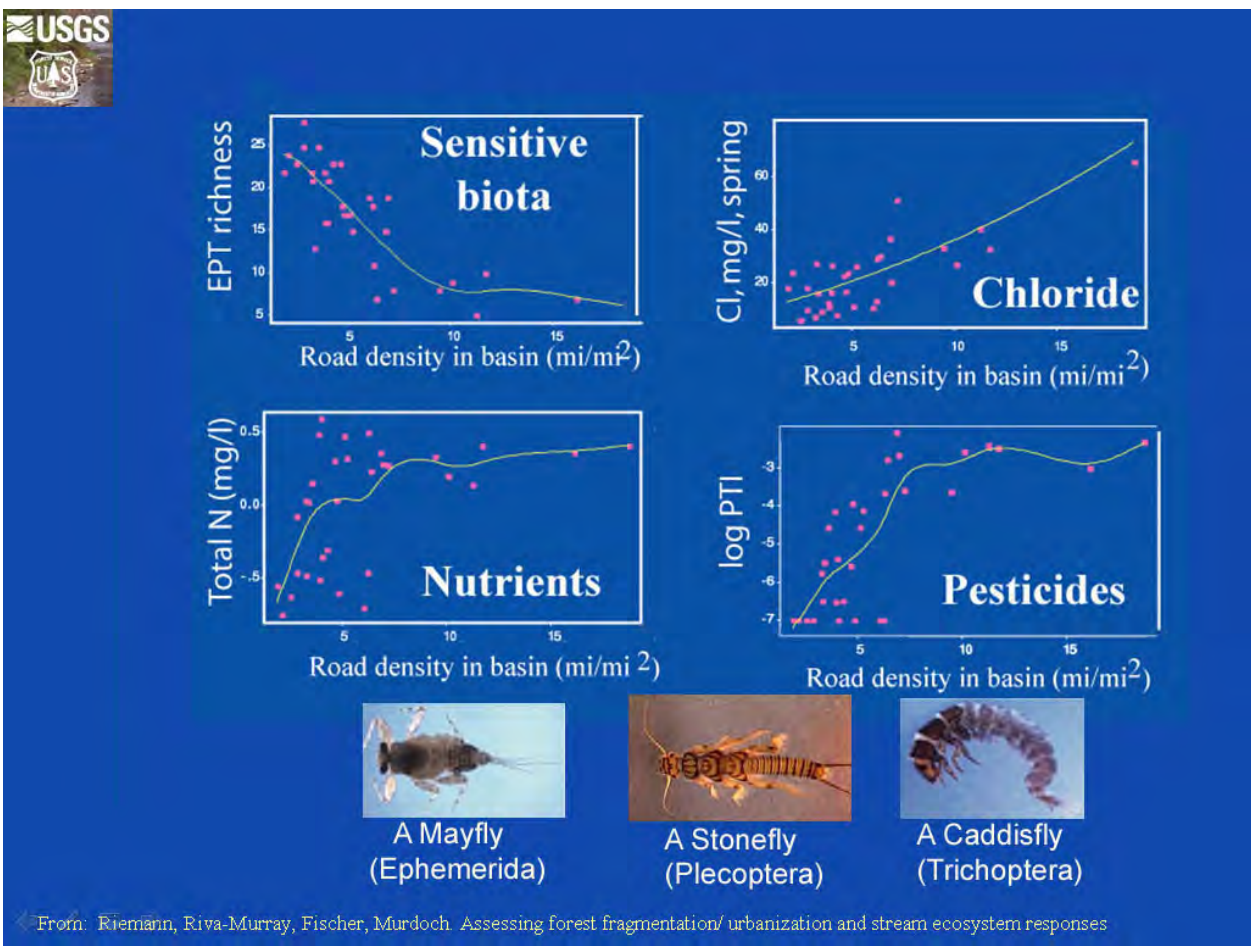
Natural biological functions of all wetlands include food chain production, general habitat, and resting-nesting-spawning-rearing sites for animals and fish. Many rare species of plants and animals are directly dependent on wetland habitats. Trees are the largest kinds of plants and have the greatest ability to modify the environmental effects of solar radiation, precipitation, temperature, humidity, and air quality as a result of their above-ground biomass. These natural, localized environmental modifications are of vital importance to the other plants and to the animals that live within and beneath forest cover. Tree leaves produce more tons of biomass per acre than shrubs for consumption by grazers and accumulate larger standing crops of organic material above ground. Tree trunks and limbs provide food for some animals and homes for many, with more complex structure than scrubs or herblands.

Pennsylvania forests consist of a wide variety of broadleaf deciduous trees, each species of which provides a somewhat different diet to the consumers that depend on it (Zimmerman *et al*. 2012; McShea & Healy 2002). Oaks, maples, ashes, elms, cherries, birches, and beech reflect the ancient geological history of Appalachia, and they returned to glaciated regions when the Pleistocene ice sheets melted. Pennsylvania forests also support many needleaf evergreen trees such as pines, hemlocks, and spruces. Very few stands of unharvested primeval forest remain in Pennsylvania; most of its forests have regrown following two or more episodes of intensive logging, burning, and other human disturbance during the past four centuries---episodes that have greatly affected the streams of the Commonwealth. Closed canopy forest consisting of mature trees requires about a century to recover to a recognizable mature forest structure after fire or clearcutting. About one third of Pennsylvania's forest stands are 80 years old or more; only 7%, 100 years old or more (McCaskill *et al*.

2013). Regenerated forest stands may or may not resemble their predecessors in their species composition when examined in detail, and the largest regrown individual trees are significantly smaller than historic records document as inherited by European colonists. Selective harvesting can remove key forest constituents, thereby reducing habitat value, and the forest canopy is further disrupted by logging roads, well pads, pipeline rights-of-way, borrow areas, and spills of fuel, brine, and other pollutants. Various kinds of shrubs and herbs grow only beneath a mature forest canopy. Wood ducks (*Aix sponsa*), a particularly handsome native species of waterfowl, require tree cavities for nesting as well as nearby water.

Trees growing in adjacent wetlands and streambanks are the major source of food for aquatic organisms in small, headwater streams. The intensity of ongoing human disturbance on the streams of forested areas can be estimated by the linear extent of roads per unit area. As summarized graphically by the United States Forest Service and US Geological Survey, human activity as approximated by road density has a dramatic effect on the quality of streams for sensitive aquatic insects that form the base of the aquatic food chain:

Road Density and Aquatic Parameters.



Both broadleaf and evergreen trees can dominate Pennsylvania wetlands, although broadleaf trees remain much more abundant (McCaskill *et al*. 2013). The value of forested wetlands to wildlife and to landowners is affected by the number of kinds of trees and other plants present (species diversity), their density and biomass (timber volume), the amount of dead timber standing and on the ground, the amount of grazing by domestic livestock and browsing by white-tailed deer, and the proportion of non-natives present. Diverse, high-quality vegetation is at greatest risk of human degradation and is the most difficult to restore (Olson and Doherty 2011). Wetland forests provide nesting, rearing, resting, and feeding sites for birds and mammals. One third of the bird species in the United States depend on wetlands (230 of 636; Welsch *et al*. 1995). Bears spend 60% of their time in forested wetlands during spring and summer (Newton 1988).

Unfragmented wetland forests are of great importance to many declining species of migratory songbirds. Wet forest floors are attractive wintering areas in which endangered bog turtles hibernate, and thick stands of evergreens shelter wintering deer and other animals. As already noted, the nutrients derived from tree leaves and twigs are vital to the macroinvertebrates and fish of Pennsylvania streams. Forest ecosystems are limited in their growth capability and affected in species composition by the availability of nutrients provided by the weathering of rock and transported in by air masses. The carbon from tree litter in turn can make up 99% of the total dissolved organic carbon at the base of the aquatic food web in forested streams (Stoler and Relyea 2011). Isolated vernal pools free of predatory fish are critically important to many uncommon reptiles and amphibians whose populations are dwindling. Discharges of stormwater, waste chemicals, and rubbish can degrade general habitat functions in forest and other wetlands.

Permanent forest disruption across Pennsylvania wetlands and uplands.

Scrub wetlands accumulate less standing biomass than mature forests. Hence any of the functions that derive from quantity of biomass are reduced in scrub as compared with forest wetlands, such as influence on microclimate, the amount of organic matter available for consumers of plant biomass, or the protection offered to soil from erosion. Some herbaceous wetlands can produce biomass in quantities rivaling forests above and below ground, but they lack the structural diversification of above-ground biomass of the woody wetlands. For animals adapted to herbaceous wetlands, such ecosystems provide important general habitat, nesting, resting, and rearing sites. The microtopography of hummocks provides habitat diversity critical to many species. Temporarily or permanently inundated herbaceous wetlands linked to streams and lakes have key importance as spawning and nursery grounds for fish, and inundated scrub wetlands are more common than inundated forests in Pennsylvania. The scrubs and sedge meadows with deep organic deposits associated with very wet herbaceous wetlands are prime spring and summer areas for various reptiles including the endangered bog turtle (*Glyptemys muehlenbergii*). Bog turtles prefer to overwinter in mats of tree roots where emerging groundwater warms near-surface temperatures. Herbaceous wetlands are of special importance to migrating waterfowl.

2. Environmental Study Areas and Refuges

Forested wetlands can serve as environmental study areas, particularly when located near schools, in public parks, and on other sites available to the public. Because natural plant succession in Pennsylvania normally trends toward forest vegetation, forests usually characterize refuges and sanctuaries relatively undisturbed by people, and forested wetlands typically provide high quality habitat to wildlife. The significance of forest cover to wetland wildlife increases as the size of wetlands decreases, particularly in landscapes with intensive human activity.

Scrub and herbaceous wetlands also can serve as study areas and biological refuges. They are less screened visually and aurally from adjacent human activities by their relatively lower quantities of biomass. They provide key habitat for wetland plants and animals that require open sun reaching the soil surface. Herbaceous wetlands are prime locations for birders.

3. Water Quality and Quantity Protection and Drainage Patterns

Forest wetland vegetation has maximal effect on processes affecting water movement and interaction with the land. By their mass, trees are able to slow the energy of falling raindrops and thereby limit soil erosion. Similarly, their mass and shade render the affected ground beneath the trees moister and cooler than nearby areas open to the sun. Decaying leaves provide a surface that readily accepts precipitation and allows it to infiltrate soil rather than quickly running off the surface.

The interflow through soils in turn contributes to natural extended flow of streams, minimizing both flooding and stream dryup. Nutrients can be bound up in tree trunks for centuries, and thereby kept out of waterways. The complex chemical reactions in wetland soils allow bacterial denitrification fostered by the carbon from leaves and vital to preventing excess nitrate-nitrogen from reaching streams. Wetland tree roots also can help anchor banks of streams against erosion. Forest loss to other land uses in Pennsylvania occurs at the rate of about 150 acres per day (McCaskill *et al*. 2013). Presumably most of these converted lands are not wetland forests, inasmuch as PADEP acknowledges the loss of less than 100 acres of all wetlands annually via individual permits, including forested wetlands.

Scrub and nonpersistent herbaceous wetlands stockpile less biomass on the land surface year-round than forested wetlands. They may offer less protection to the soil than forested wetlands, and their smaller roots may provide less resistance to physical erosion of streambanks.

Discharges of wastewater can contain pollutants at sufficient concentrations to overwhelm the ability of natural wetland systems to accommodate the pollutants, resulting in severe damage to the wetland ecosystems by manure, sewage, spilled brine, oil, and other chemicals. Rubbish also can degrade general habitat functions in forest and other wetlands.

4. Shoreline Protection and Stormwater Shielding

Aside from those on the banks of lakes and large rivers, forested wetlands in Pennsylvania generally have limited opportunity to shield other areas from wave and storm damage. Tree roots can stabilize streambanks large and small against stormwater erosion. To a lesser degree scrub wetlands can function similarly. Shrub willows often are planted to stabilize shorelines.

Some herbaceous wetlands occupy the shallow fringes of large water bodies, where they serve to reduce wave action and encourage sedimentation (thereby protecting water quality).

5. Flood Storage

Forested wetlands often serve as temporary storage areas for storm and flood waters. The economic value of such storage increases annually as flood damages rise in response to increased runoff from a growing human population, impervious surfaces from ever-expanding land development, and storm events of increasing severity driven by global warming in response to the burning of fossil fuels. Many forest ecosystems are adjusted to and dependent upon seasonal flooding, unlike most human structures that are easily damaged even by short-term inundation during flood peaks. Scrub and herbaceous wetlands, provided that they are suitably located, can function equally as well as forested wetlands for temporary stormwater storage, although they may not shade the stored water so effectively and therefore not keep its temperature so low as a dense forest cover.

6. Groundwater Discharge

Spring seep areas are characteristic along the base of slopes in Pennsylvania forested wetlands. The forest shade keeps summer temperatures low as groundwater travels over the land surface toward headwater streams. Trout are a major feature of Pennsylvania streams and much sought-after by anglers. Many Pennsylvania streams have water near the limit of summer warmth that trout can tolerate. Forested wetlands along watercourses are essential to maintaining temperatures low enough for trout to survive and reproduce as global warming continues in response primarily to the burning of fossil fuels. Conversely, because of the warmth of groundwater, spring seeps may become snow-free earlier than dry uplands, and thereby attract feeding turkeys and other wildlife.

Shrub and herbaceous wetlands also can be associated with seeps flowing toward small streams. They are less able to keep surface water temperatures low than forests because of their lesser shade, but they may transpire fewer gallons of water during the course of a hot day. As mentioned previously, groundwater seeps closely associated with masses of tree roots are especially attractive areas for overwintering bog turtles.

Forested Wetland with Seeping Groundwater Discharge.

7. Groundwater Recharge

Countless local topographic depressions in forested wetlands store precipitation, slow its movement toward streams during periods of flood, and enable it to recharge local groundwater during wet seasons. Recharged groundwater, in turn, typically finds outlets to local streams. Recharge can be greater in scrub and herbaceous wetland depressions, because their plant cover transpires less water into the atmosphere than large trees.

8. Pollution Prevention and Sediment Control

Forested wetlands prevent pollution of water bodies by reducing the erosive force of rainstorms. Their trees break the fall of droplets hitting leaves and branches; they anchor the soil with roots and cover it with absorptive leaf litter; their roots bind streambank soils against erosion. Forested wetland soils enable sedimentation, denitrification, and other biogeochemical processing as surface waters pass through. Scrub and herbaceous wetlands can function comparably, but provide less physical protection against soil erosion by precipitation. Forested buffers surrounding wetlands can provide the most effective long-term protection of wetlands from sediment influx originating in disturbed lands.

9. Human Recreation

Wetland forests provide recreational opportunities for Pennsylvania citizens and visitors, calling forth significant contributions to the economy of the Commonwealth on a sustainable basis by those who use the outdoors. Great numbers of people find the seasonally changing display of blooms and colored leaves highly attractive and a sharp contrast to landscapes in urban centers. Recreational hunters seek the game animals---deer, bear, squirrels, waterfowl, and other game birds---that depend on wetland as well as upland forests. Anglers depend on riparian forests to keep the Pennsylvania streams cool enough and to supply food for salmonids. Forested wetlands are especially effective in providing humans with natural landscapes contrasting sharply with urban commercial and industrial environments.

Scrub and herbaceous wetlands also provide recreational opportunities for hiking and for game habitat. Herbaceous wetlands often attract spectacular flocks of migratory waterfowl.

Palustrine Deciduous Scrub Opening in Needleaf-Dominated Bog on Peat.

Rosencrans Bog Natural Area, Clinton County. Photograph by Staff of The Western Pennsylvania Conservancy.

Through its recent draft technical guidance documents PADEP appears to be seeking to expand from a strictly acreage-based evaluation of wetland impacts and working instead toward a weighting of functions, indexing to reference ecosystems, and consideration of conditions adjacent to the affected wetland. State methodology also is just beginning to consider cumulative effects on a watershed basis, which is essential for rationally offsetting the negative side effects (externalities) of construction in wetlands. The proposed technical guidance draws conceptually on federally sponsored work on wetland functions that has been underway for twenty years (Smith *et al.*, 1995) as well as the more recent work by Robert Brooks and his coworkers at Riparia, the Cooperative Wetlands Research Center at Pennsylvania State University. PADEP's current list of functions is displayed below.

Table 2
Wetland Functions and Their Value

Functions Related to Hydrologic Processes	Benefits, Products, and Services Resulting from the Wetland Function
Short-Term Storage of Surface Water: the temporary storage of surface water for short periods.	Onsite: Replenish soil moisture, import/export materials, conduit for organisms. Offsite: Reduce downstream peak discharge and volume and help maintain and improve water quality.
Long-Term Storage of Surface Water: the temporary storage of surface water for long periods.	Onsite: Provide habitat and maintain physical and biogeochemical processes. Offsite: Reduce dissolved and particulate loading and help maintain and improve surface water quality.
Storage of Subsurface Water: the storage of subsurface water.	Onsite: Maintain biogeochemical processes. Offsite: Recharge surficial aquifers and maintain baseflow and seasonal flow in streams.
Moderation of Groundwater Flow or Discharge: the moderation of groundwater flow or groundwater discharge.	Onsite: Maintain habitat. Offsite: Maintain groundwater storage, baseflow, seasonal flows, and surface water temperatures.
Dissipation of Energy: the reduction of energy in moving water at the land/water interface.	Onsite: Contribute to nutrient capital of ecosystem Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality
Functions Related to Biogeochemical Processes	**Benefits, Products, and Services Resulting from the Wetland Function**
Cycling of Nutrients: the conversion of elements from one form to another through abiotic and biotic processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Removal of Elements and Compounds: the removal of nutrients, contaminants, or other elements and compounds on a short-term or long-term basis through burial, incorporation into biomass, or biochemical reactions.	Onsite: Contributes to nutrients capital of ecosystem. Contaminants are removed, or rendered innocuous. Offsite: Reduced downstream loading helps to maintain or improve surface water quality.
Retention of Particulates: the retention of organic and inorganic particulates on a short-term or long-term basis through physical processes.	Onsite: Contributes to nutrient capital of ecosystem. Offsite: Reduced downstream particulate loading helps to maintain or improve surface water quality.
Export of Organic Carbon: the export of dissolved or particulate organic carbon.	Onsite: Enhances decomposition and mobilization of metals. Offsite: Supports aquatic food webs and downstream biogeochemical processes.
Functions Related to Habitat	**Benefits, Goods and Services Resulting from the Wetland Function**
Maintenance of Plant and Animal Communities: the maintenance of plant and animal community that is characteristic with respect to species composition, abundance, and age structure.	Onsite: Maintain habitat for plants and animals (e.g., endangered species and critical habitats), for rest and agriculture products, and aesthetic, recreational, and educational opportunities. Offsite: Maintain corridors between habitat islands and landscape/regional biodiversity.

Stressors

The functional values of wetlands can be reduced by many stressors, most of which are directly or indirectly the result of human activity and also are more intense and persistent than natural disruptive forces. The evolving PADEP list of stressors lists 37 kinds that are readily observable in the field, grouped into five categories (Draft Technical Guidance Document 310-2137-002, March 2014, p. 33). They prudently have left a blank for other, unlisted stressors in each of the five categories, for less commonly encountered conditions.

PADEP-listed Wetland Stressors.

Vegetation Alteration
Mowing
Moderate livestock grazing (within one year)
Crops (annual row crops, within one year)
Selective tree harvesting/cutting (>50% removal, within 5 years)
Right-of-way clearing (mechanical or chemical)
Clear cutting or Brush cutting (mechanized removal of shrubs and saplings)
Removal of woody debris
Aquatic weed control (mechanical or herbicide)
Excessive herbivory (deer, muskrat, nutria, carp, insects, etc.)
Plantation (conversion from typical natural tree species, including orchards)
Other:
Total Number:
Hydrologic Modification
Ditching, tile draining, or other dewatering methods
Dike/weir/dam
Filling/grading
Dredging/excavation
Stormwater inputs (culvert or similar concentrated urban runoff)
Microtopographic alterations (e.g., plowing, forestry bedding, skidder/ATV tracks)
Dead or dying trees (trunks still standing)
Thermal alteration (power plant or industrial discharges with evidence of high temperatures)
Stream alteration (channelization or incision)
Other:
Total Number:
Sedimentation
Sediment deposits/plumes
Eroding banks/slopes
Active construction (earth disturbance for development)
Active plowing (plowing for crop planting in past year)
Intensive livestock grazing (in one year, ground is >50% bare)
Active selective forestry harvesting (within one year)
Active forest harvesting (within two years, includes roads, borrow areas, pads, etc.)
Turbidity (moderate concentration of suspended solids in the water column, obvious sediment discharges)
Other:
Total Number:

Eutrophication
Direct discharges from agricultural feedlots, manure pits, etc.
Direct discharges from septic or sewage treatment plants, fish hatcheries, etc.
Heavy or moderately heavy formation of algal mats
Other:
Total Number:
Contaminant/Toxicity
Severe vegetation stress (source unknown or suspected)
Obvious spills, discharges, plumes, odors, etc.
Acidic drainages (mined sites, quarries, road cuts)
Point discharges from adjacent industrial facilities, landfills, railroad yards, or comparable sites
Chemical defoliation (majority of herbaceous and woody plants affected, within one year)
Fish or wildlife kills or obvious disease or abnormalities observed
Excessive garbage/dumping
Other:
Total Number:

The more numerous the stressors affecting a wetland, the lower its value. When rating the value of wetland conditions, the proposed PADEP scoring also assigns higher value to wetlands surrounded by forests than to those surrounded by scrub, and assigns higher value to those wetlands surrounded by scrub than to those surrounded by herblands or ponds. Managed wetland buffers are scored lower than wild, unmanaged buffers (Draft Technical Guidance Document 310-2137-002, March 2014, p. 33).

In 2006 PADEP sampled 204 wetlands and used their evolving protocols to rank the condition of those wetlands (PADEP 2014c). How representative the sampled wetlands might be of Pennsylvania wetlands as a whole was not stated, but the rankings from their protocol testing were reported as follows:

Condition Category	Number of Wetlands	Total Acreage	Percent of Resource
Highest	13	127.74	6.10%
High	59	556.19	26.70%
Medium	41	468.89	22.50%
Low	91	930.07	44.70%
Totals	**204**	**2082.88**	**100.00%**

Conversion of Woody Wetlands to Herbaceous Wetlands

Forest and scrub wetlands can be converted to herbaceous wetlands in various ways with effects more or less catastrophic, even if wetland conditions are not intentionally obliterated permanently to enable the construction of roads, buildings, or farm fields. Woody stems can be cut at the ground surface and merely the aboveground trees and shrubs removed, if the goal is to reduce disruption of the soil. More invasively, tree stumps and shrub roots can be grubbed. Biologically active soils can be removed entirely. Hydrology can be diverted or impounded. The amounts and kinds of functions lost and gained will be determined by what conditions previously existed in the wetland as well as the nature and extent of disturbance. If any one of the three major wetland characteristics (hydrophytic vegetation, hydric soils, or hydrology) is not or cannot be restored to natural conditions, then the conversion of wetland to non-wetland will be permanent. The conversion of forested wetlands to scrub or herbaceous wetlands is not readily reversible, inasmuch as forest regrowth at best requires many decades, and may be intentionally prevented by repeated cutting or by spraying herbicides.

When wetland vegetation is changed by people from forest or scrub to herbaceous, many of the wetland's functions can be altered. Detailed study is necessary in order to predict accurately the probable changes and compose plans for appropriate mitigation, because the affected functions will vary at each location supporting a natural wetland.

Where naturally variable wetland hydrology has been restored, some generalist wetland plants usually will follow quickly unless toxic substances also have been introduced, and hydric soils eventually will become recognizable after many years of weathering have elapsed. Pennsylvania wetlands evolved after the retreat of glacial ice, and their biota retains the ability to recover following natural disturbances that are less drastic than those of current technology. Unless artificial plantings are made to accelerate the establishment of desirable species, however, invasives that thrive in human-disturbed wetlands are likely to invade and crowd out preferred species of native plants. Construction activities usually provide ample opportunities for invasive plants and animals to arrive at construction sites. Various online sources provide links to information on invasive species, including those of the Governor's Invasive Species Council of Pennsylvania (www.invasivespeciescouncil.com), the Pennsylvania Department of Conservation and Natural Resources (www.dcnr.state.pa.us/conservationscience/), and the US Forest Service (www.fs.fed.us/invasivespecies).

If the objective is to restore pre-disturbance native wetland vegetation, then near-replacement of pre-disturbance hydrology and soils is most likely to yield the desired plant community. Such replacement only succeeds where careful investigation of plants, soils, and hydrology preceded the wetland disturbance, so that mitigation site modification effectively can mimic the structure of the lost wetland. Light-tolerant herbaceous and scrub wetland plants can be restored more rapidly than forest vegetation, which takes many years for trees to reach mature size and natural diversity even where maximally successful. Protection of new plantings of native woody species from browsing deer and rabbits often is critical for the survival of the plants during the early years after wetland creation or restoration, and supplemental watering may be necessary during unusually dry years while root systems are being formed. Plantings of herbaceous wetlands can be devastated by migrating waterfowl. Moreover, the early-succession trees which will thrive in an open wetland only slowly are replaced by shade-tolerant species of late forest succession. Late-succession native herbs characteristic of mature Pennsylvania forested wetlands would not be expected to grow until the forest canopy has become reestablished and soil formation has proceeded to approximate natural conditions.

Compensatory mitigation in the form of replacement wetland creation or degraded wetland restoration is intended to result in functioning wetlands that do not require ongoing human intervention. Pennsylvania permit conditions long have required five years of monitoring for wetland restoration and creation projects along with written reports to PADEP, but post-construction monitoring has been sporadic at best and approved wetland restoration plans often have been unsuccessful in execution. Ponds are much easier and quicker to build than forested wetlands, but do not provide mitigation for various wetland functions. Similarly, basins engineered to detain stormwater flows from developed areas seldom result in high-value wetlands.

As one illustrative example of the conversion of woody wetlands to herbaceous cover, pipelines can be considered. The excavation of trenches for miles uphill, downhill, and across streams and wetlands is a catastrophic event followed by some measure of soil cover replacement on top of the pipes. But few pipeline operators

Pipeline construction through Pennsylvania wetlands. The corridor will be maintained free of woody vegetation after the pipe is buried.

Herbaceous Wetland 40 Years after Pipeline Installation.

.

are prepared to allow reforestation to obscure right-of-way conditions. Thus pipelines are likely to involve vegetation stressors such as right-of-way clearing, clear-cutting of brush, and removal of woody debris both prior to and for the long term subsequent to pipeline installation. Mechanical clearing using equipment occurs, as does spraying with non-selective chemical herbicides to prevent the reestablishment of trees and shrubs so that rights-of-way can be quickly inspected on the ground and from the air.

In summary, the most probable, usually adverse effects of human conversion of forest or scrub to herbaceous wetlands on PADEP-listed wetland functions, the following would be expected and should be considered carefully:

1. **General Habitat and Natural Biological Functions**
   Aboveground biomass: decrease
   Forest interior habitat: loss
   Structural diversity: decrease within converted wetland
   Visual and aural screening from human activity: loss
   Local climate amelioration: decrease
   Evergreen winter cover for wildlife: loss
   Suitability for shade-loving species of plants: loss
   Production of mast (such as acorns) for wildlife: loss

Exposure to harsh wind, ice, sun: increase
Localized effects of global warming on biota: increase

2. **Study Areas and Refuges**
   Structural diversity of ecosystem: decrease within converted wetland
   Species diversity of plants and animals: decrease within converted wetland
   Visual and aural screening from human activity: loss
   Rare, ancient trees: loss

3. **Drainage Patterns, Water Quantity, and Water Quality**
   Streambank anchoring against erosion: decrease
   Soil stabilization: decrease
   Erosion and sedimentation: increase
   Nutrient storage in ecosystem: decrease
   Maintenance of cold water temperature for trout: decrease

4. **Storm Damage Shielding and Shoreline Protection**
   Streambank stabilization: decrease

5. **Flood Storage**
   Storage volume: no significant change

6. **Groundwater Discharge**
   Volume discharged: increase (reduced transpiration)

7. **Groundwater Recharge**
   Volume recharged: increase (if soil not disrupted)

8. **Pollution Prevention and Sediment Control**
   Erosion and sedimentation control: decrease

9. **Human Recreation**
   Landscape aesthetics: disruption
   Species composition, plants and animals: change
   Forest interior species: loss
   Maintenance of cold water temperature for trout: decrease
   View and hiking corridors: increase

How much functional loss will occur as a result of authorized conversion from forest or scrub to herbland at any wetland location will depend on the functions initially present in the forested wetland, the severity of the disruption to the elements of the environment such as its soil and surface elevation, the location of the converted area in the landscape, and its connection with other wetlands, especially along stream corridors. As some functions decrease, others may increase. The degree to which impacts are negative also depends on the context of reference: “edge” species such as whitetailed deer benefit from forest fragmentation. Given the complexity of the natural world, under some sets of circumstances an anticipated negative change actually could prove beneficial. The functional loss of forested wetland is never quickly reversible, even if active maintenance were to stop, nor is it capable of offsite mitigation except, at best, until after long time delays.

Not currently identified by PADEP in its list of functions, conversion of forest to herbaceous wetland also entails a reduction in the ability of the wetland to affect human climate and to reduce air pollution. Herbaceous wetlands cannot rival forests in providing shade and screening people from wind. Likewise, they cannot promote the deposition of airborne pollutant particles or take up as much gaseous pollution as forest trees.

In principle, some of the functional losses of vegetation conversion eventually can be replaced by successful wetland mitigation onsite or offsite. But the actual substitution of lost functions by compensatory wetlands is not routine.

Wetland Compensatory Restoration and Creation

Because wetland damage and destruction routinely are authorized by permits, agencies by regulation are to require the restoration of temporary damage and the offsetting replacement of permanent loss of natural wetlands. A plan for the mitigation of unavoidable impacts by regulation is required as part of every individual joint permit application for wetland encroachments in Pennsylvania, other than "small" projects deemed by PADEP to have no significant impact on safety or protection of life, health, or the environment [25 *Pa. Code* 105.13(d)(1)(ix)]. Mitigation is defined (at 25 *Pa. Code* 105.1) as

> An action undertaken to accomplish one or more of the following:
>
> Avoid and minimize impacts by limiting the degree or magnitude of the action and its implementation.
>
> Rectify the impact by repairing, rehabilitating or restoring the impacted environment.
>
> Reduce or eliminate the impact over time by preservation and maintenance operations during the life of the action.
>
> If the impact cannot be eliminated by [the foregoing measures], compensate for the impact by replacing the environment impacted by the project or by providing substitute resources or environments.

PADEP records fewer than 100 acres of wetlands authorized for damage annually under individual permits during recent years, along with about 40 miles of streams (PADEP 2014c). These wetland statistics do not include losses through construction authorized by general permits. The statistics also do not include enforcement against unauthorized encroachments into streams and wetlands. (These stream statistics omit altogether about half of the land area of the Commonwealth that occupies small watersheds where stream, but not wetland, destruction is authorized automatically by waiver.)

Since the 1990s PADEP has sought 1:1 minimum replacement for wetland acreage and functions, with a preference for mitigation adjacent to the loss and on the same property. Mitigation has been designed on an acreage replacement basis, typically with no allowance for less than complete success or the time during which wetland functions are absent. Functional replacement itself has seldom if ever been mandated. For enforcement cases, PADEP policy long has sought to require 2:1 acreage mitigation (PADEP 1992, 1997a). PADEP's stated preference has been for onsite mitigation close to the allowed wetland destruction rather than for remote offsite mitigation. Such mitigation would be undertaken by the permittee, who seldom is expert in wetland mitigation.

Because less intervention is required, the restoration of wetlands previously converted to agricultural uses typically is easier and less uncertain than conversion of uplands to wetlands. Wetland hydrology, for example, sometimes can be restored simply by crushing the drainage tiles installed by farmers in order to dry fields sufficiently for commercial crops. To the extent hydrology is removed temporarily, but then restored, wetland vegetation and some semblance of a wetland ecosystem can be recovered onsite where care is taken to reconstruct natural conditions insofar as practicable. Habitat functions often can be attained more readily in rural mitigation areas than adjacent to urban development sites where the restored or created wetlands are isolated from other areas of comparable habitat. Areas amenable to wetland restoration, however, often are located offsite at considerable distance from impacted areas and affected watersheds. Wetlands in stream valleys and floodplains do not necessarily substitute functionally for wetlands along headwater streams.

Successful wetland creation from dry land, even more than restoration, depends on careful identification of water budgets pre-construction to guide attempted restoration. Abundant field experience has demonstrated that small inaccuracies in analyzing or reconstructing hydrology will result either in dry non-wetlands or in open water ponds rather than vegetated wetlands.

Hydrology normally is removed by blocking the movement of water into a wetland (1) by diking or channelizing and diverting its flow and/or (2) by expediting the removal of water from a wetland by drainage pipes or pumps. Restoration of hydrology may require detailed attention to creating almost flat slopes, and often requires design for seasonal variability in wetness. Most natural wetlands, unlike typical farm ponds and detention basins, have very gently sloping land surfaces rather than abrupt banks. Effective wetness of surface soils within a wetland can be reduced by removal of natural vegetation on and adjacent to the mitigation area, impeding the recovery of wild plants and affecting the survival of replacement plantings. Hydrology derived from channelized stormwater can be toxic to wetland plants, if the stormwater brings in road salts, oil, excessive nutrients, and other pollutants. Trees typically are less tolerant of salinity change than herbaceous plants (Adamus & Brandt 1990). Where urban runoff is the source of wetland hydrology, functional mitigation may be difficult to achieve.

Timely restoration of near-surface hydric soils that have wetland characteristics depends on the successful removal and segregation of topsoil, and then its replacement above the subsoil. By keeping holding time for stockpiled topsoil to a minimum, some of the natural seed bank can be salvaged to aid in wetland revegetation. Where the structure of the soil layers has been drastically altered, years are required for horizontal layering to become restored by natural weathering. If wetland hydrology was caused by impermeable subsurface layers such as clay lenses, and those are disrupted by excavation, capturing sufficient hydrology for wetland restoration may be impossible. If surface soil density is compacted, additional years are required for natural porosity to return along with the ability for water to penetrate (Stoler and Relyea 2011). The placement of only a few inches of soil on wetland trees and shrubs, as well as herbs, can be fatal to the disturbed plants. Mulch and short-lived cover crops can help stabilize soils without offering severe competition to desirable native wetland plants. A natural balance of groundwater recharge and discharge in constructed or restored wetlands is not easily achieved.

Given these technical considerations and the historical fact that practical humans long focused on draining and converting rather than restoring wetlands and wetland functions, the actual mitigation of wetland impacts has proved generally unsuccessful in Pennsylvania for many decades (*see*, for example, McCoy 1987, 1992; Kline 1991) and has not improved recently (Campbell *et al*. 2002, Cole & Shaffer 2002, Gebo & Brooks 2012, Hoeltje & Cole 2007, Kislinger 2008, PADEP 2014c). Seldom has mitigation created the same kind of wetlands as those damaged. Most attempted mitigation that succeeded in creating wet areas resulted in open water ponds rather than forested or scrub wetlands (Cole and Shaffer 2002). Monitoring and reporting on mitigation success on paper is required of applicants, but often not performed. PADEP staff seldom monitor wetland mitigation sites or require remedial measures of permittees.

PADEP has found that the ability of permittee-constructed mitigation

> to address the needs of a watershed is limited at best. Applicants generally do not have adequate resources to identify watershed needs, plan for and identify high value project sites, and/or secure rights to and produce significant restoration activities. (PADEP 2014c)

69 Permit Wetland Mitigations Scored by PADEP Interns, 1992-1995

Size (acres)	Success	Failure	Not Rated	% Success
0-.10	5	3	1	62.5
.10-.25	8	6	1	57.1
.25-.50	9	7	0	56.3
.50-1.0	11	3	0	78.6
1.0->	13	2	0	86.7
Total	46	21	2	68.7

Most Pennsylvania wetland impacts authorized by individual permit, after avoidance and minimization have been addressed, affect small acreages. Thus PADEP has implemented an acreage-based fee-in-lieu program to enable most permittees affecting small (0.5 acre or less) areas of wetland to substitute a one-time cash payment instead of undertaking their own construction of mitigation wetlands (PADEP 1997b). The half-acre "allowance" for cash contributions was deemed sufficient to allow any landowner enough wetland impact to build a house. Fees were set by PADEP based on its expectation that willing landowners across the Commonwealth would allow conversion of uplands to wetlands or restoration of wetlands with higher quality through voluntary cooperation with PADEP and the National Fish and Wildlife Foundation. This program has greatly assisted permittees, but it has not demonstrably resulted in compensatory wetland mitigation similar in kind or location to wetlands destroyed.

Contributions to the Washington, D.C.-based National Fish and Wildlife Foundation's Pennsylvania Wetland Replacement Project ID 95-096 became routine across the Commonwealth beginning in the 1990s. According to its web page, as of May 2014 this Foundation had sponsored 486 environmental enhancement projects of various kinds in Pennsylvania. Locational and descriptive information for these projects are displayed on an interactive map. But no data apparently exist comparing wetland acreage or functions lost to mitigation accomplished under the Pennsylvania in-lieu-fee program or identifying the geographical proximity of wetland losses versus gains on a watershed basis. Only first-time readers of PADEP regulations might expect any applicant eligible to use the Fund even to consider undertaking onsite mitigation, which is always far more expensive than scheduled contributions to the State's

Fund. The in-lieu fees long have represented a major subsidy to permittees from Pennsylvania residents and their environment (Schmid 1996a, b). Pennsylvania mitigation fees have been the same for Exceptional Value as for Other wetlands, and the acreage-based fees have been presumed to compensate for any and all wetland functions associated with the wetlands lost.

Pennsylvania Wetland Mitigation Replacement Fees (1997-2013).

De minimis impact less than or equal to .05 acre	$ 0.00
Greater than .05 acre to .10 acre	$ 500.00
Greater than .10 acre to .20 acre	$ 1,000.00
Greater than .20 acre to .30 acre	$ 2,500.00
Greater than .30 acre to .40 acre	$ 5,000.00
Greater than .40 acre to .50 acre	$ 7,500.00

Contributions to the Fund relieve permittees of any followup responsibility for mitigation monitoring or success. Between 1997 and 2013 the buying power of cash contributions to the Fund dwindled by about 30% due to inflation, while the market costs of wetland creation can be $100,000 per acre in some locations, according to the Pennsylvania Department of Transportation. Costs are less where free land and prison labor can be obtained (FHWA 2011). Moreover, the success of the wetland mitigation work done under PADEP's Replacement Project apparently has been limited and certainly has been sparsely reported. Pennsylvania's in-lieu-fee program was deemed unacceptable for use to satisfy federal wetland mitigation requirements in 2008, and its "grandfathering" expired in 2013 (33 CFR 332.8). Hence the PADEP currently is seeking federal approval for a new in-lieu-fee program (PADEP 2014c).

The generally laudable goals of the new program include (1) high quality mitigation addressing wetland functions as well as acreage, (2) ecologically based mitigation site selection, (3) efficiencies of scale in constructing, monitoring, and administering a few large mitigation projects instead of many small ones, (4) streamlined federal and State permit approvals, and (5) more effective accounting and compliance reporting (PADEP 2014c). PADEP claims that it has the expertise and staff to run an in-lieu-fee program effectively. As has been repeatedly demonstrated by PADEP staff and by independent academics, mitigation to date by permittees affecting more than the half acre of wetlands to which Fund contributions are limited typically has been of poor quality in Pennsylvania and has failed altogether in replacing the functions of wetlands lost.

The new PADEP technical guidance potentially represents an opportunity to have those who hope to benefit from damaging wetlands more effectively internalize the negative externalities of their conduct, a goal consistent with both Pennsylvania and federal law. It is not self-evident that the functions of multiple small, scattered wetlands high in the landscape can be replaced effectively by larger wetlands in floodplains, and PADEP may be asked to address this issue, as well as many other technical details, prior to gaining federal approval for its proposed in-lieu-fee program. Unquestionably, more information will need to be generated during preparation and review of each application to damage wetlands, if new PADEP technical guidance is adopted along the lines of its current draft. A significant outcome should be the more effective tailoring of compensatory mitigation to the amount and type of wetland impacts. The full costs of mitigation should include both the risk of mitigation failure and the temporal lag between impacts and restoration of functions---which, for forested wetlands can be immense.

Only if this opportunity is fully exploited will future mitigation begin to compensate for permitted impacts in Pennsylvania. The new guidance also can provide a corrective to the mitigation failures and lack of accountability long prevalent in Pennsylvania, while reducing the previous economic subsidies encouraging private destruction of wetland resources. The new information available also should allow better public understanding of the external costs of development and the benefits of successful mitigation, particularly if public access to permit records is made electronically available.

It is high time that human behaviors with harmful side effects in Pennsylvania be mitigated more effectively to enable continued prosperity for its residents and the planet's survival, as well as compliance with Article 1, Section 27, of the Pennsylvania Constitution:

> The people have a right to clean air, pure water, and to the preservation of the natural, scenic, historic and esthetic values of the environment. Pennsylvania's public natural resources are the common property of all the people, including generations yet to come. As trustee of these resources, the Commonwealth shall conserve and maintain them for the benefit of all the people.

When completed, the new PADEP technical guidance may make possible the actual functional mitigation for conversion of forest and scrub wetlands to herbaceous wetlands. If effective, it also should help reduce so-called "natural" hazards from waters---hazards which are in fact failures of human design, construction, planning, and community development in areas subject to natural processes of stormwater movement. If the opportunity is missed, the alternative includes increased environmental plundering of remaining wetland resources, high costs for disaster survivors, especially the most vulnerable, as well as harm to communities and ever growing costs to taxpayers.

Completion of public review, PADEP revision, and implementation of the new technical guidance for wetland assessment and mitigation may take considerable time. Pennsylvania wetlands only slowly have begun to receive some attention from regulators in the context of damage by longwall (that is, high-extraction underground) bituminous coal mining, which was first allowed by Act 54 of 1994. PADEP long refused to recognize even the possibility of damage to wetlands from longwall mining, but gradually has been implementing more thorough data collection for mine applications (Schmid & Co., Inc. 2000, 2010a, 2011a, 2012, 2013).

The minimal current PADEP information and review requirements for oil and gas permits provide virtually no assurance that wetlands will be identified and protected from this extractive industry, which currently is experiencing a boom across much of the Commonwealth. Similarly, PADEP has failed to protect too many streams, particularly those streams of highest ecological value (Van Rossum *et al*. 2011; Kunz 2011; Schmid & Co., Inc. 2010b). Oil and gas permit applications generate far less environmental information than coal mining applications. Proposed regulations governing surface oil and gas activities currently are under review (25 *Pa. Code* 78, Subchapter C). PADEP and the Environmental Quality Board are preparing responses to the 24,000 comments received on their proposed oil and gas regulations. New Chapter 78 regulations could specify protection for streams and wetlands far more effectively than the regulations they are replacing.

Whether the proposed wetland analysis and mitigation technical guidance will receive similar public attention remains to be seen. Its comment period is still open and likely to be extended.

Authorship

This report was prepared by James A. Schmid, a biogeographer and plant ecologist. Dr. Schmid received his BA from Columbia College and his MA and PhD from the University of Chicago. After serving as Instructor and Assistant Professor in the Department of Biological Sciences at Columbia University and Barnard College, he joined the environmental consulting firm of Jack McCormick & Associates of Devon, Pennsylvania. Since 1980 he has headed Schmid & Company of Media, Pennsylvania.

Dr. Schmid has analyzed and secured permits for some of the largest wetland mitigation projects in the mid Atlantic States, as well as a myriad of smaller projects. He is certified as a Senior Ecologist by the Ecological Society of America, as a Professional Wetland Scientist by the Society of Wetland Scientists, and as a Wetland Delineator by the Baltimore District, Army Corps of Engineers. He has served on the professional certification committees of the Ecological Society and the Society of Wetland Scientists.

When the US Fish & Wildlife Service Pleasantville Office evaluated actual compliance with approval conditions requiring mitigation by about 100 of the Clean Water Act Section 404 fill permits issued by the Corps of Engineers in the State of New Jersey during the period 1985-1992, every Schmid & Company mitigation project was judged in the field to exhibit full compliance with all permit requirements and mitigation goals. Schmid & Company mitigation projects represented 21% of all the mitigation projects judged fully successful in New Jersey by USFWS in its written report to USEPA. Dr. Schmid analyzed and secured Wetland Mitigation Council approval for the first major freshwater mitigation bank in New Jersey on behalf of DuPont. That bank was donated to The Nature Conservancy.

Dr. Schmid has often analyzed environmental regulatory programs and commented on proposed regulations. His clients continue to include the construction industry, conservation groups, and government agencies, including the Pennsylvania Department of Environmental Protection.

References

Adamus, Paul, and K. Brandt. 1990. Impacts on the quality of inland wetlands in the United States: a survey of indicators, techniques, and application of community-level data. US Environmental Protection Agency. Washington DC 392 p. EPA 600/3-90/073.

Braun, E. Lucy. 1950. Deciduous forests of eastern North America. The Free Press. New York NY. 596 p.

Campbell, Deborah A., C.A. Cole, and R.P. Brooks. 2002. A comparison of created and natural wetlands in Pennsylvania, USA. Wetlands Ecology and Management 10:41-49.

Cole, C., and D. Shaffer. 2002. Section 404 wetland mitigation and permit success criteria in Pennsylvania, USA. Environmental Management 30:508-515.

Crabtree, Allen F., L.E. Fisher, and C.E. Bassett. 1978. Impacts of pipeline construction on stream and wetland environments. Michigan Public Service Commission. Lansing MI. 171 p.

Environmental Laboratory, Waterways Experiment Station, Department of the Army. 1987. Corps of Engineers wetlands delineation manual. Washington DC. 169 p.

FHWA (Federal Highway Administration, US Department of Transportation). 2011. Results of the FHWA domestic scan of successful wetland mitigation projects [in Pennsylvania]. www.environment.fhwa.dot.gov/ecosystem/scanrpt/pa.asp.

Gebo, Naomi A., and R.P. Brooks. 2012. Hydrogeomorphic (HGM) assessments of mitigation sites compared to natural reference wetlands in Pennsylvania. Wetlands 32(2):321-331.

Hoeltje, S., and C. Cole. 2007. Losing functions through wetland mitigation in central Pennsylvania, USA. Environmental Management 39:385-402.

Houlihan, Jeff E., P.A. Keddy, K. Makkay, and C.S. Findlay. 2006. The effects of adjacent land use on wetland species richness and community composition. Wetlands 26(1):79-96.

Kislinger, R. 2008. Successful wetland mitigation projects. National Wetlands Newsletter 30:14.

Kline, Norma L. 1991. Palustrine wetland creation mitigation effectiveness. Gannett Fleming, Inc. Camp Hill PA. Prepared for US Environmental Protection Agency Region 3. 83 p.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. American Geographical Society Special Publication 36. 116 p. plus map.

Kunz, Stephen P. 2011. Comments on DSEA Permit Application E5729-014. Schmid &. Co., Inc. Media PA. 24 p.

Lichvar, R.W. 2013. The national wetland plant list: 2013 wetland ratings. Phytoneuron 2013-49: 1–241. ISSN 2153 733X

Lichvar, R.W., M. Butterwick, N.C. Melvin, and W.N. Kirchner. 2014. The national wetland plant list: 2014 update of wetland ratings. Phytoneuron 2014-41:1-42.

McCaskill, George L., W.H. McWilliams, C.A. Alerich, B.J. Butler, S.J. Crocker, G.M. Domke, D. Griffith, C.M. Kurtz, S. Lehman, T.W. Lister, R.S. Morin, W.K. Moser, P. Roth, R. Riemann, and J.A. Westfall. 2013. Pennsylvania's Forests, 2009. Resource Bulletin NRS-82. U.S. Department of Agriculture, Forest Service, Northern Research Station. Newtown Square PA. 52 p.

McCoy, Richard W. 1987. Evaluation of mitigation activities, Sky Haven Coal Company (Clearfield County PA). US Department of the Interior, Fish and Wildlife Service. State College PA. Special Project Report 87-3. 9 p.

McCoy, Richard W. 1992. An evaluation of 30 wetland mitigation sites constructed by the Pennsylvania Department of Transportation between 1983 and 1990. US Department of the Interior, Fish and Wildlife Service. Special Report 92-3. 127 p.

McShea, W.J., and W.M. Healy. 2002. Oak forest ecosystems: ecology and management for wildlife. Johns Hopkins University Press. Baltimore MD 432 p.

Olson, Erik R., and J.M. Doherty. 2012. The legacy of pipeline installation on the soil and vegetation of southeast Wisconsin wetlands. Ecological Engineering 39:53-62.

PADEP (Pennsylvania Department of Environmental Protection). 1992. Design criteria for replacement wetlands. Harrisburg PA. 8 p. (reissued 1997a as Technical Guidance Document 363-0300-001. 11 p.)

PADEP. 1997b. Pennsylvania wetland replacement project. Harrisburg PA. Techical Guidance Document 363-0200-003. 9 p.

PADEP. 2001. Pennsylvania wetlands program overview. Harrisburg PA. http://www.dep.state.pa.us/dep/deputate/watermgt/wc/subjects/wwec/general/wetlands/WetlandReplaceFd.htm

PADEP. 2014a. Pennsylvania function based aquatic resource compensation protocol. Draft version 1.0. Bureau of Waterways Engineering and Wetlands, Division of Wetlands, Encroachments and Training. Harrisburg PA. 36 p. TGD 320-2137-001.

PADEP. 2014b. Pennsylvania wetland condition Level 2 rapid assessment protocol. Draft version 2.0. Bureau of Waterways Engineering and Wetlands, Division of Wetlands, Encroachments and Training. Harrisburg PA. 37 p. TGD 320-2137-002.

PADEP. 2014c. Pennsylvania’s integrated ecological services, capacity enhancement, and support program (PIESCES) in lieu fee program prospectus. Bureau of Waterways Engineering and Wetlands. Harrisburg PA. 22 p.

Rastorfer, James R. 1995. Ecological effects of pipeline construction through deciduous forested wetlands, Midland County, Michigan. Gas Research Institute. Chicago IL. 262 p.

Richardson, Curtis J. 1994. Ecological functions and human values in wetlands: a framework for assessing forestry impacts. Wetlands 14(1):1-9.

Riva-Murray, Karen, R. Riemann, P. Murdoch, J.M. Fischer, and B. Brightbill. 2010. Landscape characteristics affecting streams in urbanizing regions of the Delaware River Basin (New Jersey, New York, and Pennsylvania, US). Landscape Ecology 25:1489-1502.

Schmid, James A. 1996a. Fire sale in Pennsylvania. National Wetlands Newsletter 18(1):4-5

Schmid, James A. 1996b. More on fire sales. National Wetlands Newsletter 18(5):4

Schmid, James A. 2000. Wetlands as conserved landscapes in the United States. *In* A. B. Murphy and D. L. Johnson, eds. Cultural encounters with the environment: enduring and evolving geographic themes. Rowman & Littlefield. Lanham MD. p. 133-155.

Schmid & Company, Inc. 2000. Wetlands and longwall mining: regulatory failure in southwestern Pennsylvania. Prepared for the Raymond Proffitt Foundation, Langhorne PA. Media PA. 123 p. http://www.schmidco.com/Wetlands%20and%20Longwall%20Mining%202000.pdf

Schmid & Company, Inc. 2010a. Protection of water resources from longwall mining is needed in southwestern Pennsylvania. Prepared for Citizens Coal Council, Washington PA, with support from The Sierra Club. Media PA. 190 p.

Schmid & Company, Inc. 2010b. A need to identify "Special Protection" status and apply existing use protections to certain waterways in Greene and Washington Counties, Pennsylvania. Prepared for Citizens Coal Council, Buffalo Creek Watershed Association, and The Foundation for Pennsylvania Watersheds. Media PA. 15 p. plus appendixes.

Schmid & Co., Inc. 2011a. The increasing damage from underground coal mining in Pennsylvania, a review and analysis of the PADEP's Third Act 54 Report. Prepared for Citizens Coal Council, Bridgeville PA. Media PA. 50 p. http://www.schmidco.com/17April2011SchmidAct54Analysis.pdf

Schmid & Company, Inc. 2011b. Streams and wetlands on Bear Mountain, Elkland Township, Sullivan County, Pennsylvania. Prepared for Bear Mountain Homeowners. Media PA. 74 p.

Schmid & Company, Inc. 2012. Pilot contract for an independent technical review of the proposed Donegal Mine, Donegal Township, Butler County, Pennsylvania. Prepared for Pennsylvania Department of Environmental Protection on behalf of Rosebud Mining Company. Media PA 130 p.

Schmid & Co., Inc. 2013. Review of Foundation Mine, a new longwall mine. Prepared for Greene County Watershed Association, Waynesburg PA. 60 p.

Smith, R. Daniel, A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indexes. US Army Corps of Engineers. Technical Report WRP-DE-9. Washington DC. 88 p.

Sonntag, Daniel H., and C.A. Cole. 2008. Determining the feasibility and cost of an ecologically-based design for a wetland mitigation in central Pennsylvania, USA. Landscape and Urban Planning 87(1):10-21.

Stoller, Allen B., and R.E. Relyea. 2011. Living in the litter: the influence of tree leaf litter on wetland communities. Oikos 120:862-872.

Tiner, Ralph W. 1987. Mid-Atlantic wetlands, a disappearing national treasure. US Department of the Interior, Fish and Wildlife Service. Newton Corner MA. 29 p.

Tiner, Ralph W. 1990. Pennsylvania's wetlands: current status and recent trends. US Department of the Interior, Fish and Wildlife Service. Newton Corner MA. Prepared for Pennsylvania Bureau of Water Resources Management. 104 p.

USACE (U.S. Army Corps of Engineers). 2012. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region Version 2.0. Eds. J. F. Berkowitz, J. S. Wakeley, R. W. Lichvar, C. V. Noble. ERDC/EL TR-12-9. U.S. Army Engineer Research and Development Center. Vicksburg MS. 182 p.

USACE. 2014. National wetland plant list, viewer version 3.2. http:rsgisias.crrel.usace.army.mil/nwpl_static/viewer.html#

U.S. Department of Defense, Department of the Army, Corps of Engineers and Environmental Protection Agency. 2008. Compensatory mitigation for losses of aquatic resources; final rule. 73 FR 70:19594-19705. 10 April.

U.S. Environmental Protection Agency. 2011. Level III and IV ecoregions of the conterminous United States. Office of Research and Development. Scale 1:3,000,000. Corvallis OR. 1 sheet. www.epa.gov/wed/pages/ecoregions.htm

U.S. Environmental Protection Agency and U.S. Army Corps of Engineers. 2014. Definition of "Waters of the United States" under the Clean Water Act. Federal Register Docket Number EPA HQ OW 2011-0880. 79 Federal Register 22187-22274, 21 April.

Van Rossum, Maya K., C. Towne, F. Zerbe, and K. Kraus. 2011. Protecting Pennsylvania's cleanest streams: a review of Pennsylvania's antidegradation policies and program with recommendations for improvement. Delaware Riverkeeper Network. Bristol PA. 78 p. http://www.delawareriverkeeper.org/resources/Reports/DRN_Rpt_Protecting_PAs_Cleanest_Streams.pdf

Vasilas, L.M., G.W. Hurt, and C.V. Noble, eds. 2010. Field indicators of hydric soils in the United States, a guide for identifying and delineating hydric soils, Version 7.0. U.S. Department of Agriculture, Natural Resources Conservation Service, National Technical Committee for Hydric Soils. U.S. Army Corps of Engineers. Vicksburg MS. 44 p.

Welsch, David J., D.L. Smart, J.N. Boyer, P. Minkin, H.C. Smith, and T.L. McCandless. 1995. Forested wetlands, functions, benefits, and the use of best management practices. US Department of Agriculture, Forest Service Publication NA-PR-01-95. Radnor PA.

Zimmerman, E., T. Davis, G. Podniesinski, M. Furedi, J. McPherson, S. Seymour, B. Eichelberger, N. Dewar, J. Wagner, and J. Fike (editors). 2012. Terrestrial and palustrine plant communities of Pennsylvania, 2nd edition. Pennsylvania Natural Heritage Program, Pennsylvania Department of Conservation and Natural Resources. Harrisburg PA..